Celebrating Silver Jubilee

1993 – 2018

150 YEARS OF CELEBRATING THE MAHATMA

ISRS

National Symposium on

Advancements in Geospatial Technology for Societal Benefits

and

Annual Conventions

of

Indian Society of Geomatics (ISG)

&

Indian Society of Remote Sensing (ISRS)

December 5 - 7, 2018 | Ahmedabad, Gujarat

SOUVENIR CUM ABSTRACT VOLUME

www.isgns2018.in

NATIONAL SYMPOSIUM ON ADVANCEMENTS IN GEOSPATIAL TECHNOLOGY FOR SOCIETAL BENEFITS

AND

ANNUAL CONVENTIONS

OF

INDIAN SOCIETY OF GEOMATICS AND

INDIAN SOCIETY OF REMOTE SENSING (ISRS)

WITH

SILVER JUBILEE CELEBRATIONS OF

THE INDIAN SOCIETY OF GEOMATICS

December 5-7, 2018, Ahmedabad, Gujarat

Souvenir cum Abstract Volume

ORGANIZED BY

Indian Society of Geomatics, Ahmedabad &

Indian Society of Remote Sensing, Dehradun

ISRS

HOSTED BY

Space Applications Centre, ISRO, Ahmedabad

and

Indian Society of Geomatics, Ahmedabad Chapter

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डॉ.कै. शिवन / Dr K. SIVAN
अध्यक्ष / Chairman

MESSAGE

I am pleased to extend my sincere greetings to all delegates of the National Symposium on "Advancements in Geospatial Technology for Societal Benefits", being organized jointly by Indian Society of Geomatics and Indian Society of Remote Sensing at Space Applications Centre, ISRO, Ahmedabad during December 05-07, 2018.

It is gratifying to note that Indian Earth Observation satellites are being extensively utilized by the geospatial community in several areas of applications. Many new developments are taking place with regard to NavIC system and soon the country will see many new applications. Efficacy of geospatial technology in addressing various application areas for societal benefits are well proven during past few decades. It is heartening to know that various Ministries and Government Departments have adopted geospatial technology for efficient monitoring of natural resources, Governance, Early Warning and effective management of disasters. In the recent times, geospatial industry has also played a major role in contributing to newer applications that has widened usage of the technology in the country.

With the rich constellations of Earth Observation, Navigation and Communication satellites in place, the country is in a good position to address the growing demands of user community. The geospatial community is always faced with newer challenges, such as, rapid data processing, big data analytics, efficient use of geoportals and mobile Apps based services. In addition, technologies related to cloud computing, Artificial Intelligence & data analytics, product quality & security, including real time information dissemination are the order of the day. I am sure that the Symposium will deliberate on many of these challenging areas and provide directions for technologists and younger researchers. I also hope that this Symposium will focus on technologies that improves quality of life of people and specifically on climate and disasters.

I am happy to note that the event is coinciding with the Silver Jubilee year of the Indian Society of Geomatics. I take this opportunity to congratulate all members of the Indian Society of Geomatics on this important occasion. I wish the Symposium a grand success.

कै. शिवन
26/11/2018

(कै. शिवन / **K. Sivan**)

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डी के दास
निदेशक
D K Das
Director

MESSAGE

On behalf of Space Applications Centre, I extend a warm welcome to all delegates of the **National Symposium on *"Advancements in Geospatial Technology for Societal Benefits"***, being jointly organised by Indian Society of Geomatics and Indian Society of Remote Sensing during December 5-7, 2018.

Over the years, geospatial technology has been making phenomenal impact on its usage in diverse fields related to natural resources management, sustainable development, disaster management, environmental applications and more recently in Good-governance. It is heartening to note that delegates of the National Symposium shall be discussing recent advancements made in various key areas viz., geospatial technology, data processing techniques, machine learning, web GIS, navigation, mobile apps and application areas of societal benefits like agriculture, environment, forestry, geosciences, cryosphere, water resources, soil, land degradation, urban, coastal, marine, planetary sciences etc.

Space Applications Centre (SAC) is playing a key role in design, development and delivery of payloads for earth observation, navigation, communication satellites and planetary Missions of the Indian Space Programme. These missions are catering to the national and international needs of societal benefits and fulfilling the vision of Dr. Vikram Sarabahi, father of Indian Space Programme. SAC is also facilitating development of image processing software, retrieval of meteorological and bio-geo-physical products, process understanding, applications of the technology in early warning of disasters, weather forecasting and also in several coastal, marine and land applications. Dissemination of value added products and web-services are being provided by SAC Web portals MOSDAC and VEDAS. These can be utilised by concerned scientists, students and geospatial fraternity at large.

I am sure that scientific deliberations shall not only bring out recent trends in geospatial technology and applications but also identify goals for future endeavors including requirements of new sensors.

I wish this National Symposium a grand success.

Place: Ahmedabad
Date: November 22, 2018

(डी के दास)
(D K Das)

Tapan Misra
President, ISG & ISRS
Senior Advisor, ISRO

MESSAGE

I am pleased to extend a warm welcome to all delegates of the National Symposium on, ***"Advancements in Geospatial Technology for Societal Benefits"****, being jointly organised by the Indian Society of Geomatics (ISG) & the Indian Society of Remote Sensing (ISRS) at Space Applications Centre (SAC), Indian Space Research Organisation (ISRO), Ahmedabad during December 5-7, 2018.*

It gives me immense pleasure to note that the event is coinciding with the Silver Jubilee Year of ISG .We are fortunate that Silver Jubilee of ISG also coincides with Birth centenary Year of Dr. Vikram Sarabhai, founder of Indian Space Programme. Dr. Sarabhai was the ardent proponent of Societal Applications of Space Technology and I am happy to note that organisers have chosen a theme which is in line with inspiration by Dr. Sarabhai.

It is quite heartening to note that around 220 abstracts have been received for the Symposium. Apart from 18 parallel technical sessions, the Symposium will have special Plenary sessions on each day, whereby eminent scientists will speak on important topics. I convey my deep sense of appreciation and gratitude for their efforts in organizing such a comprehensive symposium.

I am sure that the Symposium Organising Committee and its sub-committees have made excellent arrangements for deliberations by nearly 350 delegates of the Symposium, spanning over three days. I believe that scientific deliberations during the Symposium shall be useful in understanding recent trends in geospatial technology for various applications of societal benefits and in charting future roadmap.

On behalf of ISG & ISRS, I take this opportunity to convey my sincere thanks to Secretary DOS and Director, Space Applications Centre, for providing all necessary infrastructure and support to organise this Symposium.

I wish the Symposium a grand success.

Tapan Misra

(Tapan Misra)

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C.P. Singh
Organising Secretary
ISG – ISRS National Symposium 2018
Ahmedabad

Tel: 079-26914117
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Acknowledgement from Organising Secretary

I extend my gratitude to Shri Tapan Misra, President, ISG & ISRS and all other members of the Executive Council of ISG and ISRS for giving us the opportunity to organise this symposium in Ahmedabad. I am thankful to Shri D.K. Das, Director, SAC for allowing to host the symposium in SAC campus. He has provided guidance and extended wholehearted support in organising the event as Chairman of Symposium Organising Committee (SOC). I also thank Dr. Raj Kumar, Deputy Director, EPSA and Alternate Chairman, SOC for his guidance, constant encouragement. The mammoth task of organising this event would have not been possible without full hearted support from other members of SOC, all the sub-committee members of the SOC, guidance from senior colleagues and participation of large number of scientific and academic community as well as young researchers.

We are blessed with presence of various dignitaries including Shri Pramod Kale, former Director, SAC and VSSC (Chief Guest), Lt. Gen. Girish Kumar, VSM, Surveyor General of India (Guest of Honour), Prof. George Joseph (former Director, SAC), Shri Kartikeya V. Sarabhai, Director, CEE during the inaugural function of the Symposium.

The symposium technical program has been planned to address most recent advancements in geospatial technologies for societal benefits with its targeted theme specific sessions. Additionally, eminent speakers of various plenary sessions are thanked for enlightening on current advances and future trends in relevant themes to geospatial community. I extend sincere gratitude to Chairs, Co-Chairs and paper presenters of all the sessions. All the tutorial co-ordinators, faculty and participants are specially thanked.

This symposium would have not been possible without co-sponsorship from ISRO Head Quarters, Antrix Corp. Ltd., DELL India, ESRI India, NetApp, The Green Environment Services Co-op. Soc. Ltd., NESAC, NORINCO, NRSC, Meatech Solutions, Deekay Marine Services Pvt. Ltd., RSI Softech India Pvt. Ltd., Hexagon geospatial, IIRS, Electrotek International and APSAC.

Last but not the least, our thanks to SAC management, administration, CISF, canteen, facilities, PRO, CMG and volunteers from all corners of SAC. We are thankful to all those who supported the symposium to make it sparkling.

C. P. Singh
On behalf of Symposium Organising Committee

INDIAN SOCIETY OF GEOMATICS (ISG)

www.isgindia.org

Indian Society of Geomatics (ISG), established in 1993, is a premier society of professionals and institutions involved in promoting and popularising Geomatics in India. It has about **2156 Life Members, 34 Patron Members, 17 Fellows and 2 Sustaining Members besides a few Annual & Student members.** It has **27** very active **Regional Chapters** located at Ahmedabad, Ajmer, Bhagalpur, Bhopal, Chennai, Dehradun, Delhi, Hisar, Hyderabad, Jaipur, Kharagpur, Lucknow, Ludhiana, Mangalore, Mumbai, Mysore, Pondicherry, Pune, Ranchi, Shillong, Srinagar, Surat, Trichi, Vadodara, Vallabh Vidyanagar, Visakhapatnam and Trivandrum.

ISG regularly brings out a **quarterly newsletter** (ISSN: 0972-642X) for circulation to its members. ISG has published many special issues on various themes such as Agriculture, Urban Planning, Coastal and Marine Environment, Space-based Cartography, GIS: Education and Training in India, Water Resources, Location-based Services, Geomatics in India: Retrospect and Prospects, Infrastructure, Mountains, Impact of Climate Change etc.

The ISG is also bringing out a peer-reviewed journal named "**Journal of Geomatics**" (ISSN: 0976-1330). The journal covers all aspects of Geomatics – geodata acquisition, pre-processing, processing, analysis and publishing. Broadly, this implies inclusion of areas like GIS, GPS, Photogrammetry, Cartography, Remote Sensing, Surveying, Spatial Data Infrastructure and Technology including hardware, software, algorithms and modelling. It endeavours to provide an **international forum** for rapid publication of developments in the field – both in technology and applications.

ISG has its website http://www.isgindia.org which contains all pertinent information about ISG and its activities. This site is updated every three months for the benefit of its members and anyone interested in Geoinformatics. Indian Society of Geomatics has instituted one **National Geomatics Award for Excellence.** This award is given in recognition of outstanding and conspicuously important contributions in promoting geomatics technology and applications at country level. The award consists of Rs. 50,000/-, a medal and citation. Two **National Geomatics Awards** are given each year: a) for original and significant contribution in technology, b) for innovative applications in the field of Geomatics. Each award comprises a medal, a citation and a sum of Rs 25,000/-. The guidelines for these awards are available on ISG website. Apart from these awards, ISG has also instituted **Best Chapter of the Year & President's Medal for Contribution to the Society Award** for promoting the chapter activities and encouraging chapters to conduct various regional events. The **Best Chapter Award** is given to an active chapter of Indian Society of Geomatics, which has made significant contribution to further the mandate and goal of the society. ISG has also instituted **Prof. Kakani Nageswara Rao Endowment Young Achiever Award** to encourage young scientists working in the field of Geomatics. The award consists of a citation and medal. The guidelines for these awards are available on ISG website.

ISG also celebrates Science-day, GIS-day and Technology-day every year as the mandatory activities of the society. For this ISG provides funds to the tune of Rs. 15,000/- every year to each chapter.

Fellows

1. Shri Pramod P. Kale, Pune
2. Dr. George Joseph, Ahmedabad
3. Dr. A.K.S. Gopalan, Hyderabad
4. Dr. Prithvish Nag, Varanasi
5. Dr. Baldev Sahai, Ahmedabad
6. Shri A.R. Dasgupta, Ahmedabad
7. Dr. R.R. Navalgund, Bengaluru
8. Shri Rajesh Mathur, New Delhi
9. Dr. Ajai, Ahmedabad
10. Prof P. Venkatachalam, Mumbai
11. Dr. Shailesh Nayak, Delhi
12. Prof I.V. Murli Krishna, Hyderabad
13. Prof SM Ramasamy, Tiruchirapalli
14. Dr. Ashok Kaushal, Pune
15. Shri A.S. Kiran Kumar, Bengaluru
16. Prof. P.K. Verma, Bhopal
17. Maj. Gen. Siva Kumar, Hyderabad

National Geomatics Awards for Excellence

2014	Dr. Baldev Sahai, Ahmedabad
2015	Dr. A.K.S. Gopalan, Hyderabad
2016	Prof. Arup Ranjan Dasgupta, Ahmedabad
2017	Dr. K. Mrityunjay Reddy, Hyderabad

National Geomatics Awards

2007	Technology	Dr. Parvatham Venkatachalam, IIT - Mumbai
	Applications	Shri K. Kalyanraman, Navayuga Spatial Technologies Ltd., Bangalore
2008	Technology	Maj. Gen. (Dr) B. Nagarajan, SOI, Dehradun
	Applications	Dr Yellisetty Venkata Naga Krishna Murthy, RRSSC, Nagpur Dr. Vandana Sharma, NIC, New Delhi
2009	Technology	Shri Chirag Soni, SGL, Ahmedabad Dr. Pradeep Kumar Srivastava, SAC (ISRO), Ahmedabad
	Applications	Dr. S.K. Pathan, SAC (ISRO), Ahmedabad Shri T.P. Singh, BISAG, Gandhinagar, Gujarat
2010	Technology	Shri D.R.M. Samudraiah, SAC (ISRO), Ahmedabad
	Applications	Dr. S.M. Ramasamy, Bharathidasan Uni., Tiruchirapalli

2011	Technology	Shri B. Gopala Krishna, SAC (ISRO), Ahmedabad
	Applications	Shri V. Tamilrasan, SAC (ISRO), Ahmedabad
2012	Applications	Prof. K. Nageswara Rao, Andhra University, Visazg Dr Nagaraja Ravoori, NRSC, Hyderabad
2013	Technology	Shri Shashikant A. Sharma, SAC (ISRO), Ahmedabad
	Applications	Prof. P.K. Verma, MPCST, Bhopal
2014	Technology	Dr. P.G. Diwakar, NRSC, Hyderabad
	Applications	Prof. Anjana Vyas, CEPT, Ahmedabad
2015	Technology	Dr. J.R. Sharma, RRSC, Jodhpur
	Applications	Dr. S.S. Ray, MNCFC, New Delhi
2016	Technology	Dr. Ashish Kumar Shukla, SAC (ISRO), Ahmedabad
	Applications	Shri P.L.N. Raju, NESAC, Shillong
2017	Technology	Dr. Sameer Saran, IIRS, Dehradun
	Applications	-

President's Appreciation Medal for Contribution to the ISG

2011	Shri I.C. Matieda, SAC (ISRO), Ahmedabad Shri M.H. Kalubarme, SAC (ISRO), Ahmedabad
2012	Shri R.P. Dubey, SAC (ISRO), Ahmedabad
2013	Dr. Alpana M. Shukla, Gujarat University, Ahmedabad
2014	Dr. S. Palria, MDS University, Ajmer
2015	Prof. Shakil Ahmad Romshoo, Kashmir University, Srinagar
2016	Prof. G. Sandhya Kiran, MS University, Vadodara
2017	Dr. Markand Oza, SAC (ISRO), Ahmedabad

Prof. Kakani Nageswara Rao Endowment Young Achiever Award

2013	Dr. Arbinda Sharma, BRCM CET, Bahal Ms. Shweta Sharma, SAC (ISRO), Ahmedabad
2014	Dr. (Mrs.) Dipanvita Haldar, SAC (ISRO), Ahmedabad
2015	Dr. Gaurav Jain, SAC (ISRO), Ahmedabad
2016	Dr. K. Ch. V. Naga Kumar, CWRDM, Kozhikode
2017	Ms. Neetu, MNCFC, New Delhi

For more details and online registration, visit our website http://isgindia.org

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Indian Society of Remote Sensing (ISRS)

www.isrs-india.org

The Indian Society of Remote Sensing was registered during 1973-74 vide Reg. No 1357/73-74. The registered office of the society is located in Indian Institute of Remote Sensing (IIRS) Campus, Dehradun. The constitution of the society consists of (i) memorandum and (ii) rules and regulations. The society functions under the given rules and regulations framed by it. The society has the right to affiliate any other national/ international society with similar scientific aims.

The society has the Life members (5315), honorary members (11), Fellows (39), Patron Members (61) and Annual Members (59) as on date.

Membership Fee:
Life Members: (a) Admitted before 45 yrs of age: Rs. 3000 (b) admitted after 45 yrs of age: Rs. 2500
Annual Members: Rs. 500
Patron Members: Rs. 2,00,000

Annual Conventions: The society has been organizing annual conventions, national symposia preceded by two day pre symposium tutorials for the students regularly, giving opportunities to the remote sensing community in the country to present their research papers and discuss the problems and methods of applications of remote sensing in development and management of natural resources.

Remote Sensing Popularization Activities: The society also takes initiative to spread awareness in the field of remote sensing by conducting various activities. In 2017, The National Workshop on 'Popularization of Remote Sensing' was conducted. This year, The National Remote sensing Day was celebrated amongst the school children and a drawing competition was conducted at national level.

Executive Council: The affairs of the Society are managed by an Executive Council consisting of six office bearers, five elected members and the Ex-officio Member. The ISRS Executive Council for the term April 01, 2018 to March 31, 2020 is:

President	: Shri Tapan Mishra
First Vice President	: Dr. Prakash Chauhan
Second Vice President	: Dr. V.K. Sehgal
Secretary	: Dr. Sameer Saran
Jt. Secretary	: Dr. Rama Rao Nidamanuri
Treasurer	: Dr. Hitendra Padalia
Member (Ex-Officio President)	: Dr. Shailesh Nayak
Member (Chief- Editor)	: Dr. George Joseph
Member (Industry)	: Shri Rajesh Mathur
Member (Academia)	: Prof. P.K. Verma

Chapter: The Society approves the establishment of a Chapter in response to a request by at least 15 members from a town or a city. Areas lying within 40 km of a town can be included in the jurisdiction of a Chapter. Each Chapter has formal recognition from the Council in the form a Chapter. There can be any number of Chapters in a Zone. Chapters are grouped on a zonal basis for representation in the Council. Presently society has 26 chapters namely Ahmedabad, Ajmer, Allahabad, Bangalore, Bhopal, Bhubaneswar, Chandigarh, Chennai, Dehradun, Delhi, Guwahati, Hisar, Hyderabad, Indore, Jaipur, Jodhpur, Kolkata, Lucknow, Ludhiana, Mumbai, Nagpur, Pune, Shillong, Tiruchipalli, Thiruvanthapuram and Vishakhapatnam distributed across the country.

Awards: ISRS recognize individual in the form of awards in order to encourage and motivate the individual who are promoting the aims and objectives of the society. These awards are of different categories subject to their individual contributions. Awards are conferred every year by the ISRS under various categories. Some of the prestigious awards of the society are as follows:

- Bhaskara
- Satish Dhawan
- National Geospatial Awards for Excellence
- Indian National Geospatial Award
- PR Pisharoty Award
- President's Appreciation Award
- Young Achiever Award
- Best Chapter Award
- Best Paper award

Journals: One of the significant contributions of ISRS to meet the objectives of the society is the publication of national peer reviewed journal on Remote Sensing called Journal of Indian Society of Remote Sensing (JISRS). The Journal of Indian Society of Remote Sensing is a monthly journal that publishes original research contributions in all the related filed of remote sensing and its applications. At present, the journal has an impact factor of 0.810 and it is improving year by year. All the members of the society have facility to access the JISRS online from our website (http://isrs-india.org).

International Linkages

International Society of Photogrammetry and Remote Sensing (ISPRS)

ISRS is an ordinary member of the International Society of Photogrammetry and Remote Sensing (ISPRS). India has been awarded Chairmanship of **Technical Commission V: Education and Outreach for the period 2016-2020**. India has successfully chaired Technical Commissions during 1996-2000, 2000-2004, 2004, 2008 and 2012-2016. ISRS has successfully hosted ISPRS TC V Mid Term Symposium 2018 during November 20 – 23 at IIRS, Dehradun. Around 450 delegates participated globally (website: http://isprstc5india2018.org).

Asian Association of Remote Sensing (AARS)

ISRS is also member of Asian Association of Remote Sensing (AARS). ISRS has successfully hosted ACRS-2017 during October 9 – 13, 2017 at New Delhi. India had earlier opportunity of hosting the ACRS twice in the past.

Way Ahead:

- To expand its outreach, it is planned to have more publications in the form of monographs, books series etc. It is anticipated that more chapters are likely to be formed in newer/cities to increase the awareness among researchers, professionals and students communities.
- Sensitization & Popularization of remote sensing among people through ISRS Chapters
- Accreditation by ISRS for offering RS & GIS related Technical services
- Supporting AARS and ISPRS Activities.

Please visit ISRS website for details and online registration (http://isrs-india.org).

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Web GIS

A web portal for monitoring and evaluation of biodiversity conservation and public partnership initiatives for the river Ganga

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Protecting the Ganga River has become a national priority and the responsibility has been shared and undertaken by various government and non-government organizations. Various issues in terms of pollution, river water abstraction and allocation, river bank development, village development, etc. are being resolved. However, there needs to be a mechanism to measure the success of these initiatives. While water quality assessments and infrastructural development can certainly certify these, a true reflection can only be found in the biodiversity thriving in the rivers and the awareness in the native inhabitants. Conserving the biodiversity and monitoring its status has been accepted as an effective tool to assert the river's rejuvenation status. Incorporating this, the National Mission for Clean Ganga has adopted Biodiversity Conservation for Ganga Rejuvenation as an important component of its programmes. As part of the project entrusted to Wildlife Institute of India, a large number of stakeholder trainings and workshops, and sensitization and community empowerment programmes are being continuously conducted. This is done to strengthen the commitment of agencies as well as communities for this cause. Apart from this, it is also important to avail to common people, knowledge of the diverse aqua life dwelling in the Ganga River, right from the exclusive Gangetic river dolphin, elusive otters, specialist gharials, ancient turtles to the breeding resident as well as migrant birds. Very little is known to the local people as well as to common people about the biodiversity harbored by the Ganga River. Dissemination of facts and multimedia pertaining to Ganga River and its aqua life thus is a necessary step for spreading knowledge and thereby creating an enthusiasm to preserve the richness in the rivers. A web portal integrating all these efforts being developed which will not only act as platform for interdepartmental linkage and coordination, but also serve as a critical IT tool for linking various stakeholders groups and communities related to Ganga River in their efforts towards biodiversity conservation.

Keywords: Information system, Repository, Aqua life, Biodiversity conservation

Dynamic analysis of NDVI time-series in WebGIS environment to improve crop management

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Demands for timely information, dynamic analysis and data accessibility to support agriculture management using new technology are increasing worldwide. Thus, it is essential to devise the information system which provide timely information about crop for better planning and management. Information regarding crop phenology is essential for crop management. Time-series data of Normalized Difference Vegetation Index (NDVI) obtained from various satellites is widely used for studying vegetation phenology. Although these data products come pre-processed to mitigate noise, residual noise in the vegetation indices time-series data, even after applying strict pre-processing, impedes further analysis and risks generating erroneous results. Therefore, smoothing of the data becomes a necessity. Two smoothing techniques have been used for this purpose: Modified Savitzky-Golay filter and the Whittaker Smoother. The results obtained from these two techniques were also evaluated. Using spatio-temporal analysis of smoothed time series, variations in annual vegetation phenology were estimated. Based on annual crop cycles at a particular pixel location, number of crops are estimated at that location. In this paper, WebGIS based application is presented. It facilitates user with on-the-fly analysis of time series NDVI data of clicked location on map. It involves smoothening of NDVI profile,

estimation of crop cycle etc. Entire process was implemented and automatized using GDAL, Python, Flask (REST API) and WebGIS technologies.

Keywords: NDVI, REST API, Crop, WebGIS, Phenology

Applications of geospatial technology to evaluate world's largest social safety net

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Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is considered to be World's largest social safety net program. The geospatial evaluation of MGNREGA involves acquisition and synthesis of multi-date remote sensing data, thematic information, geospatial indicators (such as NDVI, land erosion and water spread areas) and geo-tagged information of development activities that resulted into construction of physical infrastructure and assets. This article emphasizes the applications of geospatial technology to evaluate the results of sustainability due to MGNREGA program. Web-based Geoportals, namely Bhuvan and VEDAS, are providing wealth of useful and important information to the citizens. These geoportals further provide effective and efficient extraction of interesting, meaningful and relevant knowledge from data archives and dashboards. A set of geospatial indicators like land use / land cover changes, maximum NDVI, forest loss/gain, water spread area, agriculture productivity along with statistics were used to study the impact of development activities that are outcome of MGNREGA programmes on environment factors like agriculture, water resources and forest. The primary purpose of MGNREGA is for poverty alleviation and employment generation. The spin-offs originated from this program have led to useful national assets creation. Our research found that the anthropological effects due to the development of assets have balanced the ecosystem components and strengthened the sustainable development due to social safety net implementation. Geoportals are not only useful for monitoring the development activities but also proven to be very much effective to assess the sustainable development.

Keywords: Geoportals, Sustainable development, Social safety nets, Geospatial technology

Development of satellite derived value added agromet products for agro-advisories

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Decision making in day-to-day farming operations is a complex process in which many threats need to be considered to optimize resources for utilization to minimize cost of cultivation and crop loss. Today farming community is under many types of threats related to management, production, marketing, legal, social and human aspects, which arise primarily due to anomalous weather conditions. To streamline and advise on day-to-day farm operations, there is a need to augment current agricultural extension work using new advanced techniques at regional to landscape scale. This opens a pathway to use space data to generate near real-time value added products that will help to develop a usable decision support system for existing national agro-met advisory services to support management, monitoring and execution activities at different spatial scales. To

assist the farmers at local to regional-scale forewarning models of mustard aphid in *rabi* season and weekly dryness index product for *Kharif* season were developed. *In-situ* long-term pest observations and satellite data assimilated weather forecasts were used to develop mustard aphid pest forewarning model at all mustard grids of 5×5 km over Rajasthan state. The model provides 20-days advance forecast for (i) crop age (in days) at first appearance of aphid, (ii) crop age (in days) at peak population of aphid, (iii) maximum aphid population (count) from first week of January to second fortnight of February during crop season. The developed model was made operational and information disseminated through VEDAS geo-portal (vedas.sac.gov.in) and weekly updated as per the Standard Meteorological Week (SMW). The forewarning model was validated in two districts of Rajasthan state at multiple sites; showed 8 to 10% difference in days for crop age at first appearance and 5 to 6% in days for crop age at peak population during crop season with 15-20% difference in maximum aphid population. The model showed minimum difference during second fortnight of January to first week of February during crop season. To assess the dryness in *Kharif* season over rainfed agricultural regions, weekly dryness index was developed using daily reference evapotranspiration and rainfall (HEM) products generated from INSAT 3D at MOSDAC portal. The dryness index product was made operational at VEDAS geo-portal since June 2018 and regularly updated as per SMW. The portal also provides different online tools to user for comparison of (weekly and past year) dryness index of a particular place so accordingly advisory can be issued. It is expected that these value added products will be added in bi-weekly national Agro-advisory issued under Gramin Krishi Mausam Seva (GKMS) from IMD Agrimet, Pune after rigorous validation at multiple locations.

Keywords: Agromet products, Mustard Aphid, Dryness index, VEDAS, Agro-advisories

GIS based land suitability analysis for crop diversification in central parts of Punjab

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Rice-wheat cropping system (RWCS), dominantly followed in Punjab, has induced many soil and water related problems like deterioration of soil structure, declining underground water and lesser water productivity. One of the options is to identify the range of suitable alternate crop options in existing cropping areas to facilitate diversification. Therefore, the land area not suitable for growing paddy was determined by taking into account its intrinsic characteristics (like soil texture) and other parameters in Geographical Information System (GIS). We used the Spatial Analytical Hierarchy method introduced by Saaty to define the suitability for growing paddy in Ludhiana district (Central region of Punjab, India). The major parameters considered for suitability analysis were slope, soil texture, drainage, soil fertility (pH, electrical conductivity, organic carbon, macro- and micronutrients) and ground water quality for irrigation. The weightages for each parameter were computed using the multiplicative method followed by calculation of combined weightage which is expressed as Cumulative Suitability Index (CSI) of all the parameters. The area suitable for growing paddy in Ludhiana district was defined using CSI. The marginally suitable and not-suitable area (due to number of limitations) for growing paddy was 12 and 7% of the total area of district, respectively. These results suggest that depending upon the limitations and potential, marginally suitable area of paddy may be brought under crop diversification, which may be one of the high-volume options for replenishment of depleting groundwater in Punjab.

Keywords: AHP, Crop diversification, Land suitability, GIS

Disease control and combat mapping for tribal fortification using GIS: A case study for selected tribal blocks of Rayagada district, Odisha

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Importance of health with respect to all living beings needs no special mention in the contemporary society. However, due to lack of awareness and health care services, many parts of our nation are still gravely affected due to several diseases, mostly the rural areas in general and much in particular the tribal villages. Most of the regions in India still have poor health protecting infrastructure facilities and as a result of which majority of the rural population is suffering from many diseases that could have been controlled with proper understanding of the disease causative process and possible preventive measures. In order to provide with better health care facilities in the PHCs, a data base of the disease causing agents and the remedial measures in the form of GIS maps will help in regularly monitoring the health level of rural public. An attempt has been made to map most common factors of prevalent diseases in rural and tribal regions (Selected Blocks) spread over Rayagada district of south Odisha state and further attempt to develop a health care information system for the tribal regions considered. A well set methodology has been derived to find out the Disease vulnerability index for the selected blocks. The sum of the product of the weightage and rating will result in an index which is referred as "Disease Vulnerability Index" (DVI) and this index is evaluated specific to the diseases considered. Data analysis has been done for disease vulnerability mapping considering Environmental Parameters, Parameters that favor the sustenance of Disease Causing Vectors (DCVs) (Climatic factors), and Parameters that resist the growth of D.C.Vs (General Sanitation & Drainage). Each of the Disease causing agents and disease spreading means has been assigned with a weightage factor indicative of the disease causing potential. Based on the relative levels of disease causing agents, each parameter has been assigned with a ranking on a 1 to 10 scale to assess the vulnerability level of the parameter at a certain location. Finally, Disease Vulnerability Map and Disease Control and Combat maps have been derived. It has been observed that high % vulnerable values with respect to B. Cuttack, K. Singhpur, Kashipu, Munigua and Gudari blocks are 9, 13, 11, 12 & 9 respectively. Similarly less vulnerable percentage villages of B. Cuttack, K. Singhpur, Kashipu, Munigua and Gudari blocks have percentage of 47, 59, 50, 54 and 51 respectively. From the control and combat information, it concluded that villages with possible high control percentage in the blocks of B. Cuttack, K. Singhpur, Kashipu, Munigua and Gudari have percentages of 23.05, 14.35, 14.78, 15.3 and 9 respectively. The corresponding %s with possibly & less control in B. Cuttack, K. Singhpur, Kashipu, Munigua and Gudari blocks are 37.23, 44.39, 64.29, 56.83 and 53.95 respectively.

Keywords: Disease mapping, Disease vulnerability index, Geospatial analysis, Primary Health Centre

Deployment of blood bank information system in Delhi: A web mapping application

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The primary aim of blood bank information system is to reduce the wastage of blood, besides ensuring its availability to the patients in minimum time lag. This study demonstrates a blood bank information system based on the real time information, along with an Operational Surveillance System and a Mobility Medical Application. The proposed system facilitates communication between the blood bank and different Hospitals so that the appropriate information can be retrieved on a single platform. It also integrates the blood stock information for individual blood groups scattered among different blood banks along with the patient's

information of different hospitals to eradicate the blood wastage. The hospital authorities, blood banks and the blood bank management authorities are able to use this web application, thereby bridging the communication gap. The information system provides the necessary information in transparent manner thereby reducing the time taken to arrange blood during emergency cases and tracking the blood availability in real-time. The application will help the users to locate the nearest blood banks and obtain information regarding the bloodstock. A dashboard has been built for real time data updating for tracking, report generation on blood groups most in demand and difficult to collect, graphical representation for stock as per blood group etc.

Keywords: Web application, Real time tracking, Blood bank, Health GIS

Forecasting of NDVI time series using statistical methods

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Use of remote sensing derived information in agriculture sector plays an important role for decision makers to know status of vegetation on larger spatial scale. Researchers has developed various indices for this purpose. Normalized Difference Vegetation Index (NDVI) is one such index that measures vegetation vigor of crop. Agricultural community has shown its uses in various applications viz. vegetation health monitoring, crop growth assessment, crop yield estimation etc. NDVI forecasting helps to make an educated guess, based on its temporal behavior in past years, on likely vegetation condition ahead of time and thus supports decision makers to formulate mitigation strategy. In this paper, MODIS 16-days maximum value composite satellite data (MOD13A1) with spatial resolution of 500 m, is used for calculating NDVI and then, NDVI forecasting is performed based on 2002-2016 NDVI time series data. This paper uses two statistical approaches, (i) Conditional mean and variance based statistical approach, and (ii) Auto Regression Integrated Moving Average (ARIMA) technique for forecasting. Forecast of NDVI values are compared with observed NDVI data for year 2016-2017 using mean absolute percentage error (MAPE) over Gujarat region of India. To investigate seasonal impacts on forecast of NDVI, seasonal MAPE is calculated and reported. This seasonal study of NDVI forecasting can be used to supplement the routine monitoring of environmental conditions for wide range of applications. The developed forecasting model is currently operationalized on VEDAS web portal (https://vedas.sac.gov.in).

Keywords: NDVI forecasting, ARIMA, MODIS, VEDAS

Internet of Things (IoT) based smart DES

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Internet of Things (IoT) is an upcoming concept. It is a network that helps in connecting, collecting and exchange of data among the different devices, software, sensors and systems over Internet. Delhi, the sixth-most populated metropolis in the world (second largest if the entire NCR is included), is one of the most heavily polluted cities in India. IoT concept can be extended to monitor the air pollution in Delhi Earth Station (DES) using low cost gas sensors. This will help to have a quality check on the air quality. Major air pollutants like CO_2, NO_2, CO, temperature and humidity sensor etc., can be monitored. Using a “Raspberry Pi” board, these sensed values obtained can be processed, and alarms/messages for the air-quality can be sent over the internet

through email server and SMS to the employees, so that proper precautions could be taken during the days when the pollution peaks in Delhi. This system thus provides an innovative, cost effective and easy to implement approach for a smart office in terms of environment monitoring.

Keywords: Internet of Things (IoT), Raspberry Pi, Gas sensors, Email server, Humidity.

Geospatial technology for weather and ocean information services from MOSDAC

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Indian satellites providing meteorological and oceanographic observations are important components of Earth Observations Satellites (EOS) of Indian Space Research Organization (ISRO). The Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) (www.mosdac.gov.in) is a data repository for the missions that also serves to disseminate these data for operational prediction of weather and ocean states, validation of prediction and data retrieval models and research requirements in Near Real Time (NRT) mode. MOSDAC provides weather and ocean information services on a Geospatial platform related to weather and ocean forecasts at different prediction lead times ranging from immediate short range (nowcasts), medium range to seasonal time scales. We have used the Geographical Information System enabling the creation, organization and presentation of the data in a spatially referenced form as well as production of maps and charts. Use of GIS platform in web dissemination of the information services are valuable in terms of providing a Decision support system to Disaster Management Program. These services include high resolution NWP based forecasts of weather parameters, Ocean state forecast (Ocean Eye), very short range prediction of heavy rainfall and cloud bursts for Utarakhand and Himachal Pradesh, prediction of Cyclogenesis, Cyclone tracks, intensity and storm surge forecast (SCORPIO), as well as the high resolution seasonal prediction of summer monsoon rainfall. MOSDAC also provides regular observations and information related to extreme weather events like All - India heavy rain (>5mm per hour) using the real-time observations from INSAT series of operational satellites. The daily weather forecast in terms of temperature, humidity, pressure, rain, and winds is regularly disseminated and used by state agencies like Karnataka State Natural Disaster Management Centre (KSNDMC) and Jharkhand Space Applications Centre for regular agricultural advisories to millions of farmers. All these forecast is also accessible over Android based Mobile devices. The alerts in terms of notification related to extreme weather events on Android devices through the MOSDAC Mobile Weather App.

Keywords: MOSDAC, Web GIS, Extreme weather events, Data dissemination

TS - 1/2
Geo Sciences

Estimating the intra-plate movement of India along Narmada Son lineament

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India, having unique geological and structural conditions, is susceptible to various precarious tectonic plate activities. Albeit, from time to time such movements are reported by geological, geomorphological, geophysical, petrological and mineralization evidences. All these processes are tedious and may or may not yield perfectly accurate results and the predictions to any consequential disaster is too late to come. India has many fault zones and the prominent one of them is the Narmada-Son Lineament (NSL). This active fault zones can be studied using GNSS data which is far more precise and accurate in predicting the actual orientation and magnitude of plate movements. It was observed that if the deformation zone is aligned with the NSL across central India, 2±1 mm/year of north-south convergence are indicated. We have a good network of IGS (International GNSS Service) sites around the world which ensures high quality GNSS data products. Furthermore, many organizations in India keep record of data from GNSS dual frequency receivers installed at various sites in the country. The baseline processing can be performed between some sites in the northern part of NSL with IGS stations in Eurasian plate, and the same process can be repeated with some southern sites of NSL with IGS stations in Indian or Indo Australian plate. Comparison of the processed baselines of last 5-6 years would definitely indicate the precise value of intraplate movement of India. It can also provide a prediction of movement in near future and consequences related to it. The comparison of the results from GNSS baseline processing with that obtained from the tectonic geomorphometric studies will help to validate the results obtained from the later.

Keywords: Active fault, Narmada Son Lineament (NSL), North-South convergence, IGS, Baseline processing

InSAR constraints on the September 3, 2017, North Korean Nuclear test

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North Korea conducted an underground nuclear test on September 3, 2017 at the Punggye-ri nuclear test. According to USGS the nuclear explosion corresponds to a seismic event of magnitude Mb=6.3. We report the surface deformation caused by the nuclear test using ALOS-2 InSAR data. We observe that the explosion caused large-scale surface deformation causing decorrelation of the InSAR data directly above the test site, on the top of Mt Mantap. However, we map crustal deformation associated with the event near surrounding regions, along the flanks of the mountain. The LOS deformation from ascending and descending data are opposite in nature suggesting large-scale horizontal deformation. We model the source parameters of the Nuclear explosion using Mogi homogenous half-space dislocation approach. The preferred location and depth of event is 129.0775°E, 41.330°N, 400-600 m below the surface, respectively. The present study demonstrate that the capability of InSAR data to provide location and source characteristics of nuclear tests.

Keywords: InSAR, Surface deformation

Land subsidence in Mehsana region of Gujarat: Detection by radar interferogram and GRACE

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Groundwater overdraft is a serious issues particularly in clay based stressed aquifer system of semi-arid region of Mehsana. With a surge of rapid industrialization and excessive dependency to groundwater for industrial, agricultural and domestic use the subsurface clay-bearing confined aquifer system are undergoing permanent deformation under stressed hydrodynamic condition. In this work, we portray land surface subsidence due to prolonged groundwater depletion, both at regional and local scales, using Gravity Recovery Climate experiment (GRACE) satellite data with ground water depletion trend from year 2003 to 2017 and vertical subsidence rate of 3.11 mm/year and 20 km^2 of horizontal extent using interferometry techniques using ALOS-2 and RADASAT-2 data.

Keywords: DInSAR, GRACE, Ground water depletion, Land subsidence,

Mapping hydrothermal alteration in parts of Ambaji using imaging spectroscopy

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Ambaji-Deri region is well known for occurrence of Volcanogenic Massive Sulphide (VMS) type deposits of base metals such as lead, zinc and copper. Chloritic hornfels and diopside marble of Ajabgarh formation are the major host rock for sulphide mineralization in the region. In some cases, mineralization is also found to be associated with biotite-quartz-schist while it is rarely associated with amphibolite. Rock types in the area first experienced low grade regional metamorphism under greenschist facies. Later on during emplacement of intrusives (granites and alkali syenite), the metamorphosed rocks were further subjected to hornblende-hornfels facies thermal metamorphism. In the present study, we have used hyperspectral datasets of airborne AVIRIS-NG sensor to study the hydrothermal alteration associated with base metal mineralization in Deri-Ambaji region. Most of the alteration minerals such as white mica, clays and carbonates have diagnostic absorption feature in Short Wave Infrared (SWIR) region, which aids in unambiguous identification of these minerals. Wavelength position of deepest absorption feature in SWIR region (2.0-2.5 μm) was modelled by fitting quadratic polynomial to spectra. It was observed that majority of the pixels show absorption in wavelength range 2.30-2.35 and ~2.20 μm indicating presence of carbonate and clay species. Detailed analysis of reflectance spectra revealed presence of calcite, dolomite, epidote and kaolinite as spectrally dominant mineral species present in the region. To map the spatial distribution of these mineral species, Integrated Band Depth (IBD) technique was used. For carbonate species, integrated band depth of absorption in wavelength range 2.29-2.35 μm was used while for clay, wavelength range of 2.10-2.24 μm was used for computing the IBD. It was observed that near Deri, white mica core is surrounded by carbonate minerals. Based on mineral assemblage and their spatial distribution near Ambaji-Deri region, propyllitic alteration was found to be associated with base metal mineralization.

Keywords: Imaging spectroscopy, Ambaji-Deri, Integrated band depth

Deformation study of Mahanadi delta region using InSAR technique

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Phase Arrayed type L-band Synthetic Aperture Radar (PALSAR) onboard Advanced Land Observation Satellite (ALOS) has been used to study the deformation of Mahanadi delta using Interferometric Synthetic Aperture Radar (InSAR) technique. Generic Mapping Tool for Synthetic Aperture Radar (GMTSAR) software package is employed to process the raw ALOS-1 data. The entire Mahanadi delta is covered in three different frames, which consists of 17 scenes each and span for a period from 2007 to 2011. The scenes are processed using software GMTSAR for the generation of the interferrogram with the coherence threshold of 0.15. Total 36 interferrogram were generated using 17 scenes, with a baseline threshold of 1 km within each frame. SBAS technique is used for the estimation of the deformation rate of the region. Subsidence and upliftment zones are identified along the deltaic region. An increased rate in ground water extraction along the Mahanadi delta is reported for sustaining of agricultural land, industries and the cities, which may have increased the soil porosity and have likely contributed towards the subsidence along the deltaic region. The shoreline is observed to have a sequences of subsidence and upliftment zones. The coastal region of Puri and the river mouth are the major subsidence zone identified from the study. The sediment depletion due to water conservation infrastructures also play a crucial role in the subsidence of the region.

Keywords: Deformation, Mahanadi delta, SBAS, ALOS, GMTSAR

Seismic risk zonation using geospatial tool: A case study over East and South district of Sikkim

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Assessment of risk due to seismic hazards in the vulnerable zones provide not only safer and healthy sites for homing but also its necessarily important to drive the pathway of sustainable development especially in the areas like Sikkim where there is highly undulating terrain with continuous orogeny. The Landsat 8 OLI data was used to prepare the land-use\ land-cover map of East and South district of Sikkim, while Digital Elevation Model (DEM) derived from Cartosat-1 Stereo pair was used to look into the physiographical aspects of the region. Furthermore, the soil and geological map prepared by Geological Survey of India (GSI) were used to retrieve susceptible zones with the help of Analytical Hierarchy Process (AHP) technique with weightage function as per Saaty's scale. Ground motion data of four different parameters were acquired from United States Geological Survey (USGS) for an earthquake event on September 18, 2011, epicentered at 27.730°N, 88.155°E. The area with soil type of udorthents entisol in the 10 km buffer zone from the major faults were mostly affected by the seismic hazard. Historical earthquake data acquired from USGS was used to get the location of earthquake epicenters in the past. The AHP comparison matrix indicated that the proximity of any area to the fault lines was most important parameter, followed by the ground motion vectors, while the LULC categories were found to be least influential. Using the weighted overlay analysis, the western boundary of East district and north-west of South district were found to be under high seismic risk zone.

Keywords: Seismic hazards, Analytical Hierarchy Process (AHP), USGS, Fault line

Drainage morphometry analysis of coastal tract from Mahanadi to Dhamra river, Odisha

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Morphometric analysis is important in any hydrological investigation and it is inevitable input in development and management of drainage basin. A critical evaluation and assessment of morphometric parameters of the study area have been achieved through measurement of linear, aerial and relief aspects of basins by using remote sensing and GIS techniques. The quantitative analysis of morphometric parameters is proved to be of immense utility in the study of coastal watershed management, water conservation and natural resources management at micro level. The present work is an attempt to study of linear, relief and areal morphometric parameters along with a drainage vulnerability map based on the drainage density. For planning and management activity, a detailed present land use/land cover (LULC) map is needed, thus an attempt has been made to generate the LULC of the study area. Besides these, the vegetation index and elevation distribution map have been prepared. The study area has an area of 1085.72 km^2 and lies in the administrative unit of Kendrapara district of Odisha, India. The SRTM DEM data for the year 2017 has been used to delineate drainage system. Different hydrological tools of ARC GIS and ENVI software have been utilized in the drainage analysis. Again a historical drainage set-up for different time period viz. 1973, 1985, 1995, 2005 and 2017 by using LANDSAT series data has been analyzed. The findings will be useful for the coastal managers and decision makers in the sustainable management of the fragile coastal environment.

Keywords: Morphometric analysis, Remote sensing, GIS, SRTM

Study of episodic reactivation of palaeochannels in parts of Barmer, Rajasthan using multi-sensor data

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Palaeochannels are geomorphological representations of remnants of old fluvial channels, which are either buried or abandoned. These units are expected to be repositories of larger amount of good quality groundwater compared to their surroundings. Thus, identification and characterization of such hydro geomorphic unit is of even greater importance in arid desert terrains, particularly in western Rajasthan, India. One such distinct palaeochannel surfaced episodically on the deserts of Barmer, Rajasthan after devastating flash floods in the years 1990 and 2006 respectively. Two sinuous shaped drainage scar located at 71°29'E and 25°54'N trend dominantly in NW-SE direction along the local gradient. The distinguishable non-vegetated extent of the channels covered with post flood Aeolian deposits extend for 2.1 km downstream and varies between 0.2-0.75 km in width. The channels converge and terminate abruptly near the village Kawas (located 20 km north-east of Barmer city) where flood water remained stagnant due to the impervious sub-surface lithology. The steeply sloping rising limb of the flood hydrographs indicate a sudden increase in the water level. The turbid flood yield with high sediment influx breached the thick sand dunes along it's gradient, in turn exposing and reactivating these buried channels and also forming water-logged ponds in the low-lying depressions. In this study, we used multi-sensor satellite data to get a synoptic view of the different stages of reactivation, disappearance and reappearance of these paleo-channels between the period of 1990-2006. We integrated observations from multi-spectral Indian Remote Sensing (IRS) Satellite Resourcesat-1 LISS-III data, Japanese quad polarized Advanced Land Observation Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) images, Digital Elevation Model (DEM) data from the Shuttle Radar Topography Mission (SRTM), daily ground precipitation data from Indian Meteorological Department (IMD) and field observations. The data was used to study the driving factors behind the reactivation of these palaeochannels in the multiple-flood events. This study

will contribute both to the identification of underground fresh water aquifer sites and also to recognize techniques and policies to effectively divert and utilize the flood run-off for the benefit the society.

Keywords: Palaeochannels, Flash flood, Barmer, Aquifer

ANN-based approach for landslide hazard assessment in Alaknanda river basin

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The physical factors of the terrain such as unstable geological structures, and rugged topography along with the triggering factors like earthquake and heavy precipitation during monsoon cause severe landslide phenomena in the Indian Himalayas. Within the Himalayan region, Garhwal Himalayas is one is one of the most landslide prone regions. In this context, the present study assesses the spatial probability of landslide occurrences through analyzing the relationship of landslide events with various geo-environmental factors in Alaknanda basin of the Garhwal Himalayas. Landslide causative geo-environmental factors has been used in the present study to calculate the weights. The topographical and hydrological factors have been derived from 12.5 m resolution ALOS-PALSAR DEM. Land use and landslide inventory maps were prepared from 10 m resolution Sentinal-2 satellite image for the year 2017. To make the landslide hazard map, first of all weights for each landslide causing factors have been calculated. For this purpose, Multi-Layer Perception (MLP) Artificial Neural Network (ANN) was used. From the analysis, it was found that the probability of occurrence increases with the slope gradient, the concavity of the slope and proximity of the river. Among land use, it is found that most of the landslide occurs in sparse forest area, followed by barren land, agricultural land, moderately dense forest area. From the susceptibility analysis, it is found that about 18% area comes under highly landslide prone area whereby 54% of total landslides have occurred. Presence of more than half of the landslides in predicted high landslide prone zone indicating the reliability of the prediction.

Keywords: Landslide, Susceptibility, Artificial Neural Networks, Alaknanda river basin

Dynamics of land cover changes and its impact on groundwater in Central Punjab

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Ground water is essential for our daily life where both quantity and quality have significant importance for human life. More and more groundwater extracted to meet the increasing demand of fresh water for drinking and irrigation, resulting in rapid depletion of groundwater resources in Punjab (India). The present study carried out to assess the dynamic change in land use/ land cover and its impact on the groundwater depletion over the period of 2000 to 2015 using remote sensing and GIS. To monitor the changes in land use/ land cover, supervised classification and NDVI techniques used. The changes in land use/ land cover during 2000 to 2015 obtained using Landsat satellite data and change detection map was prepared and correlated with ground water level data to understand the relation of groundwater depletion with changes in land use/land cover. The study shows that several land use land cover changes directly or indirectly affect ground water storage. For example urbanization, deforestation and industrialization has negative impact on groundwater storage whereas plantations have positive impact. Present study shows that wherever the urban area was increased the ground water level declined at an alarming rate. The average rate of ground water depletion is 48 cm per year. Ground water depletion was high in Ludhiana city and its surrounding area because of low recharge and high extraction of ground water for

domestic, industrial and irrigation purposes. In agricultural area, the ground water depletion was not significant in earlier years but in recent days, it was severe due to higher use of ground water for irrigation purpose.

Keywords: Ground water, GIS, Landsat, NDVI

TS - 1/3
Agriculture

Space technology based solutions for claim verification under income tax exemption

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In the last few decades, remotely sensed data in combination of geographic information system (GIS) played a vital role for the assessment and management of earth resources. In the recent few years, new avenues were opened up for the use of remote sensing and GIS in the field of crop insurance, mapping of property tax, geo-tagging of government assets, decision support systems for agricultural marketing, impact analysis of government schemes etc. Here, in this paper, an advanced use of remote sensing (RS) data is presented in the field of Income Tax (IT). In 2017-18, solution / guidance was provided to IT Department for about twenty cases related to income tax especially related to tax exemption claimed on, so called, agriculture income or capital gain exemption due to sold out income of agricultural land or investment in purchase of agricultural land or investment in construction / purchase of own / new house. Out of 45 land parcels of 20 different IT cases, most of them were multi-year or multi-season cases. It needed analysis of more than 100 Cartosat-2 merged with LISS-IV images and more than 150 Google-earth images. Cadastral maps showing the particular survey number of the respective village were overlaid over the ortho-rectified multiple RS image layers. The temporal profile of Normalized Difference Vegetation Index (NDVI) was also generated and studied for each land parcel for final interpretation. The land parcels having NDVI above the threshold (0.25) continuously for more than three months were considered under the active agriculture. It was finally visually verified with Google earth images to omit the falsely claimed active agriculture but actually under the grass-dominated–fallow field or wildly grown babul trees for a long duration. It was found that most of the cases (>80%) were falsely claimed for income tax exemption. Seeing the success of capability of space-based solutions Income Tax Department is actively considering to operationalize the approach in association with ISRO.

Keywords: Income tax, Remote sensing, Geo-informatics, Agriculture income, Capital gain

Monitoring acreage and harvesting pattern of wheat crop in Punjab, India using geospatial technologies

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Wheat is a key global commodity in terms of acreage and tradable value and as a staple in household diets. Many factors affect wheat prices including climate, yields, oil prices, lagged prices, and imports. In addition to gradually and consistently increasing global wheat demand, these market drivers posited to impact world prices and, ultimately, food security. India is one of the main wheat producing and consuming countries of the world. The production of wheat has shown a huge increase after the Green Revolution in 1970's. The major wheat growing states of India are Uttar Pradesh, Punjab and Haryana. Because of the availability of better irrigation facilities, the yield of wheat in Punjab is the highest. The wheat crop harvested after the grains harden and the straw becomes dry and brittle. In Punjab wheat, sowing starts from Mid-October and continues until late December. The harvesting starts form early April to start of May. The harvesting time varies from zone to zone as rain fed crops reach the harvesting stage much earlier than irrigated crop depending on the soil and climatic conditions. Remotely sensed images offer great potential in estimating crop extent and yield over large areas owing to their synoptic and repetitive coverage. In the present study acreage under wheat for the crop season 2017-18 and its harvesting pattern was monitored using multi-data, multi-sensor optical satellite data for the period October 2017 to May 2018 following hybrid classification. The results of the study revealed that acreage under wheat for the crop year 2017-18 was 3524.66 thousand ha and the harvesting of wheat started from the 1st week of April and ends up in the 2nd week of May 2018. Harvesting pattern of wheat in the Punjab State

revealed that harvesting started in southwest Punjab and then to the central Punjab and extends towards North and North-Eastern & North West Punjab. The maximum wheat area was harvested between 9th April to 18th April 2018 i.e. 1103.29('000 Ha.) and minimum between 2nd May to 9th May 2018 i.e. 372.00 ('000 Ha.).

Keywords: Wheat, Geospatial technologies, Punjab, Acreage, Harvesting pattern

Remote sensing based semi-physical approach for spatial yield prediction of cotton

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India has the largest area under cotton and ranks second in cotton production. Cotton yield forecast is required for making decisions regarding export and import policies, distribution and price policies. Past experience has shown that the semi-physical approach with remotely sensed inputs can be successfully used for operational forecasting crop yield. Hence, the present study was carried out to explore the feasibility of this approach for estimating cotton yield at spatial scale. Gujarat state of India, which is the second largest producer of cotton in India, was taken as the study area. The semi-physical approach uses the radiation use efficiency based model to estimate net primary productivity (NPP) or potential biomass. Potential seed yield was computed using the integrated biomass over the cotton growth period (sowing to harvest) and Harvest Index (HI). The potential seed yield was then converted to actual yield using water stress and temperature stress. Remotely sensed data products from GEO (INSAT-3D)-LEO (AWiFS, MODIS) satellite sensors were used for deriving different model input. In addition, interpolated temperature data was used to derive the temperature stress. Sowing date was derived from time-series NDVI data over cotton growth period. The seed yield was converted to lint yield using the ginning percent and is expressed as bales/ha. The lint yield was then compared with the reported lint yield. The seed yield was found to vary from 500 to 4200 kg/ha. The spatial distribution showed highest seed yield in Vadodara (3.55 bales/ha) and lowest seed yield in Jamnagar (2.4 bales/ha). The absolute deviation was within 15 % in all districts except for Bharuch (18 %). The root mean square error (RMSE) between the estimated and reported lint yield was found to be 0.29 bales/ha (10.46 % of the mean yield). From this study, it may be concluded that the semi-physical approach with remotely sensed inputs could be used to forecast cotton yield at district level with an RMSE of 10.5 %. This approach shows the ability to capture the spatial variability in cotton yield within the district.

Keywords: Radiation use efficiency, INSAT-3D, RS2-AWiFS, MODIS, Cotton yield

Paddy yield prediction using multi-temporal satellite data and AquaCrop model over Sahibganj district, Jharkhand

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Agriculture has vital role in the economy of numerous developing countries including India. Rice (Oryza sativa) have a significant role by providing the nutritious requirement to the approximately 66% of the world's population and over 90% of total population of the Jharkhand state. Yield prediction before harvesting using remotely sensed satellite imagery and crop models are significant steps to make key decision on food storage, procurement, public distribution, export-import (EXIM), and related issues. Present study has utilized the time-series MODIS-based Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI)

data in conjunction with CCE data to derive a linear regression and multi-regression model for paddy yield prediction over Sahibganj district in Kharif (monsoon) season of year 2017. The CCE data were collected from ten random paddy plots over the district. In addition, Area, Production, and Yield (APY) data were collected during harvesting period by interacting with eighty farmers belongs to eight villages over the district. The AquaCrop model was used to simulate the paddy yield for Kharif season of year 2017. Based on the survey-based APY data, paddy yield over the district was estimated at approximately 4217 kg/ha whereas, NDVI and EVI based data showed about4089 and4711 kg/ha yield respectively. With respect to survey-based data, relative deviation (RD) of yield based on NDVI data was -3.04% (underestimation), while EVI was 11.71% of RD (overestimation). Both, multi-regression based yield model and Aqua Crop model was overestimated by 1.56% and 1.89% of RD, respectively. Thus, we can infer that multi-regression based and AquaCrop model based yield were close to survey-based yields. It can be conclude that satellite data based yield prediction can be reliable with ± 10% of RD. Nevertheless, remote sensing technology can be beneficial over traditional survey method as the satellite-based methods are cost-effective, robust, reliable, and time saving then the traditional methods.

Keywords: Yield prediction, Remote sensing, Satellite data, AquaCrop model, CCE data

An assessment of green and blue water use over Indian agroecosystem using Geo-Leo satellite observations

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Increasing population growth and threat of climate change pose the increasing demand for agricultural water usage threatening food security. Hence, comprehensive assessment and quantification of consumptive water use (CWU) in agricultural sector is necessary on an urgent basis. Indian agriculture is a fusion of both rainfall and irrigation water, and hence, without proper segregation of green (CWUg, evapotranspiration streaming from rainfall) and blue (CWUb, evapotranspiration streaming from irrigation) water, water-use assessments are incomplete. The present study thus, quantifies the spatio-temporal assessment of CWUg and CWUb over Indian agroecosystem in kharif and rabi seasons during 2009-2014. The key variables are crop water requirement (CWR), actual evapotranspiration (ETa) and effective rainfall (ER). Monthly reference-evapotranspiration (ET0) was estimated from daily ET0 using daily solar insolation from Kalpana-1 VHRR (8km) and Weather Research and Forecasting (WRF) variables (3 km) through data fusion in FAO 56 framework. Composite crop co-efficient (Kccomp) computed using stage-specific crop-coefficient (Kc) from FAO 56 manual and weighted through crop area fraction from published statistics in a given administrative unit were adjusted using local meteorological data from WRF model. Time series of fractional canopy cover (*fc*) estimated from temporal NDVI profile at 1 km resolution (10-day INSAT 3A CCD during January 2010-November 2014; 16-day MODIS during July-December 2009; INSAT corrected) were fitted with pre-computed Kccomp to develop season-specific Kccomp model to generate distributed Kccomp, which were averaged together to construct monthly Kccomp. The CWR, a seasonal sum of ETc (crop-evapotranspiration) was estimated from Kccomp and corresponding ET0. Monthly ER was estimated from daily rainfall of NOAA CPC data (10 km) using USDA SCS method. ETa was estimated using single-source surface energy balance framework with thermal observations from MODIS and MERRA reanalysis data. The CWUg Results showed that during 2009 to 2014, the average CWU was found to be 5777 mm (CWUg ≈ 88%; CWUb ≈ 12%) and 4306 mm (CWUg ≈ 26 %; CWUb ≈ 74%) in kharif and rabi seasons respectively. Although, during 2009-2014, CWUg showed increasing trend (6%) in kharif season but the reported drought years e.g. 2009 (4784 mm), 2012 (5018 mm) and 2014 (5070 mm) showed lower values as compared to the normal years 2010 (5066 mm), 2011(5182 mm) and 2013 (5383 mm). The CWUb showed increasing trend (12 %) during rabi season indicating improved irrigation facility over the years. The Indo-gangetic plains showed the highest CWUg (kharif: 1510 mm; rabi: 494 mm)

and CWUb (kharif: 174 mm; rabi: 895 mm) due to high crop intensification. Moreover, most of the rainfall occurs in this region during kharif season and has extensive irrigation application during rabi season for crop production. This study is an innovative approach with scope to prioritize proportion of water allocation in agriculture. This will lead to develop decision support system for sustainable agricultural production with respect to climate change.

Keywords: CWU, NDVI, MODIS, WRF, Kharif season, Water allocation

Evaporative fraction variability modelling over an irrigation canal command using remote sensing

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The spatial and temporal evaporative fraction (EF) is useful for the estimation of regional and temporal evapotranspiration (ET). The remote sensing based Surface Energy Balance Algorithm for Land (SEBAL) method is useful to estimate the EF and this also helpful in estimation of soil moisture, irrigation water requirement and crop water stress. The factors like evaporative fraction, soil moisture, available energy, vegetation and meteorological parameters affects the evapotranspiration. The land surface temperature (TS) and evaporative fraction relation can help in estimation of ET using SEBAL method. The evaporative fraction evaluated based on spatio-temporal approach over Ozat-II irrigation canal command in Junagadh district, Gujarat, India. The Landsat-7 and Landsat-8 images of summer season used to derive the biophysical and land surface variables required for SEBAL. The lower values of EF were observed during initial and end crop growth stages i.e. March, First fortnight of April and late May revealed the low vegetation cover. In the agricultural land, the maximum EF observed as 0.840 during mid-crop growth stage. The higher values of NDVI were observed with higher values of evaporative fraction and shows a similar seasonal variation with that of EF. The relation between the EF and surface temperature, TS gives the negative correlation. The Landsat image based land surface temperature; TS (LST) can be helpful to estimate spatial and temporal EF through the relationship between EF and TS. The remote sensing offers the possibility to estimate the spatial and temporal distribution of land surface heat fluxes and ET over different land surfaces. It is the tool to provide reasonable estimation of the instantaneous EF and daily ET using remote sensing based surface temperatures.

Keywords: Evaporative fraction, Land Surface Temperature, Evapotranspiration

Wheat crop growth monitoring using multi-spectral vegetation indices of Bhal track, Gujarat

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The applications of remote sensing techniques in the field of agriculture are wide and varied ranging from crop discrimination, inventory, assessment and parameter retrieval and assessing long-term changes and short-term characterization of the crop environment. The spectral crop profile development, as monitored using Vegetation Indices derived using multi-spectral Remote Sensing data offers unique advantages in crop identification and crop growth stage estimation. The analysis based on values of NDVI at regular time interval provides useful information about various crop growth stages and performance of crop in a season. In the present study, multi-date Landsat-8 data for the *Rabi* crop season from October-2017 to April-2018, covering Dholka and

Dhandhuka Talukas in Ahmedabad District, was used various indices. The spectral Vegetation Indices (VIs) namely Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Short Wave Infrared - Water Stress (SWIR - WSI) indices were generated using the NIR, RED and SWIR channel digital data. Field data was collected in the selected areas in the study area for identification of wheat and other competing crops grown during *rabi* season. The other competing crops observed in the study area are rice, cotton, jowar and bajara. The ground truth details like type of crop, sowing date, expected date of harvest, percent canopy cover, cropping pattern, irrigation facilities, crop growth stages, crop health /condition were also recorded. Multi data spectral indices of wheat & cotton were generated at different growth stages. The spectral profiles of these two crops indicate that the crops are well separated at different growth stages since there crop phenology is quite distinct. The Water Stress Indices (WSI) and Normalized Difference Vegetation Indices (NDVI) saw the exactly opposite profiles and they can also indicate about the spectral emergence and decline stages which are indicators of spectral emergence and spectral maturity of wheat crop. The study revealed that during normal crop season, the NDWI values were positive for both the crops throughout the growing season. The positive values of NDWI were due to higher NIR-Channel reflectance than SWIR-channel, which indicates sufficient quantities of water in the vegetation canopy.

Keywords: SWIR, NDVI, Rabi crop, WSI, NDWI

Micro-scale forecasting of sugarcane production at mill command area using space technology: A case study in Gujarat

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Estimating the sugarcane (*Saccharum officinarum* L.) production, prior to harvest is required for fixing of Fair and Remunerative Price (FRP) payable by Sugar factories, levy price of sugar and its supply for public distribution systems and regulation of supply of free-sale sugar. This may also help the sugar mill owners to plan for crushing the expected cane biomass, estimate the production of sugar in each mill and look for opportunities to sell or buy from nearest sugar mills if expected production is more or less than factory crushable capacity. This study attempted to estimate sugarcane production over the command area of 5024 km^2 area consisting of 334 villages under the Shree Narmada Khand Udyog Sahakari Mandli Ltd. in Bharuch district of Gujarat state. The mill command area is divided into 19 micro-zones having 7 to 63 villages in each zone. Discrete GPS surveyed data of each sugarcane field under the command area, registered at mill authority were acquired, which were organized in GIS environment after removal of data ingestion errors. To discriminate fresh plantation from ratoon, multi-date LISS-IV derived Normalized Difference Vegetation Index (NDVI) from November 2016, January 2017, February 2017 and April 2017 were used to generate unique temporal sugarcane growth profiles. In the month of August and September 2017, two crop-cutting experiments were conducted corresponding to the peak growth of sugarcane to collect field-measured above ground biomass (AGB) data in 30 diverse plots selected by random stratified sampling using the LISS-III derived NDVI of May 2017. Total fresh crushable cane (only stem) yield was also measured during harvesting for each zone in more than 100 pre-identified fields. Statistical relationships were developed at first between LISS-III derived NDVI, water scalar and AGB, and then between AGB and crushable cane yield. Finally, zone-wise and mill-wise acreage and production were computed.

In sugarcane crop, fresh plantation sugarcane sett is sown and has 12-month growing season from November-December of 1st year to December-January of 2nd year while sugarcane-ratoon crop regrows from the harvested

sugarcane-plant having cropping cycle of 9-10 months during January- February to October-November of the same year. The temporal NDVI profile characteristics of complete growing season can clearly differentiate ratoon from fresh plantations, as ratoon plant has shorter growing season of 1-3 months. In addition, there is early bud sprouting and early high vigor of shoots resulting in higher rate of increase in NDVI. The rate of increase in NDVI was found to be less for fresh planting than ratoon crop during February to April. Based on these NDVI profile characteristics, discrimination was made between fresh planting from ratoon crop. Digital counts of area from satellite image raster and unified GPS vector data were found to be 5,402.70 and 6,399.73 ha for sugarcane fresh and ratoon plantation respectively, with a sum of 11802.43 ha for the mill command area while manual counting by factory showed 11,660.267 ha producing a relative deviation of 1.2% between two sources. Inclusion of water scalar based on SWIR band along with NDVI significantly increased the prediction accuracy of AGB using multiple linear regression as compared to individual univariate regressions. The predicted AGB was found to have good correlation with the actual crushable cane yield. A quadratic equation was fitted between AGB and final crushable yield with R^2 of 0.81. The crushable cane production and productivity in the 19 zones under the mill command area ranged from 21.26 to 129.46 thousand tons and 117.74 t/ha to 139.63 t/ha. This model can be successfully employed for a priori estimation of millable cane yield at village-level using satellite observations and can be aggregated to find out command area and mill -specific cane production and productivity. However, the ultimate benefit of the mill authority can be achieved through implementation of web-based services and training the mill officials especially of IT cells of mill cooperative federation or Indian Sugar Mill Association for operational monitoring of sugar mills using space technology.

Keywords: Ratoon, Village-level, Crushable cane yield, Water scalar, Satellite remote sensing

An assessment of anthropogenic forcings on large-scale evapotranspiration using satellite remote sensing and GIS: A case study for Bihar

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Large-scale Evapotranspiration (ET) is influenced by both natural and anthropogenic forcing factors. Recently, long-term and large-scale Evapotranspiration change hotspots have been identified over India primarily using 30 years satellite remote sensing observations (NOAA, MODIS), surface energy balance framework calibrated with respect to in situ micrometeorological data. This brought out some states where significant long-term ET change is coupled with natural forcing factors such as solar radiation and rainfall. However, some states such as Bihar and Madhya Pradesh, where there is significant increase in ET in last decade (2001-2010) without any significant change in rainfall and solar radiation. The purpose of the present paper to assess how did anthropogenic influence in terms of agricultural management led to increased ET pattern over Bihar state. Calibrated MODIS annual ET data during 2001-2010 were used for the present study. Different district-level statistics related to agricultural management factors such as Net Sown Area (NSA), Gross Cultivated Area (GCA), Agriculture Sown area More than Once (ASMO), Net Irrigated Area (NIA) and Gross Irrigated Area (GIA) were used. The Ground Water Recharge (GWR) data (pre and post-monsoon) at 610 locations spread over Bihar state was collected from WARIS, and was interpolated through IDW techniques in GIS environment. Annual ET have been averaged at district-level and extracted for 10 years. Mann Kendall trend test statistics for district-level annual ET and agricultural management factors were computed. Significant increase in all agricultural management factors except GWR were noticed along with ET for 15 out of 38 districts, constituting 46% area of the state. Correlation coefficient of these parameters with ET were found to be above 0.9.

Keywords: Gross cultivated area, ET, Net sown area, Agricultural management

Conjugation of AMUL and ISRO: Development of feed and fodder for dairy industries

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Large scale fodder assessment in terms of area and production is one of the primary needs of dairy sector, although feed is the most crucial input for enhancing the milk production. Due to increasing human population, land available for fodder cultivation has been decreasing. In addition, shift from forage crops to cash/commercial crops like cotton, castor, fruits etc. has led to significant shortage of feed and fodder. This is evident with the sharp increase of fodder prices from rupees 2 to 8 per kg, over the years. The work on fodder crops have not been extensively reported as compared to major food crops. No specific work based on mapping of fodder crops had been done in India till now either by surveying or by remote sensing. The development of fodder mapping is challenging because of the high diversity of agricultural production systems. Generally, farmers are not growing pure fodder crops or cultivate as single crop in small areas. Further, there is lack of information with government department, regarding the fodder crop growing districts and total fodder crop areas available in a state. Therefore, efforts are needed by all stake holders in dairy sector for estimating the fodder areas and to fill up this gap. The traditional approach of crop census data is time consuming and biased due to human errors therefore, an alternative approach needs to be adopted. With the advent of remote sensing technology in the field of agriculture, it has shown its potential in improving the crop statistics in the field of estimation of area under major field crops such as wheat, rice, sugarcane, etc.

We have implemented remote sensing technique for fodder crop assessment at state level to create a base-line for developing fodder crop discrimination for its management. To address the issue of fodder availability at first, its assessment is required. We have assessed the fodder growing areas in a cropping season for states like Gujarat, Rajasthan, UP, Bihar and Haryana. We have devised a technique for remote sensing based fodder crop assessment based on spectral pattern of growth i.e. normalized difference vegetation index (NDVI) profile and Land surface wetness Index (LSWI) profile of series of IRS LISS-III satellite data taken during the crop growth cycle. Based on these profiles we have tried to segregate between fodder crops v/s other field crops. Since fodder growing areas are far less compared to other food crops, the tendency of misclassification in the form of commission of food crops classes is more. Hereby to avoid that, we have taken a hybrid way of classification. In this approach, we have taken two steps of classification. First step is hierarchical decision rule method of classification where all non-agriculture pixels are culled out based on hierarchical decision rule. In this way, major classes of current fallows, forest, wastelands, water bodies get segregated. Then in second step, ISODATA clustering approach is used on rest of the pixels left from first step. Fodder crops pixels are identified based on their spectral profile behavior and segregated from other food crops. To validate the spectral profile of fodder crops GPS based ground truth observations are recorded as reference curves for spectral profiles of fodder crops.

To address the issue of mitigating the deficit of fodder crops, we have demonstrated the remote sensing technique of identifying the current fallow lands available in a state. We have also generated spatial map of fallow lands available in that cropping season. For macro level planning in a state for developing new fodder growing areas, we have demonstrated the availability of soil wetness factor from SMAP data. The intersection of probable high soil wetness area and available current fallows, can be utilized for growing fodder crops. For this approach daily level SMAP data is accumulated and a decadal (10 day) composite image is created. The consistent available high wetness factor is considered suitable areas for fodder intensification. In India, fallow land available between two cropping seasons can be utilized for growing short duration fast growing fodder crops. By adopting this technique, satellite derived fallow land can be utilized for mitigating fodder deficit in the country. This technique has been demonstrated at AMUL Inc., Anand.

Keywords: AMUL, Fodder, NDVI, ISODATA clustering, SMAP

TS - 2/1
Navigation and Mobile Apps

Extended Kalman filter based NavIC L5 differential positioning

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NavIC, Indian Navigation System, is transmitting L5 (1176.45 MHz) and S Band (2492.028 MHz) signals from the constellation of GEO and GSO satellites. NavIC receivers generate pseudo-range and carrier-phase observables after receiving signals from the NavIC satellites. Carrier-phase measurements can provide cm-level accuracy using base & rover station data when used in differential mode. When both reference and rover receivers are seeing the same set of satellites, common errors are eliminated using differenced code and carrier-phase measurements from reference and rover. Since the location of the reference receiver is known, errors common to the user and reference receiver can be measured and removed in user positioning calculations. The approach proposed in this paper, uses double differenced code and carrier-phase measurement to estimate the integer ambiguity and achieve the centimeter level user position accuracy. Relative position of 6.69 m baselines between reference and rover receivers was obtained using NavIC measurements at Ahmedabad, India using Accord NavIC receivers. Single frequency carrier-phase measurements on L5 were used for the analysis. An Extended Kalman Filter (EKF) was developed and implemented in C on double differenced data. RMS-3D errors of around 50 cm was achieved. This development can find potential applications in survey and land records, navigation of Unmanned Aerial Vehicles (UAVs) etc. using NavIC signals.

Keywords: Differential NavIC, Double difference, Integer ambiguity, Relative positioning, SVD

Enhanced modelling of ionosphere error and its assessment for single frequency GNSS receivers in LEO orbit

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For the computation of position from Global Navigation Satellite System (GNSS), ionosphere introduces the highest error for single frequency receiver users. GPS ground receivers use Klobuchar model to compute ionosphere delay. In Klobuchar model, the formulation is simplified considering that the ionosphere is concentrated at a shell height of 350 km from the surface of earth and valid for elevation angle greater than zero. For receivers at low earth orbiting (LEO) platform, the same algorithm is modified by changing the shell height of ionosphere and accordingly scale factor is applied. In some LEO missions such as Gravity Recovery and Climate Experiment (GRACE), Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC), CARTOSAT-2F, Microsat etc., GNSS receivers are capable of tracking signals up to -20 degree elevation angle or less. In addition, if the elevation is negative, there are chances that the line of sight signals pass through high-density ionosphere even though the LEO receiver is at an altitude greater than the ionosphere shell height. Thus, in Modified Klobuchar Ionosphere (MKL) algorithm (MKL), the formulation has to be refined when the receiver is in LEO satellites and is able to track signals with negative elevation angle. In this paper, an enhanced Klobuchar user algorithm is described, which can provide a modified formulation approach to compute ionosphere delay for single frequency user receivers onboard LEO platform covering elevation angle goes below zero also. The results are compared with available COSMIC and GRACE precise ionosphere data (PID). The mean absolute error varies from 0.3 to 0.5 m at L1 frequency of year 2008 with respect to GRACE PID and reaches more than 1.0 m when compared with COSMIC PID. Overall, this approach provides better results than MKL when applied for negative elevation angle data.

Keywords: GNSS receiver, Ionosphere, Low earth orbit mission, Negative elevation angle

Design and development of low-cost GNSS based drifter for studying rip currents

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Lagrangian drifters are analogs of particles that are relevant to a flow field characterization and therefore they are capable to represent realistic surface currents as compared to Eulerian techniques. The use of Global Navigation Satellite System (GNSS) in such drifters with DGPS mode at high frequency (5-10 Hz) sampling and Post-Processing Kinematic (PPK) results in position estimates with centimeter level accuracy. In the complex nearshore zone, deploying the expensive oceanographic instruments is a risk due to greater chances of loss. To avoid this, two drifters have been designed and developed using low-cost EMLID Reach® GNSS receivers, antennae and "off the shelf" PVC components to measure the surface currents. The dimensions of the drifters were optimally chosen to minimize the wind and wave impacts and to increase the sub-surface current drag. An analysis of relative position and velocity errors from stationary observations indicated that the drifter is capable to resolve motion very accurately with minimal errors of ±1 cm and ±0.3 cm/s respectively. These drifters were used to measure the surf zone (rip) currents in the RK Beach, Visakhapatnam during May 2018 and successfully identified dangerous rip current zones. This paper presents the design, development aspects, error analysis and testing of GNSS drifters. Although these drifters are primarily developed to measure the rip current velocities and trajectories in the nearshore zone, they can also be operated in any marine environments like rivers, lakes, estuaries etc., without any changes in the design. An extensive study using a fleet of such drifters is required to understand the complex physical processes in the marine environment.

Keywords: GNSS, PPK, DGPS, drifter, Rip currents, Surface currents

Projection based processing of range observable for robust initial position estimation of GEO/IGSO navigation satellites

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The paper describes a methodology to obtain reliable and robust initial estimates of satellite position, which is independent of satellite and receiver anomalies. In this method, a set of Satellites and receivers are selected such that each satellite in the set is visible to all receivers in the same set. Then the range observables processed using a projection-based elimination of satellite and receiver dependent unknowns. The benefits of this elimination are superior when compared to the equivalent differencing techniques. Satellite positions computed for each set using differential correction, resulting in multiple estimates of position for a single satellite. A median based screening methodology applied that provide statistically accurate estimates of the satellites. The algorithm updated for operating in real-time and its performance demonstrated. The advantages of the method when compared to double difference observables are that the baseline selections are not required and estimates have a lower error correlation. However, the above constraint on satellite visibility for each receiver results in lesser data epoch sets in the case of MEO orbit. This is not seen in GEO/IGSO orbit based satellites where receivers have visibility of satellites for almost the entire day. This method is developed for control segment processing centers of GEO/IGSO satellites, which are required to provide position estimates of the satellite in broadcast navigation data hours in advance. Initial position of all GEO-IGSO satellites in the BeiDou constellation were estimated and compared to the double differencing (short-baseline) technique for code range measurements. Precise orbit from IGS was taken as the reference. Overall, our algorithm provides a better initial estimate (over 5 km) than the double differencing technique. We also discuss and present results for NAVIC constellation.

Keywords: NAVIC, Satellite orbit determination, Data processing, Data reduction model

Surveying and mapping of Gandhinagar city using IRNSS/NAVIC system

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Surveying and mapping are the most essential part of any infrastructure project. It is necessary to carry out detailed land survey for infrastructure projects. The conventional method of surveying is very cumbersome, time-consuming and costly, as it requires a huge workforce to carry out the detailed survey. Due to advancement in space technology, various regional and global navigation satellite systems have emerged as an important tool for survey and mapping purpose. India has recently launched its own regional navigation satellite system called Indian Regional Navigation Satellite System (IRNSS) or NAVIC (Navigation with Indian Constellation). In this paper, an initial attempt is made to carry out surveying using high-performance Global Navigation Satellite Systems (GNSS) receiver. The objective of this research is to analyze the stability of the reference station and to prepare the map of Gandhinagar with reasonable accuracy by using the geodetic positional data collected from IRNSS/NAVIC system. A reference station and a temporal station was established at Nirma University campus in Ahmedabad, to get 3D positions. Ionospheric delay/errors are least during night time, so the data collected during night time were used for estimating precise position of reference stations. The true value is the manually measured distance between two stations and the observed value is the distance measured between both stations using NAVIC receiver. The longer average mean of reference and temporal station were calculated. The percentage error was 3.44% where true distance was 5.40m and observed distance was 5.22m. Surveying of Gandhinagar city was done by using IRNSS/NAVIC receiver and collected data were imported on GIS Platform and the land use map was thus generated. The study demonstrates the potentials of IRNSS/NAVIC for infrastructure mapping and navigation applications.

Keywords: IRNSS, NAVIC, Surveying, Mapping

Universal geospatial data collection

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Collection and efficient dissemination of ground truth data is a challenge faced by many researchers. Collecting data from multiple sources, transforming them to a common format, filtering the data based on parameters of interest is cumbersome process. Presence of multimedia information such as images further adds to the complexity of collecting and storing the data efficiently. This paper demonstrates the development of an Android App to address these issues in geospatial data collection, enabling ground-truth data collection along with geo-spatial information.

Keywords: Data collection, Mobile App, Data management, Web-GIS

e-PEHaL - an Android based application to monitor plantations

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Globally, forest cover is one-third less than what it once was and global deforestation continues at 13 million hectares per year. This indiscriminate felling of trees threatens the environmental health and sustainability of communities in rural and urban milieu. With the development of the economy, areas of plantations have expanded in some parts while decreased in other parts in recent years. The expansion of these plantations is likely to have substantial impacts on biodiversity, terrestrial carbon cycle, hydrology and climate. However, our capacity to better understand and predict these impacts is still constrained by lack of accurate and updated data on spatial distribution, area, and dynamics of plantations. To overcome such constraints, 'e-PEHaL' (Protect Environmental Hazards by Land Management) Android app was developed. This app can be used to map and monitor plantations. In this app, user can fill the form in two ways i.e. linear and plot. In linear, there are further two ways i.e. Line and Strip. In plot, there are also two ways i.e. regular and irregular. In linear (Line), user can give the details of latitude and longitude of two ends, length, distance, height, species and picture of field etc. In plot (regular), user can give details of four ends and other info is same as in linear data. It will help to collect data and its further processing will provide locations on map with spatial distribution. The plantation areas can be identified using optical satellite images (such as Landsat), and the information collected by e-PEHaL app be used to verify the same.

Keywords: e-PAHal, Android, Plantation, Sustainability, Land management

GPS based Vehicle Tracking and Monitoring System (VTMS) for mineral carrying vehicles in Andhra Pradesh, India

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Andhra Pradesh Space Applications Centre (APSAC) is providing technical support with Vehicle Tracking and Monitoring System (VTMS) for Department of Mines and Geology, Government of Andhra Pradesh. The objectives of VTMS include: (i) real time tracking of the mineral carrying vehicles from source to destination; (ii) to ensure delivery of mineral to its intended location within stipulated journey time specified in e-permit; (iii) navigate the route of vehicles to deter illegal transport; (iv) use modern technologies to enable better control on mining activities and transportation; and (v) increase transparency in mining and its logistics activities. A GPS based VTMS is developed and is integrated with the existing e-permit system of the department to ensure that e-permits are issued only to GPS enabled vehicles, which are registered with the department. Vehicle Tracking Device (VTD) selected for VTMS are as per AIS-140 guidelines with GAGAN and NAVIC system of ISRO with dual e-sim and are first of its kind in India. Positioning technology to obtain the location of vehicle uses indigenous space based navigation system (IRNNS). It also includes web application that provides exact location of the target. AIS 140 VTD is enabled with IP65 standard, and helps in tracking vehicle in any weather conditions. This application can operate in the absence of cellular network using GAGAN service where VTD can save 40,000 locations and send them using SMS service to the cloud server for near real-time dissemination to the end user. The VTMS is capable to push firmware on demand. APSAC has customized geospatial layers and VTMS is hosted at APSAC. The pilot test was conducted in Prakasam district by installing GPS devices in mineral carrying vehicles. The VTMS for mineral carrying vehicles is ready to be rolled out after the awareness meetings with stakeholders are completed.

Keywords: E-Permit system, Geospatial layers, GPS, Mineral transportation, VTMS

An innovative approach to interference geolocation using rainfall data

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Satellite communication has solved the communication mystery for many applications. However, the biggest challenge in satellite communication is maintaining the transponders free of interference. The most common method of resolving interference is taking shutdown from the users while observing its effect on interference. However, in case of VSAT users, where hundreds of terminals are spread across a large area, shutdown exercise to analyze the faulty terminal is cumbersome, time taking and impractical. This paper discusses an interesting case of wideband interference and presents a novel approach to solving such interference cases. Here, degradation in interfering signal is correlated with rainfall data at that time and used to predict the location of uplink of interference.

Keywords: Interference, Rainfall data, Rain fade

TS - 2/2
Planetary Sciences

Role of recent water flow and debris flow activity in gullies: New evidence from two northern mid latitude craters on Mars

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The present-day CO_2-ice sublimation related dry processes have been reported to result in new channel incision, apron deposition, and formation of terraces, levees and lobate deposits within gullies formed in the mid-latitudes of Mars. As a result, the initial interpretation of liquid water being the major source for debris-flow activity within gullies has faced several difficulties in its sustainment. To bring consensus on the definitive role of water, we report here debris-flow deposits preserved within two craters located at (1) 43.23° N, 134.2° W and (2) 44.2° N, 104.61° W. Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) images (~25-50 cm/pixel) and Context camera (CTX) images (~6 m/pixel) were used for geomorphic analysis. CraterTools and Craterstats 2.0 were used for measuring the crater size-frequency distribution and determining the best-fit absolute model age. Our study revealed unambiguous evidence of scoured channels with levee deposits, significant cross-cutting and overprinting relationships within channels, tongue-shaped deposits and multiple overlapping debris-flow lobes. The age estimates of the craters yielded 1.6±0.2 Ma and 9.1±2 Ma suggesting the recent activities of debris-flow processes. Furthermore, the landforms found in the crater walls are aspect dependent, ranging from debris-flow dominated pole-facing slopes to complete absence of gullies on the equator-facing slopes. Based on terrestrial examples analogous to Mars (Ladakh), we further propose that episodic melting of snow accumulated within the sheltered alcoves is the probable source of water ultimately triggering the debris-flow within gullies. In summary, our study suggest that liquid water played a major role in formation of Martian debris-flow deposits vis-a-vis the present-day dry processes may not hold explaining the formation and evolution of entire string of gullies on Mars.

Keywords: Gullies, Debris-flow, Craters, Water, Mars

Craters in the vicinity of Valles Marineris, Mars: Implication for extensional activities in the region

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Valles Marineris (VM) is the largest canyon (~4000 km) in our Solar System. Previous studies have proposed VM to originate by tectonic events and collapse activities in which grabens and incipient pits deformed the crust as a result of horizontal tension and collapse of material along grabens. Further, the pits merged and coalesced to form the troughs and the canyon we see today. However, previous studies have not been able to clarify about the period up to which the graben and pit formation were ongoing in the vicinity of VM (within ~100 km). The main purpose of this study is to bring a consensus to the periods up to which graben and pit formation activities continued in the VM region. We have used MRO CTX images (~6m/pixel) for morphological analysis and MGS MOLA datasets (~463m scale) for topographic studies. Craters are selected within ~100 km vicinity of VM' wall to find relative ages of grabens and pits. Therefore, we intend to select only those craters that have discernable ejecta and exhibit association with grabens and pits. Based on this criteria, 48 craters were selected out of total ~1516 craters. Crater size frequency distribution and model absolute ages for craters were determined using CraterTools and CraterStats2 software. We estimated ages for 48 craters in VM region using crater counting technique. Additionally, we derived the relationship between craters, pits and grabens using law of superposition and crosscutting. Taken together, the relative timescale of geological activities, which prolonged in the vicinity of Valles Marineris is interpreted. We find that grabens formation possibly terminated on or before ~3.7 Ga and the formation of pits prolonged after ~3.45 Ga in VM region. These results suggest

that VM extensional activities (grabens and pits formation) were prolonged from Early Noachian to Middle Hesperian epochs.

Keywords: Craters, Valles Marineris, Mars, Grabens, Pits

Study of Nernst crater in the lunar highlands: New insights

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Nernst(35.5°N, 94.7°W) is a Floor Fractured Crater (FFC) with a diameter of ~123 km situated in ~365 km diameter basin named Lorentz (34°N, 97°W). We carried out a detailed topographic, mineralogical and chronological study of Nernst to understand its origin and the spectral behavior of crater materials vis-à-vis other similar craters in lunar highlands. Lunar Reconnaissance Orbiter Wide Angle Camera global mosaic of resolution ~100 m/pixel and Narrow Angle Camera data has been used at a resampled resolution of ~10 m/pixel for morphological analysis while Lunar Orbiter Laser Altimeter global mosaic data at ~118m/pixel has been used for topographic studies. Moon Mineralogy Mapper data onboard Chandrayaan-1 with 85 spectral channels and spatial resolution of ~140 m/pixel has been used to carry out the mineralogical analysis of the region. Crater chronology has been done using the Crater Tools and CraterStats 2.0. The topographic and mineralogical studies have been carried out using the QGIS and ENVI software. The crater chronology derived model age of Nernst crater has been estimated to be ~3.79 Ga. The age dating results suggest it to be of upper Imbrian period present inside pre-Nectarian basin Lorentz. A detailed mineralogical analysis revealed the presence of plagioclase and pyroxene on the crater floor and the Lorentz basin. A part of Nernst is positioned in the crustal thinning diameter of Lorentz (~140km diameter). Previous studies show presence of pure anorthosite (PAN) to be suggestive of primordial crust while presence of low calcium pyroxene indicates the lower crust-mantle origin of the source. We conclude that presence of upper crust and mantle mineral together suggests towards magmatic intrusion, which was aided by the lower crustal thickness due to Lorentz basin formation.

Keywords: Floor-Fractured Craters, Moon, Pyroxene, Lorentz, Lunar Highlands

Migration rates and morphology of Barchan dunes at different latitudes on Mars

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Dynamic wind activity on Martian surface causes morphological changes of Barchan dunes. Shuttle changes in wind direction can be deciphered through temporal high resolution data like MRO HIRISE. This research work aims to characterize the differences in migration and morphology of clustered Barchan dunes at different latitudes on Mars and understand the causal geomorphic agents and processes. This study comprised of three sites at different latitudes on Mars viz. Lyot crater (50.1°N, 28.9°E) in Vastitas Borealis region in northern mid-latitude, South-western Arabia Terra region (6.4° N, 10.8°E) in equatorial low-latitude and Green crater (52.7°S, 8.6°E) in southern mid-latitude. Using high resolution multi-temporal MRO HiRISE dataset, it is possible to delineate dune crest lines and estimate the lateral sand migration. Sand migration rates in Lyot crater (~1.3m/year during 2007-11) and Arabia Terra (~1m/year during 2007-17) are higher in comparison to the

Green crater dune field, which shows insignificant migration in crest lines. Also differences are observed in the dune morphology at the three study sites, indicating that the nature of the agents, including their relative intensity, might be playing a role. The differential migration rates and the morphology of dunes are controlled by factors such as wind velocity and stress, grain size, local topography, occurrence of CO_2 frosting and de-frosting events and presence of cementing material at particular dune site and our study can help understand these factors. This study has implications for understanding the past and present day geomorphic controls on dune properties.

Keywords: Barchan dunes, Differential migration, Aeolian geomorphology

Retrieval of Aerosol Optical Depth over Mars during dust storm events using THEMIS data

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Every year Mars witnesses heavy dust storms events which covers complete Martian surface and it has significant effect on Global Circulation of Mars. The spectral signature of dust and underlying surface has similarities due to presence of silicate materials. Hence decoupling of surface and atmosphere contribution possess a great challenge. In the present study, we have used an atmospheric radiative transfer (RT) model tuned for Martian atmospheric and surface conditions using different atmospheric profiles such as CO_2, H_2O, O_2 and CH_4. Simulations for THEMIS (Thermal Emission Imaging System) bands in thermal infrared (TIR) region (6-14 µm) with different surface, atmosphere and sensor geometry were carried out using RT model. Large number of simulations for various aerosol extinction varying from 0.1 to 5.0 at an interval of 0.1 were carried out with different surface compositions over Mars. Dust storm events of year 2007 having dust opacity ranging from 0.7 to 1.5 is processed for THEMIS TIR data. The brightness temperature is computed and its signature shows that aerosol absorption is maximum at 9µm central wavelength, which shows significant decrease in brightness temperature. Band Ratio technique has been used for aerosol optical depth retrieval from THEMIS data. Results obtained were then compared with the THEMIS AOD for the scene and found good correlation with R^2~0.61 and RMSE~0.44. The present method can be used for the retrieval of atmospheric dust effects during dust storm events.

Keywords: Radiative transfer, THEMIS, Thermal Infrared

Techniques developed for large area Mars image mosaic using ISRO's Mars Color Camera (MCC) data

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Multispectral remote sensing planetary datasets covering same and adjacent locations at different acquisition times allow for image mosaicking to study local, regional and large-scale processes of planetary bodies. ISRO's Mars Orbiter Mission launched on November 5, 2013 increases our curiosity to examine planet Mars using scientific instruments on-board MOM. Mars Color Camera (MCC) is among the five science payloads operating in visible range (0.4 µm to 0.7 µm) to image the surface feature of Mars with varying resolutions and scales from highly elliptical orbit. The systematic processing procedure for mosaicking MCC images primarily

requires radiometrically corrected MCC data with aerographic co-ordinates tagged in planetary data system (PDS) standard and involves techniques in image processing domain that includes geometric and photometric corrections, image registration, blending and normalization. These techniques are described in this paper to generate mosaic product of Mars using different MCC datasets at variety of scales to illustrate compositional diversity, morphological changes to view the features of Mars and geological issues using different perspectives. In addition, the techniques are also used to generate planet level seamless mosaic, North Pole mosaic using available MCC datasets to monitor dynamic behavior of dust devils/storms and cloud conditions over larger area of Mars.

Keywords: Image mosaic, Mars Color Camera, Photometric correction, Planetary Data System

Observations of Schluter crater using high resolution data

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The aim is to study mineralogy and morphological characters of Schluter crater (6°S, 83.5°W) of the Moon. Data of Moon Mineralogy Mapper (M^3) is used to characterize mineralogy of Schluter, which is a NASA-supported guest instrument on ISRO's remote sensing mission to Moon, Chandrayaan-1. The Minimum Noise Fraction (MNF) suggests distinct compositional variation on the central peak of Schluter. According to the sampled spectra, plagioclase and OH/H_2O signatures may be present. The morphological study has been carried out using high resolution data of Lunar Reconnaissance Orbiter's (LRO)-Narrow Angle Camera (NAC). The Schluter crater has been found to be roughly circular in shape with an average diameter of 89 km and characteristic flat hummocky floor. Peripheral area around the asymmetrical central peak indicates slumping which may be due to gravity induced mass movements that might have taken place immediately after the impact. Among secondary craters around the central peak, newly formed small craters seem optically brighter compared to older ones. Characteristic floor fractures observed around the central peak are concentric differing from radial fractures observed on the peak itself. Boulder fields observed on the crater floor may be results of erosion of central peak due to constant flux of bolide impacts and to a lesser extent, seismic activity. Several other peculiarities noticed during this study include; southern rim that exhibits a small double-crater that lies along the inner wall, a terrace system along the inner side and slender rill near the NW inner wall.

Keywords: Schluter Crater, Chandrayaan-1, Mineralogy, Morphology, Central peak

Study of layered deposits in the East Melas Chasma, Mars using MCC, HiRISE, THEMIS and MOLA data

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Mars Orbiter Mission (MOM) Mars Color Camera (MCC) image has been used to study morphology of layered deposits (LDs) and landslide emplaced within the East Melas Chasma region (12.7° S, 69.2° W) on Mars. Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) images are used for detailed morphological analysis. The observations reveal that the layers within inferred deposits are markedly toned in terms of brightness, appears finely layered, show bench-cliff morphology, and consistent with small-large exposures. Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) data reveals that the LDs and landslide are distinctly elevated. Mars Odyssey Thermal Emission Imaging System (THEMIS) data indicate

that the layered materials have thermal inertia (TI) values ranging from ~110-690 $Jm^{-2}K^{-1}s^{-1/2}$. Further, layered materials with TI values within ~310-690 $Jm^{-2}K^{-1}s^{-1/2}$ show evidence for mafic/basaltic composition at seven locations as inferred from THEMIS Decorrelation Stretch (DCS) images. Overall, the study suggests that the fine layering and exposures within individual layers of LDs may have preserved important science targets for understanding a broad range of geologic processes varying in scale and time. For instance, the emplacement of thermally contrasting layered deposits bearing mafic/basaltic rocks in a portion within VM may be related to a widespread process emplacing stratigraphically distinct units during past episodes of VM evolution. The geologic units inferred within this region in VM offer a wide range of geologic configurations consistent with materials having low TI values overlying materials with high TI values and materials with high TI values overlying materials with moderate and low TI values. It is possible that the materials associated with LDs inferred within the study region may have preserved a substantial difference in diurnal and seasonal surface temperature because of the difference in storage of heat in different layers of the deposits.

Keywords: Mars Color Camera (MCC), Mars Orbiter Mission (MOM), East Melas Chasma, Layered deposits, Thermal inertia

3D surface visualization of planetary data

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This paper describes implementations carried out in order to visualize various planetary data on a three dimensional sphere. Development consists of 3D surface rendering and dynamic terrain generation using available fine/ coarser resolution data from various available satellites and Digital Elevation Model (DEM), global data views as per the projection systems. It becomes very important to visualize various planetary 3D surface for India's future missions to Mars and Moon, as one can visualize rover landing sites, navigation to different features of planet and validate imaging site. In this exercise, we have taken full disk datasets (imagery and DEM) of Moon, Mars from USGS website and Chandrayaan-1 (TMC) and Mars (MCC) datasets respectively of varied resolutions for visualizations. Further, we have developed a software to drape imagery over DEM and GIS vector layers by using data interpolation, image-mosaicking techniques. We have also implemented level of details (LOD) technique for data visualization. Using LOD specific amount of details (coarser or finer) shown to viewer as per viewer's position. Software has been developed in such a way that it can handle large volume of data in terms of both very high resolution and bigger area coverage over any planet. Software has been designed and developed using C++ language, open scene graphs and it works in environment such as (Windows and Linux). This paper covers implementation carried to generate 3D surface of Mars and Moon using available datasets on public forum as well as data from India's mission to Moon and Mars.

Keywords: Chandrayaan-1, Mangalayaan, Open scene graph, DEM, 3D Visualization

Hypothesis validation of formation mechanism of Floor-fractured craters

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Floor fractured craters are a special class of craters modified by post impact mechanisms resulting from geological activities. Two theories of origin of FFC's have been hypothesized: magmatic intrusion and viscous relaxation. Based on morphometric observations, this study aims to validate the hypothesis regarding origin of

floor fractured craters. A tool for automatic extraction of morphometric parameters was developed to determine the morphometric parameters of craters. End members of each class were identified. End members are considered exemplary for their class because they contain majority of the characteristics for their specific class. End members were binned as per various ranges of diameter of 28-33 km, 40-42 km, 85-112 km, 160-200 km. Accordingly, Humboldt, Vitello, Gassendi, Gaudibert were identified as end members for floor-fractured class. Fresh craters were selected such that they are of comparable diameter and spatially correlated to selected FFCs. In this view, Tycho, Glushko, Hausen and Kepler were identified as fresh counter parts of floor-fractured craters Morphometric ratios of FFC were compared with those of their fresh counterparts. For comparable diameters, depth of FFC was found to be less than fresh craters leading to lower d/D ratios. Morphometric ratios involving depths showed significant decrease for FFC as compared to fresh whereas the ratios involving diameter remained unchanged. At the same time, rim elevations of FFC were found to be consistent with those of unmodified craters. Shallowing of floor can be contributed both by magmatic intrusion or viscous relaxation but the later might have also altered the rim heights which was not observed. Small d/D with unaltered height validates the hypothesis of FFC formation by magmatic intrusion and sill formation, while do not supply support to formation by viscous relaxation.

Keywords: Floor fractured craters, Magnetic intrusion, Viscous relaxation. Morphometry

TS - 2/3
Environment

Interannual variation of atmospheric carbon dioxide concentration derived from Orbiting Carbon Observatory-2 data compared with its local and large-scale variations obtained from NASA Giovanni database

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The temporal change of global atmospheric carbon dioxide (CO_2) exhibits a positive trend superimposed by an annual cycle, which is ascribed to the combined effect of ecosystem productivity and anthropogenic activities. This work intends to present an analytical treatment of the phenomena in terms of periodicity, local data and their averaging. The monthly average of zonal mean values of CO_2 flux obtained from NASA Giovanni earth science database for contrast areas, such as evergreen forest and crowded city yielded wide difference in the nature of variation; both in increasing trend and seasonal variation. The Fourier transforms resulted in two periodicities superimposed including one sub-annual variation. Possible explanations were given for such general trends in the global change of CO_2. The work was more concentrated on the Indian subcontinent. Prominent difference was found in the positive trend of temporal change at the east coast and the west coast regions over last ten years. The Orbiting Carbon Observatory-2 data were downloaded from the website with python and the data were analyzed with Panoply open source software. The local variations of CO_2 flux over and around small regions of Northern India exhibited irregular periodic increase and decrease, which when averaged, led to more regular periodicity. The frequency domain analysis with Fourier transform defined the most probable points of flux changes.

Keywords: Ecosystem, CO_2 flux, Seasonal variation, Trends

Spatial-temporal distribution, characterization and human health impacts of air pollutants in Ahmedabad city

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In India, over the past few decades, '*Air Pollution*' has become a critical environmental issue resulting from rapid industrialization, growing urbanisation, increasing vehicular emissions, higher levels of energy consumption and biomass burning etc. Ambient air with high concentrations of Particulate Matter (PM), Black Carbon (BC), gaseous air pollutants like Sulphur-di-oxide and oxides of nitrogen etc. emitted from these sources are leading to various ill-effects on human health and environment. Ground based *in-situ* observations, satellite remote sensing based columnar measurements and Geographic Information System (GIS) techniques together help to better understand the air quality and identify the potential zones of impacts, particularly in urban areas. A holistic approach is needed to account for *in-situ* measurements, satellite derived data, spatial modelling and human health impacts to arrive at a comprehensive assessment of air quality. With this background, the present study is undertaken for Ahmedabad, an urban, densely populated, industrialized largest city in the central part of the Gujarat in Western India. Regular *in-situ* measurements of pollutants concentrations and AOD were collected at more than 30 locations besides various human health ailments medical records for different seasons collected from different Primary Health Centers and recognized government hospitals during April 2017-May 2018. Diurnal variability in particulate and gaseous pollutants were studied using SAC SAFAR continuous Air Quality Monitoring Stations observations. PM fraction and spectral AOD curve analysis indicate the significant contribution by coarser mode particles with angstrom exponent (α) <1. This is also verified with space borne

CALIPSO LiDAR data analysis showing predominance of "*polluted dust*" type aerosols. Average values of PM_{10}, $PM_{2.5}$, PM_1, Inhalable, Thoracic, Alveolic PM concentrations are observed as 309.35, 90.31, 43.84, 466.78, 308.89 and 138.39 μg/m^3, respectively during the winter season. The number of reported cases of respiratory ailments also peaked during winter. Identification of '*hot spots*' of high pollutants concentrations and thematic maps of pollutants distribution were generated using spatial interpolation techniques in GIS environment. The study provides significant inputs to policy makers for formulating and implementing action plans towards suitable air pollution control measures in a fast urbanizing environment.

Keywords: Air pollution, Aerosol characterization, Human health, GIS

Assessing air pollution and climate change by utilizing lichens

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Lichens have certain ecological and physiological requirements that make them very sensitive to atmospheric changes and are thus excellent indicators of air pollution. Lichen monitoring has become a widely used standard, to evaluate air quality and is an effective early-warning system, rate of retreat of glaciers, including accumulation of heavy metals, metalloids, polycyclic aromatic hydrocarbons and radioactivity in terrestrial ecosystems. The lack of vascular system, absence of root system and dependence to absorb water and nutrients passively from their environment make it sensitive against environmental perturbation. Hot and dry, any weather conditions cause lichen to dry up and become dormant until favorable weather returns. It also helps that they are able to accumulate air pollutants throughout the year as cumulative accumulators. The sensitivity of lichen epiphytes to environmental change has resulted in their wide use as indicator for pollution monitoring and to identify forest habitat for biodiversity protection. Lichens respond relatively fast to deterioration in air quality and can recolonized urban and industrial environment as a consequence of improved condition within a few year. The sensitivity of lichens for the microclimatic changes may be used to estimate the ecological continuity of forest and to established network to monitor climate change. Lichens have numerous functional roles in forests including nutrient cycling (especially N_2 fixation in moist forest and as component of food webs). The complete dependence of epiphytic lichens on forest trees make them sensitive to forest management practices. It is estimated that old growth forest exhibit significantly higher diversity of epiphytic lichens than the young managed forest. In India, a total of sixteen lichen communities are described which indicate the status of the habitat condition, age structure of forest, type of substrates and predict the surrounding air quality.

Keywords: Active and passive monitoring, Herbarium specimens, Zone mapping

Ecosystem services in different agroclimatic zones of eastern India affected by changes in landuse and land cover at different time scales

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Land use and land cover (LULC) change have considerable influence on ecosystem services. Assessing change in ecosystem services due to LULC change at different spatial and temporal scales will help to identify suitable management practices for sustaining ecosystem productivity and maintaining the ecological balance. The

objective of this study was to investigate variations in ecosystem services in response to LULC change over 27 years in four agro-climatic zones (ACZ) of eastern India using satellite imagery for the year 1989, 1996, 2005, 2011 (Landsat TM) and 2016 (Landsat 8 OLI) was examined. The satellite images were classified into six land use and land cover (LULC) classes, agriculture land, forest, water body, wasteland, built-up and mining area using a decision tree classification technique. For ecosystem service valuation, the methodology proposed by Costanza et al., (2014) was adopted with some modifications. During the study period (1989 to 2016), forest cover reduced by 5.2%, 13.7%, and 3.6% in Sambalpur, Keonjhar and Kandhamal districts of Odisha, respectively. In Balasore agricultural land reduced by 17.2 % due to its conversion to built-up land. The value of ecosystem services per unit area followed the order of water bodies > agricultural land > forests. A different set of indicators, e.g. by explicitly including diversity, could change the rank between these land uses, so the temporal trends within a land use are more important than the absolute values. Total ecosystem services increased by US $1296.4 × 10^5 (50.74 %), US $1100.7 × 10^5 (98.52%), US $1867 × 10^5 (61.64%) and US $1242.6 × 10^5 (46.13 %) for Sambalpur, Balasore, Kandhmal, and Keonjhar, respectively, during 1989 -2016, mainly due to increase in production and productivity of crops.

Keywords: Agro-climatic zone, Ecosystem function, Ecosystem service value, Land use\land cover change

Identification of global sand and dust storm source regions and development of sand and dust storm alert system

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Sand and Dust Storm (SDS) is one of the natural phenomena, occurring all across the world, which has serious implications on the natural resources, ecosystem services and the human health. Its frequency of occurrence has been increasing all across the world during the past few decades. Thus development of sand and dust storm early warning system (EWS) is very much needed in order to prevent serious damage to the environment and human being. The first step towards the development of the EWS is to identify source regions for SDS. MODIS derived NDVI and SbAI indices have been used to identify and map the source regions of SDS of the world. Albedo, land surface temperature and insolation are used to derive the aridity index (SbAI). SDS source regions have also been identified and mapped for Rajasthan state, using high resolution MODIS data. Quantification of soil erosion have been carried out using a process based wind erosion model, called WEPS (Wind Erosion Prediction System). WEPS model calculates the quantity of soil eroded as well as the direction and distance to which the soil/sand particles are transported by wind. WEPS model has been implemented for the source regions of Rajasthan state. The quantity of sand/soil particles transported by wind, including the direction and the distance travelled, have been computed on daily basis. The information so generated is useful in issuing alert to the people living in the area where sand/soil is likely to be transported and deposited.

Keywords: SDS, Soil erosion, NDVI, SBAI, Dust storm alert system

Monitoring and modeling of land use and land cover changes and their impact on land surface temperature: A geospatial approach

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Land use and Land cover (LU/LC) change because of human intervention, has become one of the major reasons of deterioration of natural resources leading to degradation of environment and quality of life. Replacement of natural land cover (such as water bodies, forests, grasslands, etc.) with urban land use leads to increase in urban temperature compared to that of rural surrounding. To contribute in the sustainable approach of development plans, the present study has attempted a temporal pattern analysis of LU/LC change using the Landsat-TM images of 1991, 2001 and 2011 and predicts the spatial pattern of LU/LC change in 2021 using Markov model. Moreover, it has also assessed the land surface temperature alteration with respect to the land cover distribution. Post-classification change detection analysis indicated a major increasing pattern in the built-up area (46 km^2 in 1991, 62 km^2 in 2001 and 77 km^2 in 2011). A predicted land use map for 2011 was obtained and validated by the actual land use results of 2011. Results exhibited that built-up area expanded mainly at the cost of grazing and grassland, wasteland and conversion of forest area into agricultural land also took place. Waterbodies, built-up and agricultural land are the stable LU/LC types, with transition probabilities 0.98, 0.97 and 0.94 respectively. Forest, grassland and grazing land and wasteland exhibit less persistence, with probabilities of 0.79, 0.91, and 0.90, respectively. Land surface temperature analysis exhibited that among the three observation years 2001 is the hottest. Built up area and waste land have average temperature difference of 1.8°C, 2.4°C and 2.2°C compared to other class in year 1991, 2001 and 2011 respectively. This study recommends a more judicious and sustainable exploitation of the land keeping protection of natural resources and environment in mind.

Keywords: Land use/land cover change, Land surface temperature, Land change modeler, Landsat-TM, Geospatial approach

Quantifying spatio-temporal dynamics of land surface temperature and biophysical indices using RS and GIS: A study of Vishwamitri watershed, Gujarat

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Watershed and broader landscape issues are challenges with an increasingly urbanizing population especially in developing countries. Therefore, development across the watershed requires dealing with complex environmental management issues, with varying degrees of attention to ecology, landscape processes, and long-term sustainability. The Vishwamitri watershed in the center of the golden corridor of Gujarat is witnessing rapid industrialization, urbanization and shift from primary to secondary economic activity. Rapid urbanization also causes a drastic decrease in green cover, water bodies and a rapid increase in impervious area. All this together modify microclimate regime of an area. Because urbanization is expected, studies that assess and protect the watershed must be continued with developing the link of the environmental factor for the futuristic climate resilient development. This study consequently intends to quantify dynamics of LST and Biophysical indices Viz., NDVI, NDBI and BSI for 2001-2016 in Vishwamitri watershed. MODIS and LANDSAT data are used to derive LST, NDVI, NDBI, and BSI. Moreover, correlation between LST and other indices are calculated for pre and post monsoon period of 2001 to 2016, and integrated into GIS. Various stages involved in this study were i) satellite image acquisition and processing; ii) generation of land use/ land cover (LULC) map; iii) land

surface temperature (LST) retrieval; iv) assessment of NDVI, NDBI and BSI); and vi) determination of the relationship between LST and Biophysical Indices. It was observed that LST has negative correlation with vegetation and water, and positive correlation with bare soil. These indices can be used as an indicator to monitor the impact on conversion of water bodies and vegetation cover into impervious surface cover, resulting into adverse effects on micro-climate of the area. A prior attention is therefore needed to address the micro-climate changes of the area for a sustainable watershed development.

Keywords: Land Surface Temperature, Normal Difference Vegetation Index; Normal Difference Built-up Index, Bare Soil Index, GIS

Lichens on Indian monuments and their role in biodeterioration

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Biodeterioration of stone monuments and buildings is a well-recognized problem in tropical and temperate regions on India. The lichen thallus have an ability to colonize on a large variety of substrates: trees (epiphytes), ground (terricolous), stone (saxicolous), and even glass, metal, plastic and many man-made artifacts. Lichens, as biological agents play a critical role in deterioration of monuments. The qualitative as well as quantitative presence of lichens on monuments can indicate the deterioration pattern and environment of that area. Being a culturally diverse country, the Indian monuments also exhibit great diversity in their construction material and architectural pattern, thereby providing diverse habitat for growth of different lichen taxa. The investigation of lichens on monuments in India has been initiated recently, and account of lichens growing on monuments of the state of Uttar Pradesh in north, Karnataka in south, Orissa in east and Madhya Pradesh in central region of the country are available. About more than 100 lichen species are known from the country. They are listed as most deteriorating species to the monuments. The monuments also exhibit a distributional pattern of lichens depending on microclimate created at different niches by their architectural design. The maintenance and restoration of the monuments in their normal form or shape seems to be dependent on the type of growth of the lichens. The macro lichens (foliose, fruticose) can be removed manually but the removal of crustose and squamulose form requires scrubbing and chemical treatments with biocides. Some chemicals such as Paraquant dichlore (PDC), Butachlor and ammonia water impart their own colors to stone materials. In India the problem of lichen biodeterioration is under researched and much of the work published is limited to few states. Thus there is a great scope of lichen biodeterioration studies in the country.

Keywords: Monuments, Lichen, Bioreceptivity, Biodeterioration

A geo-spatial study of vegetation and terrain indices of Bardoli taluk for regional information enrichment

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The agrarian stakeholders especially the farmers are always interested to know geographic conditions of their own field, village and region for healthy agricultural practices and irrigation. Today Indian scenario exhibits need of extensive participation and association of industries and academic institution to work and provide in-house geo-spatial solutions as major GIS solutions of India are not native. Hence there is a burning requirement as to propagation, training and uncovering benefits of geo-spatial technologies in Indian states, districts and

taluks. This paper is an extension of the existing work where they have studied Bardoli taluk of Surat district [11, 12]. This paper demonstrates the application of Earth Observation (EO) satellite data products as obtained from Bhuvan Open Data Archives satellite images, Cartosat Digital Elevation Model (DEM) and Normalized Difference Vegetation Index (NDVI) along with derived terrain indexes such as Topographic Position Index (TPI), Terrain Ruggedness Index (TRI), slope and aspect, are used to study soil productivity in Bardoli taluka of Surat district. The pre-processing of satellite images using R Platform involved data sub-set extraction, geo-rectification and overlaying of administrative boundaries of the study area. The correlation analysis of the data indicated moderate correlation between soil attributes with terrain indexes, whereas higher correlation of more than 0.75 between NDVI and Organic Carbon (OC) content of the soil. The study further classified the terrain attributes by developing exhaustive rules, concluded that the soils of Bardoli taluk are rich in OC and are salinity free with moderate Alkalinity.

Keywords: GIS, Cartosat, DEM, NDVI, Terrain index

Land use land cover change analysis of Ludhiana district, Punjab using remote sensing and GIS techniques

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Land use and land cover (LULC) mapping has become an important and central component in current strategies for managing and monitoring of natural resources and environmental changes. LULC change detection during a known period is very essential to understand landscape dynamics for sustainable management. The present study was carried out over Ludhiana district covering 3709.48 km^2 of Total Geographical Area (TGA) of Punjab state using three season (Rabi, Kharif and Zaid) IRS-P6 LISS-III satellite data of the year 2011-12 and 2015-16. In this study, LULC categories were identified and changes were investigated using on screen visual interpretation and GIS techniques. The results indicated that the study area is intensively cultivated showing 83.99 % of TGA under agricultural land during 2015-16. There was 12.37 % of TGA under built-up category during 2015-16 showing an increase of 0.63 % as compared to the area during 2011-12. There was 1.23 % of TGA under industrial area and 1.51 % of TGA under water bodies in the year of 2015-16. The area under forest is less than 1 % (0.66 %) in the study area. Wastelands and wet lands covered a total of 0.21 % and 0.02 % of TGA, respectively. There was minor increase in the industrial area (0.06 %) and water bodies (0.03 %) during the study period. The study revealed that the area under agricultural land, wasteland and wetland decreased during the study period. The decrease in the area was maximum (0.48 %) under agricultural land and minimum (0.03 %) under wetlands. The area under forests showed no change. The present study revealed that, satellite remote sensing and GIS techniques are the useful tools for mapping LULC, monitoring changes and planning for the development of an area.

Keywords: Land use, Land cover, Change detection, LISS-III

TS - 3/1
Geospatial Technology

GIS based Decision Support System for greening of hillocks in Bukkapatnam Mandal, Anantpur district, Andhra Pradesh

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Advances in RS & GIS technologies have made possible to generate and update the natural resources information in spatial format for monitoring the resources, environment in a cost effective way at various scales. Sustainable natural resource management is the key for regenerating of hillocks in arid and semi-arid areas. Afforestation of degraded hillocks yields multiple results helping improving soil, water conservation apart from creating of new vegetation cover. Bukkapatnam mandal, Anantapuram district is selected for development of a Decision Support System (DSS). The mandal falls under semiarid area with average rainfall of 630 mm. Out of 17 villages in the mandal, almost all villages have hillocks of one or other category and also falling under both revenue and forest administration. These hillocks are the ridge points for watershed management and also the key areas for green cover. Agro-climatic, socio-economic and climatic factors severely affect the successes of hillock afforestation and plantation activities. For planners these factors are always a challenge. This effort provides livelihoods to poor in terms of employment under various rural development national schemes. GIS-based DSS is developed based on Multi Criteria Decision Analysis (MCDA) that includes various natural resources and climatic parameters, such as lithology, soil, geomorphology, land use / land cover, wastelands, land degradation, slope, rainfall, temperature and proximity to the habitation. The secondary data collected from bio-physical aspects of land, land use, agro-climatic aspects of land, demographics, socio-economic aspects. Weightages are given for each parameter for generating the matrix and for DSS output. The model output ranges from very good suitability zones to very low suitability area. The model also indicated the existing species as well as the recommended species with soil conservation measures for each zone. The present work will be useful to the functionaries at block level to generate action plans and budgetary estimates for implementation of greening of hillocks.

Keywords: Spatial DSS, Afforestation, Conservation, MCDA

Utilisation of geospatial tools for characterization and expansion of Khasi mandarin orange in Meghalaya

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A study was conducted to find out the role of topographic factors and soils in abundance of orange orchards in Pynursla block of East Khasi hills district of Meghalaya. Study was carried out by using Komsat image of Bhuvan, soil map (1:50K scale) and CartoDEM prepared by NESAC. About 20 orange orchards were visited and geographic locations were collected. Evergreen forests are the most dominant land use land cover in the study area, followed by broom grass, barren rocky/stony wasteland and mixed plantations that include different indigenous fruit plants, bay leaf, bamboo and other trees. From field survey it was observed that the orange orchards of Meghalaya are small in size and found mixed with other plants on the slopes of hills. The orange plantations are always associated with *arecanut*, jackfruit, litchi, bay leaf and other indigenous fruits like *soh broi*, *sohramdieng*, *soh thri* etc. and other trees on hill slopes at the lower elevation below 700 m which is having warmer climate. It is also observed that oranges are planted with indigenous fruits like *soh shang*, *sohphoh khasi*, *sohphie nam*, *sohphie bah*, *sohiong*, etc. at higher altitude ranging 700 -1000 m. Orange plantations are not observed at elevation higher than 1000 m. Orange orchards are found on hill slopes ranging from moderate slope (8-15%) to moderately steep slope (15-30%). Soils of the orchards are sandy clay loam in texture, deep to very deep in depth and moderately acidic in reaction with moderate organic carbon content. Soil site suitability

analysis for orange plantation showed that steep slope and high elevation is the main constrains for growing of orange in the block. It was found that only 3131.70 ha (7.3% of the study area) is suitable for growing of orange. Out of total suitable areas, 1953.86 ha (62.4%) area is highly suitable followed by moderately suitable areas (1127.28 ha i.e. 36%) and marginally suitable areas that covers only 50.58 ha (1.6%).

Keywords: Khasi Mandarin orange, Geospatial tool, Soil site suitability analysis, Meghalaya

Opportunity mapping to inform development planning at village level using geospatial techniques

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Opportunity mapping is a research based planning tool used to understand the dynamics of opportunities within an administrative area. In this study we mapped the opportunities available in Pulwama district, Jammu and Kashmir State, India using data from various sources; satellite, census, field and other ancillary data. Various indices like Socioeconomic Index, Resource Index, Road Index, Disaster Vulnerability Index and Facilities Index were generated and integrated to develop Opportunity Index using multi-criteria analysis. Each index was categorized into five classes ranging from very high to very low. From the Resource Index, it was found that the agriculture has decreased from about 205 km^2 in 2006 to 153.33 km^2 in 2016 showing a decrease of 51.67 km^2 in one decade and during the same period the horticulture has increased from 82.98 km^2 to 120 km^2 showing an increase of 32.27 km^2. The built-up area has increased by 23.77 km^2 during the period. Socioeconomic analysis of the census data of 2011 was done to generate the socioeconomic indices. It was found that out of 348 villages in the district, 11 villages have very high composite facility index and 121 villages have very poor composite facility index. Out of the 348 villages in the district, 3 main towns are showing very high economic development status and 148 villages are having very low economic development status. Finally, Opportunity Index was generated by integrating the four main indices viz. Resource Index, Economic Development Status, Facility Index and Road Index taking into consideration the multi-hazard disaster vulnerability index of each village in GIS environment. From the analysis, it was found that, out of 348 villages, only 74 villages have high to very high opportunity index and 107 villages possess low to very low opportunity index. 167 villages in the district have moderate opportunity index. It is believed that the study has a potential for informing development planning at the village level by making use of knowledge generated about various indices.

Keywords: Opportunity mapping, Resource index, Socioeconomic index, Road index, Multi-criteria analysis, Development planning

Spatial Decision Support System for infrastructure management: A case study of electrical utility structure of Jodhpur city

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The study aims to develop an integrated multi-disciplinary, multi-attribute Spatial Decision Support System (SDSS) for electrical distribution network management of Jodhpur city. Data and collateral information were collected from multiple sources. Jodhpur DISCOM was the major source for electrical distribution network and electrical dataset for Jodhpur city. It provided basic understanding about distribution network, flow of electricity from point of generation to point of distribution, network schematics and briefs about working and data flow

among the departments. The major source for spatial dataset i.e. ward boundary, building network etc. was Regional Remote Sensing Center, Jodhpur (RRSC-J) and Google Earth. The study includes identifying need and significance of spatial decision support system nationally and internationally, and analysis and interpretation of data so collected from different sources, major components for SDSS were identified. GIS (Geographical information system) was used to superimpose the complete electrical network assets from generation stations to distribution points on top of the base map. Development for web-based SDSS was done using ArcGIS desktop, ArcGIS Server, open source Flex Builder. Multi-Disciplinary, Multi-Attribute Spatial Decision Support System (SDSS) thus developed attempts to identify efficiency gains in operational & non-operational areas of utility business. It helps utility sector for simple and effective visualization of complex distribution network, together with timely operations. SDSS developed allows network monitoring, network tracing, query shell and analysis like advanced capabilities.

Keywords: Spatial decision support system, Electrical distribution network, Network monitoring, Network tracing, Query shell

Use of transportation network analysisfor bus stop relocation, depiction of service area and bus route details

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The growing population and urbanization are the major problems faced by the developing countries in the world today. In addition to this, traffic congestion will further enhance the problem. The main focus of this paper is on improving traffic situations and making travelling easy to a user by using Network Analysis modules of ArcGIS. The location-allocation module of ArcGIS was used to shift the location of existing bus stops taking into considerations different factors such as traffic signals, traffic constraints, etc. Bengaluru's bus system is operated by Bangalore Metropolitan Transport Co-operation (BMTC) which has introduced different buses for different routes in the city. A network service area is a layer that shows all areas that are within the reach of a facility. For example, the five-minute service area for a point on a network will include all the streets that can be serviced by the identified facility within five-minute walk. The service area helps to calculate the accessibility of a facility or to choose the nearest facility within the service area. As distance increases, accessibility to/from the facility decreases. For a person who wants to travel from one place to other and plan his travel, the transport network analysis provides him the information of bus routes with bus stops in between the starting point and the destination point. This system is designed in such a way that a person can optimally plan his travel based on the available bus route details.

Keywords: Geographic Information System, Network analysis, Service area, Location-Allocation

Very high resolution optical satellite images for property tax assessment: Issues and challenges

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The present study is an attempt to assess potential as well as limitations of Very High Spatial Resolution (VHSR) Satellite Images for calculation of potential property tax on immovable property. Very high spatial resolution of multispectral and ultra-spectral remotely sensed images in optical region of EM spectrum provide a detailed information about the earth surface. These images are specifically to observe fine details about manmade

structures such as buildings in an urban environment. VHSR images thus have a high potential for acting as a main resource of information for urban application domains. One such potential domain is assessment of potential property tax legible on a particular immovable property. Property tax is a potentially attractive means of financing municipal governments in developing countries. At present in developing countries, urban property taxes are extremely low. One of the biggest problems with property taxes is the high level of administrative costs to inspect properties and determine the new addition or home renovation. Remotely sensed data used for measuring variables of social significance in urban and sub-urban context. We use VHSR images of better than one meter to extract information required for calculating property tax. This information include area, type of building, age of building, building use. Methods of extracting building boundaries, such as Image Segmentation, Object based Image Analysis; Index based methods used in this study to calculate area to tax. Other information required for tax assessment that were not possible to derive by satellite images, gathered from secondary source of information as well as field surveys. The methods chosen for tax assessment were two key methods; most frequently used India and elsewhere, namely, the unit area method and annual rental value method. Two case areas comprising of residential, institutional, industrial and commercial buildings selected to demonstrate potential uses of VHSR images. The information on potential tax gathered from VHSR images versus the actual tax collection by the municipal authority shows a large gap and loss of potential revenue. The issues and challenges faced while extracting useful for extracting potential property tax highlighted in the study. The study shows a road map and a framework for implementing the property tax assessment using remote sensing.

Keywords: Very High Spatial Resolution (VHSR), Property tax, Annual rental method, Unit area method, Image segmentation, Object Based Image Analysis (OBIA)

Addressing sustainable development goals through space technology

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Space technology has great potential to address issues of social welfare and development. Space technology in the areas of remote sensing, communication and navigation can help in achieving valuable developmental milestones. This paper is a qualitative attempt to analyses usages of these technologies in achieving Sustainable Development Goals set by United Nations (UN) to be achieved by 2030, using secondary sources. The paper demonstrates the areas of sustainable social development that can be easily addressed with the use of satellites and further areas of research to assess its social impact, while highlighting ISRO's response in the same direction. It is a multi-disciplinary attempt to understand how satellite technology can be useful in achieving global developmental issues. By reviewing secondary data sources, the paper explains how satellite technology can cater developmental issues by addressing Sustainable Development Goals set by UN.

Keywords: Space technology, Sustainable development, UN

Novel geospatial applications for small land parcels

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Conventionally geospatial applications pertain to providing decision-support for large projects of government or industry covering hundreds of sq.km land area. Here, it is proposed to address the geospatial needs of (i)

individuals, (ii) housing societies, (iii) small business establishments, and (iv) local chapters of national bodies, etc. over areas covering less than 10 km^2.

1. Remotely monitoring the land use of a terrace or a plot or contiguous plots of land for status-of-agricultural/ horticultural growth, status-of-disease-spread-in-plants, encroachment or revenue-status-monitoring or servicing-faults-in-utilities, etc.
2. Location-time stamping and look-vector recording of visit to a point on a moving vehicle, on air/ ground, at a given instant and reporting a geospatial incident to local government for emergency response, with target description (a location-time stamp, the look-vector and user inputs).
3. Last mile connectivity for mass transport infrastructure.
4. Locating real-time transport-bottle-necks and road-conditions and suggesting alternate routes
5. Information-rich interactive maps for housing societies – generation, use & maintenance
6. Approaches and parking-location maps – for small businesses or as part of invitations for special occasions of individuals
7. Spatial analysis of customer concentration – for small businesses and organizations.

The above-mentioned applications have potential to scale up to global user community. Enhancing the quality of user experience of geospatial applications will differentiate from one implementation to another. There is no limit to our imagination in presenting the geospatial information.

Keywords: Remote sensing, Geospatial web, Mobile apps, User experience

Use of geospatial technology for efficient water resources management in the state of Maharashtra

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In India, on an average about 16.35 t / ha soil is eroded annually. This eroded soil is carried by rivers / streams and is deposited into reservoirs downstream causing reduction in their storage capacity. Sedimentation in reservoirs adversely affects planning for irrigation, power generation, water supply for drinking etc. due to reduced water availability. Today the demand of water from reservoirs is increasing fast due to increasing population, rapid urbanization, creation of new industrial estates etc. The additional reservation of water for fulfilling this extra demand disturbs the scheduled planning of reservoir water. Loss in storage on one side and the increased demand on the other side puts the management authorities of reservoirs in a difficult situation while planning the available storage. Assessment of loss in storage due to sedimentation on regular basis becomes an utmost necessity for them. Sediment assessment surveys of reservoirs are useful in this context. These surveys also enable the irrigation planner to decide the necessity of taking appropriate erosion control measures, prioritize catchment / subcatchment for controlling soil erosion and subsequently sedimentation in reservoirs which can lead to efficient management of water thereby deriving maximum benefits for the society. Looking to the importance and necessity of reservoir sedimentation surveys, which give useful information for preparing annual water budget for the reservoir, the State of Maharashtra has so far completed 145-150 surveys of major and medium reservoirs till 2017 with the help of geospatial technology. This technology is very effective, less laborious, time saving and accurate as compare to other technologies. Such type of study is immensely needed to govern the effective and efficient use of available surface water.

Keywords- Sedimentation, Erosion, Remote sensing, Water governess, Storage capacity

Geo-spatial technology application for climate change adaptation plans at micro level

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Climate change - a global phenomenon, usually investigated at macro-scale while most of the implementable climate actions are at micro-scale. The climate studies include impacts assessment on economic and natural regions (river basins), country wide, coastal vulnerability etc. While the macro scale studies are conducted with the low-resolution data and minimal ground truth, the micro level work demands high resolution spatial data and non-spatial data to simulate the natural phenomenon and long term changes in the area. The climate change adaption plan for Naroda Industrial Estate (Gujarat) is perhaps a first such work in India aimed to formulate a comprehensive assessment framework for industrial areas. The multi-sectoral vulnerability assessment framework covered land use; industrial estates due to geographical location, coping capabilities and resource consumption; trade and logistics; and socio economic aspects. This complex assessment decoded by employing Remote Sensing (RS) and GIS. The basic land use / land cover map of study area was derived from the supervised classification of EO-1 Panchromatic images for years 1990, 2000 and 2010. The contour were derived from Digital elevation Model (DEM) and GPS point survey. Flood assessment was conducted using hydrological analysis incorporated in Arc-Hydro software. NDVI calculations provided vegetation distribution for carbon sequestration study, while thermal analysis was done for building/features emissivity. The elevation and slope map were derived from ASTER DEM and was used for hydrological analysis to identify flood prone area. The thermal bands onboard Landsat ETM+ and TM data were used for thermal analysis. Furthermore, social vulnerability aspects in the framework were included to identify need of improvement in basic common amenities to industrial laborers and local residents. The study suggested various implementable strategies to reduce vulnerability, improve the biodiversity and infrastructure needs with the pilot intervention.

Keywords: Climate change, Remote sensing, GIS, Landsat, EO-1 Panchromatic

TS - 3/2
Soil/Land Degradation

Prediction of soil properties using visible-near infrared imaging spectroscopy

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Optical remote sensing and in particular Imaging Spectroscopy has shown the potential to predict the soil properties over large areas. Remote sensing-based approaches can be used to study the soil properties to be transferable to large geographical regions of similar climatic conditions. In this study, the key soil fertility parameters were quantified using Airborne Visible Infrared Imaging Spectrometer - Next Generation (AVIRIS-NG) hyperspectral image data, which was acquired over 120 km^2 area of Anand district (Gujarat), coupled with extensive field work to collect soil samples from 85 locations within the image area. The soil samples were air dried, sieved to <2 mm and analyzed for pH, electrical conductivity (EC), organic carbon (OC), available phosphorus (P) and available potassium (K) using standard methods. The AVIRIS spectra (spectral range of 380-2500 nm with an interval of 5nm) corresponding to soil sampling points was extracted and various data pre-processing techniques (standard normal variate, detrending, first and second derivation and normalization) were applied on spectra to remove the noise and offset. Partial least squares regression (PLSR) models were used to predict soil properties from AVIRIS spectra. Predictions for EC and OC of soil samples resulted in good accuracy (coefficient of determination R^2 =0.83 for EC and 0.81 for OC; residual mean square of error (RMSE) = 0.04 for EC and OC each), but were less accurate for pH, available P and K in these soils (R^2 = 0.42 for pH, 0.10 for P and 0.30 for K; RMSE=0.09 for pH, 39.4 for P and 2.60 for K). Optimum spectral ranges for prediction of these soil properties from AVIRIS data were 1350-1920 nm. It is concluded that AVIRIS data can be used for rapid and non-destructive assessment and monitoring of soil health for precision agriculture.

Keywords: AVIRIS-NG, Imaging spectroscopy, Precision soil health

Time series analysis of remotely sensed surface soil moisture for wheat and rice crops in Central Plain, India

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This study focuses on time series analysis of surface soil moisture for different spatial locations over a time period to deliver significant information regarding various factors affecting soil moisture and its influence on crop production and agriculture. As per the agro-climatic zone map of India, central plain zone in Uttar Pradesh state, hosts the highest producer of rice and wheat, exhibiting varied soil properties. The crop production is also dependent on meteorological parameters which are precipitation and temperature primarily. The co-dependency of these parameters are studied for four study sites. Mann-Kendall trend analysis in initially applied to understand the underlying trend and subsequently followed by time series modelling for fifteen years remotely sensed surface soil moisture dataset (2002 to 2016) to comprehend the dynamics of changing soil moisture. Two different satellite data are selected for this study namely, Advanced Microwave Scattering Radiometer – Earth Observation System (AMSR-E) by JAXA and NASA and Advanced Microwave Scattering Radiometer – 2 (AMSR-2) by JAXA. The study is expected to provide a better understanding of the variation of soil moisture spatially and temporally and also the impact of various parameters for crop specific locations. Annual and seasonal (meteorological and crop - sowing to harvesting) patterns provides essential information for optimum crop production. This study extends to estimate and understand crop water and irrigation water requirement necessary to compensate for the uncertain meteorological variations, as major crops in India are rain fed. A long-term understanding of soil moisture is a crucial indicator of the futuristic behavior of the same.

Keywords: Surface soil moisture, Mann-Kendall test, Time series analysis, Rice, Wheat

Performance evaluation of a newly in-house developed in-situ soil moisture sensor with standard industrial sensors and gravimetric sampling

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The calibration and validation of satellite derived soil moisture products relies upon an accurate source of ground truth data as accurate soil moisture information plays an important role in crop management, irrigation scheduling, flood and drought monitoring etc. For proper validation of soil moisture products, dense network of in-situ sensor with high accuracy, robustness and sustainability under adverse conditions are required. The primary method of providing required ground truth is to conduct intensive field campaigns with manual surface soil moisture sampling measurements, which utilize gravimetric sampling, soil moisture probes, or both, to estimate the volumetric soil water content. Soil moisture probes eliminate the need for labor-intensive gravimetric sampling. To ensure the accuracy of these probes, several studies have determined these probes need various degrees of localized calibration. This study aims at performance evaluation of two industrial sensors; MP306 (ICT International), Stevens Hydra Probe (Stevens Water) and a new in-situ soil moisture sensor developed by SAC-ISRO. Industrial probes use FDR based technique, which measures soil dielectric constant and is based on dielectric mixing model and calculates soil moisture in volumetric percentage. The in-house developed sensor was pre-calibrated by deriving an empirical relation for volumetric soil moisture through extensive field campaign. Surface soil moisture measured using commercial and in-house developed sensor was evaluated across different fields by gravimetric sampling techniques. Results obtained were analyzed using performance metrics which includes statistical measures R^2, bias, ubRMSE and RMSE. The sensors performed satisfactorily over a large range of soil moisture with respect to gravimetric methods and in-house sensor has shown better performance and good agreement than commercial probe. This in-house developed sensor has high potential to provide an economical alternative to the industrial sensors and would be helpful in development of a dense sensor network for validation of satellite derived soil moisture products.

Keywords: Soil Moisture, Frequency Domain Reflectometry, Gravimetric sampling, Soil salinity

Analysis of drought indices using Google Earth Engine

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Drought is a naturally occurring phenomenon caused by exacerbating water balance. It occurs due to shortage of precipitation, high evapotranspiration and overexploitation of water resources or a combination of all these factors prolonged over a period of time. Drought has huge impact on agricultural, ecological and socio-economic fabric causing serious national consequences. About 16% of India's total area is drought-prone, which affects about 50 million people from drought annually. Drought is characterized into four classes: meteorological, agricultural, hydrological and socioeconomic drought, based on which a plethora of indices have been developed. These indices require extensive datasets and are computationally intensive. Google Earth Engine (GEE) is an open Application Programing Interface (API), which offers free computational resources and satellite data on cloud computation platform minimizing the users need for computational resources and data availability. We have used several long term datasets available through GEE to derive various indices. We have derived several indices like Standardized Precipitation Index (SPI) and Precipitation Condition Index (PCI) using monthly Tropical Rainfall Measuring Mission (TRMM) data, Vegetation Condition Index (VCI),

Temperature Condition Index (TCI) and Surface Water Supply Index (SWSI) from Moderate Resolution Imaging Spectro-radiometer (MODIS). All these indices have high potential in detection and monitoring drought in various drought categories. A combination of indices could provide an additional advantage for drought identification and monitoring that needs to be explored. While providing an accurate description involves multifarious variables, some extremely complex, we aim to provide a probabilistic description of drought intensity through the aid of index combinations

Keywords: Drought, Google Earth Engine, Standardized Precipitation Index, MODIS, TRMM

Trends and behavior of meteorological and soil moisture drought over four homogeneous meteorological regions of India using time-series (1980-2015) MERRA-2 data

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In the climate change scenario, the increase in drought frequency and magnitude are evident in all parts of the globe. The alteration in the rate of precipitation and evapo-transpiration has a direct impact on drought occurrence. Many studies regarding different kinds of drought have been carried out, however the research addressing the relationship among them are limited. The time-series (1980-2015) MERRA-2data, i.e. precipitation, evapo-transpiration and total profile soil moisture, have been utilized for addressing the meteorological and soil moisture droughts over four homogeneous meteorological regions of India. The Standardized Precipitation Evapo-Transpiration Index (SPEI) was used to represent the meteorological drought, whereas Standardized Soil Moisture Index (SSMI) was used to address soil moisture drought. The log-logistic and empirical probability distributions were used for computing SPEI and SSMI, respectively. The effectiveness of Multivariate Moisture Anomaly Index (MMAI), a new drought index, over Indian region was tested during our study period for characterizing drought incidences. The drought occurrence was identified using threshold of SI (Standardized Index) <0. Different drought parameters, like duration and magnitude, were estimated using predefined criteria. The duration was represented by the number of months with drought incidence in each year during Kharif season (June-September), whereas the magnitude was the cumulative SI values during drought months. The trends analyses of the drought parameters for both meteorological and soil moisture drought were carried out using Mann Kendal and Sen's slope test at 95% confidence level. It was observed that except some isolated patches over north-eastern and peninsular India, in most of the parts of India both the soil moisture drought duration and magnitude is decreasing. The meteorological drought duration and magnitude was found to be increasing over northern parts of peninsular India, western parts of north-eastern India, central and north-western parts of north-western India and eastern parts of central India.

Keywords: Meteorological drought, Soil moisture drought, Standardized soil moisture index, Multivariate moisture anomaly index, Standardized precipitation evapo-transpiration index

Land degradation/desertification vulnerability assessment in north eastern region of India: A case study on Golaghat district, Assam

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Land degradation can be defined as a temporary or permanent lowering of the productive capacity of land. It adversely affects the productive, physiological, cultural and ecological properties and functions of land resources. Land degradation covers various forms of soil degradation, adverse human impacts on water resources, deforestation, and lowering of the productive capacity of farming and rangelands. As a developing country, land degradation is a common phenomenon in India due high population pressure upon land. In 2016, it was estimated that, 9.14% of total geographical area of Assam state was under various land degradation processes, primarily involving vegetation degradation and water logging. The study area Golaghat district of Assam was taken as a study site to assess the land degradation / desertification status for the period of 2011-2013, and to estimate desertification vulnerability index. It was estimated that 15.8% of total geographical area of the study area is under the land degradation/desertification process during the study period of 2011-2013. Most significant process of land degradation/desertification in the district is vegetation degradation followed by water logging. Furthermore, based on natural resource classification zones and socio economic pressure zones, the severity of land degradation was evaluated for the concern district. The natural resource (NR) vulnerability was estimated on the basis of climatic index, terrain index, natural vegetation cover, soil index and land use\ land cover. The socio economic index was derived on the basis of existing infrastructure such as medical, education, transport, communication and irrigation, and the socio economic status of the district comprising its total population, population density, agricultural workers, main workers and marginal workers. The extracted results indicate that 17.37% of district total geographical area of the district is over-utilized, 64.13% area is optimally utilized and 18.50% of area is underutilized. In terms of land degradation/desertification vulnerability assessment 7.59% of total geographical area of the district comes under very high vulnerability zone whereas 6.23% area comes under very low vulnerability zone.

Keywords: Land degradation, Natural resources, Socio economic status, Vulnerability index

Desertification Vulnerability Index (DVI): Case study of Jalore district, Rajasthan

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Dryland agriculture occupies 68% of India's cultivated area and supports 40% of human and 60% of livestock population. It produces 44% of food requirement of India. Drylands in India are undergoing desertification due to improper management and climate change. Desertification is one of the global environmental problems that threatens many arid areas around the world. Desertification is the process of fertile land becoming desert, typically as result of drought, deforestation, or inappropriate agricultural practices. Vulnerability refers to the inability of a land to withstand the effects of a hostile environment. The purpose of this study is to present Desertification Vulnerability Index (DVI) for vulnerability assessment of desertification based on remote sensing imagery and ancillary data. Rajasthan state has high rate of desertification. Jalore district, which is situated in an arid region, has been selected in this study. Land use \ land cover map of the district for timeframe 2011-12 was prepared, which was classified into 16 classes as per NNRMS guideline for level 3 classification. Using remotely sensed images and ancillary data, indices like Vegetation Index (VI), Climate Index (CI), Soil Index (SI), Land Utilization Index (LUI) and Socio-economic Index (SEI) were calculated. Desertification

Vulnerability Index (DVI) is then derived using remotely-sensed images and ancillary data indices. The results showed that 41.17% area of the district is moderately vulnerable, 0.19% area is highly vulnerable and 57.54% area is less vulnerable to desertification. High aridity, low rainfall, and low vegetation cover are the major desertification processes observed in the Jalore district.

Keyword: DVI, SI, CI, VI, SEI, LUT, Desertification, Vulnerability

Sustainable development of the village through generation of suitable action plans for soil and water resources using high resolution Kompsat data: A case study of smart village 'Saidpur Sakari', Kannauj district, Uttar Pradesh

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This study presents the work carried out for the Saidpur Sakari village of Kannauj district, which is situated adjacent to the bank of Ganga River, owning to backwardness within the district. This village was selected to develop its all resources as it is listed under *Sansad Adarsh Gram*. In order to fulfill the objective, high resolution KOMPSAT data has been used for mapping of all available natural resources through generation of Land-use/ land-cover map, infrastructure map, soil map, ground water prospect map etc. The study attempts to demonstrate the usefulness of GIS and remote sensing techniques for mapping and planning of natural resources and enhance the decision making capabilities at micro level. The broad objective was to prepare a Strategic Action Plan for the selected *Sansad Adarsh Gram* as a 'Centre point' for the surrounding villages, interlinked with basic facilities and employment opportunities, which could ensure a balance between development and ecology by revamping soil and water conservation. The study shows that the village Saidpur Sakari is dominant with Rabi crop and comes under irrigated region but certain non-fertile parcels have been suggested for aromatic plantation and certain land parcels of the village have been proposed for banana cultivation for change in cropping patterns. Furthermore the plan also identifies sites for Check Road Bund (CRB) and Agroforestry to prevent soil erosion. Desiltation has also been proposed to enrich the water level of identified dry ponds. By using the above suggestions, a suitable decision support system can be developed for soil and water resource planning of the village.

Keywords: Soil erosion, Check road bunds, Aromatic plantation, KOMPSAT

Mapping and monitoring of aeolian process in Jodhpur district, Rajasthan using multi - temporal satellite data

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Aeolian process is the activity of wind, which causes erosion, transportation and deposition of soil particles thus shaping the face of the landscape especially in arid, semi-arid and dry sub humid areas. Soil particles transported by such Aeolian activities can reach distant places and may lead to sand and dust storms. Sand and dust storm generated through the Aeolian process has become serious threat to the human health, infrastructure and ecosystem. Area undergoing the process of desertification and land degradation are the potential source areas for initiation of sand and dust storm. Thus, it is important to identify and map areas undergoing land degradation due to Aeolian activity. Remote sensing and GIS plays important role in mapping and monitoring the lands

undergoing the process of degradation due to Aeolian activity. The objective of the present paper is to monitor and assess how wind erosion is causing land degradation in Jodhpur district, Rajasthan using satellite data for the period 1992 to 2017. The Aeolian process status map has been prepared using multi-season Landsat data of 30 m spatial resolution. The map has been prepared on 1:50,000 scale for 1992 and 2017. In the study area, it is found that the major process of land degradation is wind erosion. The other desertification processes found to be active in the Jodhpur district are salinization/alkalization, water erosion, waterlogging and vegetal degradation. The change detection status of Aeolian process is analyzed for 25 years from 1992 - 2017 over the study area.

Keywords: Aeolian process, Dust storms

Assessment of drought extent using vegetation indices and rainfall data: A case study of Rajasthan, India

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Drought is an insidious hazard of nature. Unlike rapid onset disasters, it tightens its grip over time, gradually destroying an area. As the Indian economy is primarily driven by agriculture, the effects of meteorological droughts are direct and can be large. Timely assessment of drought can alleviate its severe consequences. This study emphasis upon the use of space technology and geographic information system in drought risk assessment. In the present work, an effort has been made to assess, monitor and delineate risk areas facing agricultural as well as meteorological drought by using vegetation indices (NDVI and VHI) and rainfall data. Resultant risk map obtained by integrating agriculture and meteorological drought risk map indicates the areas facing a combined hazard. NDVI trend analysis has also been done to assess the long-term changes occurred as a result of irrigation, deforestation, and urbanization. It absolutely was evident from the study that western and central parts of Rajasthan are more prone to drought either agricultural or meteorological. The analysis shows that increasing irrigation facility within the area causes a major positive change in the vegetation. The results obtained provide objective information on incidence, severity level and persistence of drought conditions, which can be useful to the resource managers in optimally allocating limited resources.

Keywords: Drought assessment, Normalized Difference Vegetation Index (NDVI), Vegetation Health Index (VHI), Agriculture Stress Index (ASI), Yield anomaly, Rainfall anomaly

Vegetation Health Index products from Resourcesat Awifs data

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Drought is a disastrous natural phenomenon that has significant impact on socio-economic, agricultural, and environmental aspects. It differs from other natural hazards by its slow accumulating process and its indefinite commencement and termination. Using remote sensing multi spectral data, surface and meteorological parameters numerous drought indices have been computed and maps of various drought indices have been generated. Standardized Precipitation Index (SPI) has been used to monitor meteorological drought. SPI offers a quick, handy, simple approach with minimal data requirements. Standardized Water-level Index (SWI) has been developed for efficient analysis of hydrological drought. Vegetation Health Index (VHI) has been employed to assess vegetative drought in the terrain. Presently global VHI products are available from AVHRR

with 4 km and 16 km spatial resolution and are proven useful for assessment of draught detection and monitoring over large areas. This paper presents the methodology to derive Vegetation Health Indices (VHI) using medium resolution (56 m) remote sensing data in an operational manner from Resourcesat-1/2 AWiFS sensor with an intention to monitor vegetation, early drought warning and estimation of losses in agricultural production in a large-scale.

Keywords: VHI, Drought, AWiFS, SPI

TS - 3/3
Machine Learning

Manifold learning with wavelet transform for hyperspectral drone image classification

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Contemporary hyperspectral imaging, with more than few hundreds of observation channels as well as high spatial resolution, is an important source of remote sensing and has been extending the application domain into precision agriculture, food quality inspection, functional soil characterization etc. Classification, the process of assigning labels of land cover classes to the pixels, is one of the prominent approaches for full-spectrum functional level analysis of hyperspectral remote sensing data acquired across space and time. Due to its narrow bands and full spectrum sampling leading to the much studied 'curse of dimensionality', providing the sufficient number of training samples for each land-cover class is a challenge, which often outweighs the advantages of using hyperspectral imagery. In this paper, we propose a robust and efficient method for hyperspectral image classification using Locally Linear Reconstruction (LLR) based manifold learning technique coupling it with an advanced method of signal decomposition-based dimensionality reduction: wavelet transform. Wavelets can separate the hyperspectral signal into fine-scale and large-scale information. Hyperspectral data may locate on a lower dimensional sub-manifold which is implanted in the high dimensional space. In order to take account into this manifold structure, we introduced a method called Locally Linear Reconstruction using Support Vector Machine as the classifier. The key idea of LLR is to choose the most representative points or local reconstruction points whose coordinates can be used to reconstruct the whole data. We have applied the proposed algorithms to a variety of drone-based hyperspectral imagery of an agricultural data comprising seasonal crops in Bangalore. The support vector machine with a linear-kernel gave an accuracy of about 80 % and RBF-kernel results in an accuracy of 90%. The results for the wavelet-based features correspond to the use of approximation coefficients. Results indicate the consistent and accurate performance of the proposed method.

Keywords: Hyperspectral Image (HSI), Manifold learning, Locally Linear Reconstruction, Wavelets

Classification of multispectral imagery using deep learning and machine learning based algorithms: A case study of mangrove forest in Maharashtra

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Mangroves are well known for their unique ecological sustainability and economic benefits in the expanse of fisheries, plant products, tourism & coastal protection. Thus, periodical accurate mapping of mangrove density and plant diversity is utmost prerequisite. Availability of high resolution spatial and temporal data like Landsat 8 OLI and Sentinel 2 MSI creates new possibilities to generate accurate extent and density level maps of mangrove health. The spectral behavior of mangrove forest and terrestrial urban vegetation creates a complexity in discrimination between them. Moreover, there is unavailability of ancillary ground truth data regarding some species, these factors are majorly influencing non-existence of any efficient and standard methodology for mangrove management. This study is attempts to map the density and extent of mangrove forest using Deep Learning based ANN and machine learning based Random Forest, Decision Tree Classifiers. The study uses the Sentinel 2 and Landsat 8 data to achieve higher accuracy in density level classification using pixel-based domain. The data phase consist pre-processing of Landsat 8 and Sentinel 2 imagery followed by spectral analysis, processing and sample selection with the help of GPS points. The spectral analysis was done to find possible number of different mangrove classes with the help of Principal Component Analysis (PCA). The study evaluates the accuracy and efficiency of algorithms based on comparison of outputs and computation time for pixel-based density level classification of mangrove forest.

Keywords: Mangrove forest, Random Forest (RF), Artificial Neural Network (ANN), PCA

Spatial-spectral classification of hyperspectral data using deep convolutional neural network

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Recent research has shown that incorporating both spectral and spatial features in traditional vector based machine learning algorithms significantly improve the performance of Hyperspectral image (HSI) classification. However, most of the approaches often limits itself to filtering methodology relying mostly on pre-processing or post-processing techniques to extract information. In this paper, a 3D convolutional neural network (3D-CNN) based framework, one of the many variant of deep learning techniques, is proposed. Its popularity focuses around providing a black box solution encompassing both the feature engineering and classification as one single entity. Furthermore, with the huge number of features available in HSI data, common issues like class imbalance and sparsity of training samples were also addressed. Other common problems like overfitting, under fitting and strategies to avoid them were also investigated. For comparison purposes, the proposed framework is carried out and tested along with other spatial spectral classification techniques like– Markov Random Field with SVM (SVM-MRF), Morphological SVM, Residual Network based CNN and 2D-CNN on an AVIRIS datasets of Anand Agricultural University, Gujarat. The proposed framework provides a simpler, lighter and fewer training parameters with competitive results to the state of art methods.

Keywords: Hyperspectral image, Deep Learning, Convolutional Neural Network, Feature engineering, AVIRIS

SAR image classification using convolutional sparse autoencoders and CNN

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Synthetic Aperture Radar (SAR) can obtain high resolution radar images with information of amplitude, phase and polarization under all weather, day and night. Classification of land-cover types is a preliminary step in most of the applications of polarimetric SAR remote sensing. Since the SAR image is heavily contaminated by speckle noise, it is difficult to extract effective features for classification. In order to enhance the class separation of polarization channels and phase differences, speckle filtering is required. Deep learning is an advanced machine learning technique that has networks which are capable of extracting features from data that is unstructured or unlabeled. Features learned from deep learning networks are better suitable for the classifier than that of obtained from other feature extraction techniques. Auto encoder is a well-known deep learning algorithm. An auto encoder neural network is an unsupervised learning algorithm where output is forced to be same as the inputs. In this research, a technique using convolutional sparse auto encoder with CNN is proposed to extract deep features and perform classification of SAR images. Initially to obtain texture features, GLCM elements are used. Pooling is done to reduce the influence of speckle noise. In place of supervised training, unsupervised sparse auto encoder is used to train convolutional kernel. Learned convolutional kernel and biases are passed to a CNN. After applying some normalizations and max pooling, pooled features and corresponding labels are used to train softmax regression classifier. To smooth the classification map, morphological operations are applied. L-band data of PALSAR-2 in stripmap mode of observation and single polarization (HH) with pixel spacing of 2.5 m is used for land-cover mapping in urban context. The experiments show that the proposed architecture produce better classification results when compared with other related algorithms.

Keywords: Synthetic Aperture Radar (SAR), Convolutional Neural Network (CNN), Sparse auto encoder, Grey-Level Co-occurrence Matrix (GLCM)

An improved polarimetric decomposition technique for ocean surface target detection

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Studying the dynamics of the ocean, based on ocean surface targets and its detection using satellite images has been a cardinal research topic since a decade. A number of detection techniques have been proposed and are evolving. Ocean target detection using SAR images is proved to be one of the efficient techniques for detecting ocean surface targets as it provides a high spatial resolution image in all weather conditions. The objective of this paper is to demonstrate the efficient utilization of eigenvalue/eigenvector based parameters like entropy (H), anisotropy (A), and average backscatter intensity (AI) for detecting ocean surface targets. These parameters help in identifying the dominant scattering behavior of the oil spill and clean ocean; thus spotting the spread of oil spill and its location efficiently. A full polarimetric analysis has been carried out on L-Band Airborne UAVSAR data acquired by capturing the oil spill event of June 2010 in Barataria Bay near the Deepwater Horizon rig site in Gulf of Mexico. A new approach has been developed in generating the square matrix for the estimation of eigenvalue/eigenvector based parameters. Result of proposed decomposition algorithm is also compared with state of the art H/A/Alpha decomposition. Comparison has shown the acceptability of the proposed algorithm in identifying ocean targets like oil spill. The study has also brought out the difference in the backscattering characteristics of different oil spill patches, which may help in further classifying the spills based on the weathering stage of oil spill.

Keywords: SAR, UAVSAR, Eigen value, Eigen vector, Oil spill

Extraction of water body and cloud-hill shadow, cloud detection using object-based classification

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In satellite image interpretation, shadow plays a crucial role as it aids in image interpretation. Shadow may sometimes obscure ground features. In optical imagery, the spectral signature of water body, cloud shadow and hill shadow are similar. Features, which lie within shadow, reflects less energy and are difficult to identify. This results in difficulties in digital classification algorithm, which depends completely on reflectance value. The object based classification approach utilizes spectral value as well as shape, texture and context information. Such additional attributes are helpful for the detection of the shadow and water body separately. In this study LISS-3 data of Surendranagar district, Gujarat was used for detection of cloud shadow and water bodies. The three parameters such as average reflectance value, reliability and threshold value were used for the shadow and cloud detection. Reliability is a criterion for providing priority to desired class in case of class mixing. Clouds were separated by keeping value of minimum threshold at 150 and reliability as 0.4. The water body is differentiated from the shadow by providing reliability of 0.3 as compared to providing reliability of 0.2 in case of the shadow. The result clearly shows that in optical satellite images cloud-hill shadows can be separated from the water body and the cloud can be detected using object-based techniques.

Keywords: Reliability, Shadow, Classification, Cloud

A cloud based automated flood mapping using Google Earth Engine

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A cloud based automated geo-processing of flood inundation mapping is done using Google Earth Engine (GEE) using Sentinel 1 Synthetic Aperture Radar - SAR images captured during the extensive Kerala floods from 9th August to 22nd August. The GEE platform provides simultaneous preprocessing of SAR image and process cloud free optical images that are available during the event from multiple open source satellite data series. A differential algorithm has been prepared to estimate the amount of flood using SAR images, which was followed by image segmentation using threshold thereby matching the inundation provided by the National Database for Emergency Management leading to mapping of the extent of flood. Since Sentinel 1 provides polarization only in VH and VV modes the inundation is mapped using both modes and it was observed that VH mode overestimates the flood while the VV mode produces better results. Finally the output was compared with the available Sentinel 1C optical image and an overall accuracy of 96% was obtained using VH mode of polarization which is very much also compatible with the available field observations over the inundated region. Since the entire processing in done in cloud servers and the entire process is automated, immediately after a satellite pass occurs the extent of flood inundation is automatically mapped which helps in a better way for decentralized effective planning of resources during disasters.

Keywords: Google Earth Engine (GEE), Sentinel 1, SAR, Flood inundation, cloud processing

Performance efficient classification of geospatial big data using geospark

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Recent advances in geospatial data classification techniques are instrumental in the generation of massive data that are being processed by geospatial big data platforms. While some of this data is stored in databases, much of the data is unstructured and temporal. In this paper, we survey alternatives available to classify data on geospatial big data frameworks. We present a comparative study of different classification approaches and an experimental evaluation of on one of the most recent platforms like Geospark. We discuss our evaluation results in the context of classification of geospatial data, especially by considering Volume, Velocity and Variety of geospatial big data.

Keywords: Geospark, Classification, Framework, Geospatial

TS - 4/1
Forestry

Himalayan timberline is product of landforms and geological processes

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Himalayan mountains are divisible into several ranges, which are product of geological processes, resulting into diversity of landscapes and altitudes, and timberline. Young mountains are still evolving and due to separation by geological fault lines, summits rise abruptly at places. Timberline, upper limit of forests, can be seen as a continuous line almost parallel to snowline in the inner Himalayas but away from the snowy ranges. Timberlines forms island type habitat around summits having favorable elevation for occurrence of alpine meadows. These two types of timberline have been investigated first time in this study and their association with geological landforms have been described on topographical influence of mountainous terrain on formation of high altitude timberline in the Indian Central Himalaya. Mapping of 2750 km long timberline in Uttarakhand state was done using satellite images (Landsat). Elevation of timberline occurrence ranges from 2600 m to 4365 m Above Mean Sea Level (AMSL). Nearly 75% of total timberline occurred between 3200 m and 3800m AMSL. In the Trans Himalayan region only 6.3% of the total timberline of the state was present while Greater Himalayan region consisted 77% of the total timberline. In the Lesser Himalayan region only 17% of the timberline was present. Mean elevation of timberline in different regions varied (3723 m, 3599 m, and 3424 m, respectively for Trans, Greater, and Lesser Himalaya). Abrupt summits (less than 4000 m) did not occurred in the Trans Himalayan region, hence timberline around summits was not observed here. Such type of timberline was largely present in the Lesser Himalayan region (ranges with moderate heights and few abrupt summits). It was observed that Himalayan ranges having more geological faults had (i) more number of island type formation of alpine meadows and a circulating timberline, and (ii) fractured timberline parallel to snow line resulting in high segmentation in continuous type of timberline. In these high ranges geological disturbances account for the discontinuation in timberline (segmentation) and isolated timberlines around peaks. These observations indicate that geological factors have a considerable role in giving shape to high elevation forests and timberline. At local scale, topography is an obvious way to size up the landscape and influencing distribution of tree species.

Keywords: Himalaya, Timberline, Topography, Summit, Geological faults

Impressions of projected climate and land use land cover changes on high altitude species - *Abies pindrow* in western Himalaya

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The anticipated twenty first century regional global warming in the Himalaya is likely to cause range of changes in the temperate species by modifications of their current suitable climatic envelops. Our study addresses the cumulative impacts of climate and land use changes on the distribution range of *Abies pindrow*, a species of the high mountains, and a principal tree species at timberline occurring between 2000 m and 3700 m Above Mean Sea Level (AMSL) Two climate change scenarios, viz. Representative Concentration Pathway RCP 4.5 and 8.5 from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) generated from Global Climate Models - GFDL-CM3, MRI CGCM3 and CNRM CM5 were used to model the changes in the range areas of *A. pindrow* in western Himalaya. The probable current and potential future distributions of the species were generated with the help of ensemble modeling using biomod2 package in R platform. The formations of projected range areas for *A.pindrow* under climate change scenarios of RCP 4.5 and 8.5 exhibit a loss of 83% and 59% respectively in its climatic niche by 2070. The land use / land cover (LULC) has been mapped from 1975 to 2015 at an interval of 10 years and the future land use has been modelled using the temporal LULC of the western Himalaya and the drivers of change. It is observed that land use changes pose

additional pressures on the species by further reducing its suitable habitat in the region, raising concerns over the footprints of anthropogenic stresses on Himalayan species.

Keywords: Species range areas, Himalaya, Climate change, Climate envelop modeling

Assessing long-term vegetation greenness in high elevation landscape of Hindu-Kush Himalaya

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Warming has led to enhanced growth of vegetation in temperature limited forest ecosystem over the globe. Study on the vegetation dynamics in Hindu-Kush Himalaya (HKH) in response to current warming trend has been carried out. We assessed the trend in greenness of high elevation landscapes in Hindu-Kush Himalaya for 34 years (1982-2015) using GIMMS NDVI3g dataset by National Oceanic and Atmospheric Administration - Advanced Very High Resolution Radiometer (NOAA-AVHRR). We quantified the relative importance of near surface air temperature using NOAA-CRU dataset on inter-annual variability and trends of greenness at regional scales. Warming-induced enhancement of vegetation growth in high elevation landscapes depends on the topography. For peak greenness, inter-annual variability and trends are dominantly controlled by climatic factors. Stronger greening trends in many parts of HKH is associated with an increase in temperature. The alpine (> 3000 m Above Mean Sea Level (AMSL)) and montane (1000-3000 m AMSL) zones of HKH were selected as the study area. The GIMMS NDVI3g ranges between -0.2 and 0.1 for snow, inland water bodies, deserts and bare soils and increases from about 0.1 to 1.0 with increasing amounts of vegetation. The NDVI value less than 0.1 were masked out before the computation of trend. In the first step, we filled months with permanent gaps series (i.e. gaps that occur in at least 20% of all years during the same season) with the minimum NDVI value. The trends were calculated on annual aggregated time series using the mean of 15-day dataset of GIMMS NDVI3g and the monthly air temperature dataset of NOAA-CRU. The significance of the trend was estimated using the Mann–Kendall trend test. In more than three decades, there has been significant ($p < 0.05$) greening trends in HKH. The highest trend of NDVI over HKH is 0.005 per year. The trend is highest within 20° to 28°N latitude. The uncertainty of NDVI trend slopes were calculated as the standard deviation of mean slope, i.e. 0.002 over HKH. Our findings show significant greening in high elevation landscape of HKH. Western and eastern HKH have significant increase in the air temperature. Highest trend of air temperature is 0.15 °C per year. The vegetation in HKH has gone greener in response to warming.

Keywords: Remote sensing, NDVI, Trend analysis, Climate change, Temperature

Monitoring impacts of climate change on forest cover and snow-line in Great Himalayan National Park using geo-informatics technology

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India is one of the 17 mega-diverse countries in world with around 708,273 km^2 forest area, which is 21.54% of the geographic area of the country. Under the National Action Plan on Climate Change and Green India Mission, conservation and improvement of forest quality has been recognized as a national priority. Forest resources can be helpful in fight against climate change. Increase in global temperature induced the tree-line/

snowlines to higher elevations. Several studies on mountain regions give evidence of shift in tree-line/ snowline. Himachal Pradesh state is vulnerable to climate change mainly because of commonly observed events like, (i) erratic rainfall and change in rainfall pattern, (ii) changes in agriculture / horticulture areas, (iii) significant changes in agricultural production, water resources, forest etc. and (iv) shift in snow line/ tree-line to high altitudes. This study aims at assessment of forest and vegetation type changes in Great Himalayan National Park. In this study, issues related to climate change in the Great Himalayan National Park (GHNP) area in Kullu district of Himachal Pradesh are studied and analyzed using multi-temporal remote sensing data, climate data and snowline/tree-line delineated from multi-date Landsat data. The changes in forest cover were also analyzed based on the supervised classification using multi-temporal Landsat TM digital data (spatial resolution 30m) of April-1993 and April-2017. Vegetation change was monitored in the study area over the period of 25 years from 1993 to 2017. The results of this study indicate that there is negative change in broadleaved and conifer mixed forest types and alpine scrub in 2017 as compared to 1993. The snowline from 1976 to 2017 was delineated with the help of Normalized Difference Snow Index (NDSI) and band ratio between Red and SWIR bands. The results indicate that there is significant change in the snowline /tree-line during last 42 years in the GHNP region, which has significantly shifted northwards to higher altitudes. Spatial variability and temporal trends of mean rainfall data were analyzed over the GHNP area. This analysis includes distribution, variability and trends in rainfall over the period of last 30 years. The impact of climate change on temporal and spatial patterns of rainfall in the GHNP region was clearly noticed in the analysis.

Keyword: Climate change, Forest cover, tree-line, snowline, NDSI

Carbon stock assessment in different land-use sectors of Ziro valley, Arunachal Pradesh using geospatial approach

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Land use change acts as a major factor reshaping the distribution of carbon stocks. The rapid changes in prevailing land use types tends to reduce the percentage cover of forests thereby reducing the potential of carbon storage. The present study was carried out to estimate the carbon stocks in different land use of Ziro Valley, Arunachal Pradesh. Altogether 24 permanent plots (0.1 ha area each) were established under different land use viz. mixed forests, pine forests and agricultural land. Non-destructive sampling method was carried out in the present study. A total 102 species were recorded from the present study of which *Pinus wallichiana*, *Castonopsis indica*, *Castonopsis hysterics*, *Rhododendron hodgsonii*, *Elaeocarpus rugosus* and *Quercus myrsinifolia* were among the most frequent species. The stand density ranges from 440 to 770 stems/ha for the forest area. Species specific volume equations were used. The results showed a positive correlation between basal area and biomass of the selected land use (r^2=0.94). The above ground biomass recorded from the mixed forests ranges from 140.55 tonnes/ha to 316.18 tonnes/ha, in pine forests 102.04 to 184.46 tonnes/ha. The biomass recorded for shrub layer in the mixed forests varied from 4.71 to 7.29 tonnes/ha and it was 5.38 to 13.46 tonnes/ha in the pine forests. The total carbon calculated for the mixed forests including soil organic carbon was 372.23 tonnes/ha to 1072.18 .4 tonnes/ha and it was recorded 358.68 tonnes/ha to 966.35 tonnes/ha in pine forests. The total carbon recorded in the agricultural field ranges from 115.33 tonnes/ha to 614.5 tonnes/ha. Study also showed that the conversion of forest in to agriculture will minimize the carbon capture potential of the forest land use. The different satellite data based modelling approach were applied in present study to predict the total carbon stock in the study area.

Keywords: Carbon, Paddy, Land use, Non-destructive, Modeling

Leaf Area Index modelling for studying forest phenology in Dalma sanctuary, Jharkhand

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Leaf Area Index (LAI) is one of the key biophysical variable, essential in variety of ecosystem modelling. LAI determines various fluxes in the ecosystem and is pivotal in CO_2 absorption. LAI can be distinctly studied and observed in typical deciduous forests and can be used for understanding phenological variation. Present study was carried out at Dalma forest in Jharkhand having deciduous and semi-evergreen type of forests with *Shorea robusta*, *Diospyros melanoxylon*, *Terminalia tomentosa*, etc. as dominating tree species. The study focuses on collection of ground data for LAI measurement at selected 22 plot locations in Dalma forest and interpolating the results using IRS Resourcesat 2 LISS-4 data. Study revealed LAI values in the region ranging up to 5.2, indicating dense forests particularly in the hilltop region, while moderate LAI values were seen on slopes. Apart from this, Sentinel-2 data was used to understand phenological variations in the forest. Temporal data showed distinct phenological variations in purely deciduous areas. Data was used to model LAI using temporal NDVI datasets and study phenological pattern in major forest species. The information was used to establish phenology for individual species based on information from species data, ground-based LAI and temporal satellite data.

Keywords: Leaf Area Index, Forest phenology, Sentinel-2, NDVI

Stress mapping of Sundarban mangroves with Sentinel-2 images using Discriminant Normalized Vegetation Index (DNVI) and fuzzy classification technique

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Remote sensing with synoptic capability of land cover mapping is non-invasively helping in monitoring and management of ecosystems, especially sensitive and vulnerable ones, such as the mangroves of tropical and sub-tropical coasts. These forests are suffering from various stresses including increasing salinity and reduced fresh water supply. Mapping these mangroves for their health condition and continuation of same for future monitoring is of pivotal importance. This study reports stress mapping with high spatial resolution of a wildlife sanctuary of Sundarban using fuzzy classification technique. A recently developed health index for mangroves, namely Discriminant Normalized Vegetation Index (DNVI) was used to as a guide for deriving the signatures of stressed and healthy vegetation and with the use of parametric fuzzy classifier a very precise stress map was generated. Fuzzy classification of the mangroves stress and health allowed the pixels to acquire partial membership of different classes. The partitioning of the classes was resolved by convolving the fuzzy classes based on the DNVI and Normalized Difference Vegetation Index (NDVI). The general saturation tendency of NDVI was evident when compared to health index and was kept second in order for convolution weightage next to DNVI. The precise result in form of micro-level stress map indicates that mangroves stress is a probable function of local geomorphology, topography and physiography. This method appropriately represents the fuzzy pattern of natural forest cover rather than that obtained with fixed algorithm based hard classification methods. The approach also highlights need of mapping the stress of different assemblages of mangroves discretely in a single health index, as similar values may not represent similar health condition in different mangroves.

Keywords: Stress mapping, DNVI, Mangroves, Sentinel-2, Fuzzy classification

Backscattering and coherence analysis using space borne C-band data for forest characterization

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Synthetic Aperture Radar (SAR) has already been shown its immense potential in the area of forestry, and proved to be one of the incredible tool of remote sensing in the various aspects of forestry. The characterization of the forest is one of the most challenging tasks. This study has been carried out in order to characterize the forest area in the Dudhwa National Park, Uttar Pradesh. This is one of the few remaining highly diverse and productive tertiary ecosystem, which supports endangered species. The species found in the forest are highly crucial and important requiring timely monitoring. To achieve this objective, two datasets were used, viz. Sentinel-2 optical data and Sentinel-1A microwave data. The datasets used are of different months of the same year. The Sentinel-2 data is of March 22, 2018, whereas Sentinel-1A data is corresponds to May 29, 2018 and June 10, 2018. The main objective was to classify the forest area using Sentinel-1A C-band SAR data and its comparison with the optical data to ensure its accuracy. The second objective is to compare the backscattering values of different classes in VV and VH intensity bands. The optical data has been classified to prepare vegetation type map using Maximum Likelihood Classifier (MLC), and the accuracy achieved is 82.3%. The classification of the Sentinel-1A image has been done using two classifier i.e., Random Forest Classifier and KD tree KNN Classifier. The Random Forest accuracy is 75.2%, and correlation is 0.75 with an error rate of 0.057, whereas the KD KNN accuracy is 82.5%, and having correlation of 0.83. Further the values were correlated with the coherence values.

Keywords: Maximum likelihood, KD tree KNN, Random Forest, C-band, Sentinel-1A

A comparative analysis of forest risk zone mapping methods: A case study

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Rapid changes in forest ecosystems like forest fuel change, human intrusion, climatic changes etc. have led to environmental degradation. For better management of problems, assessment of forest risk zones has to be done to provide a better knowledge on fire occurrences. In spite of repeated occurrences of forest fire, very less scientific studies have been conducted in past in the Indian context especially in Kudremukh region. The primary objective of this study was to find out factors that cause forest fire and identify fire risk zones in Kudremukh area using different methods. In the present study fire ignition risk factors like elevation, slope, aspect, proximity to roads, water bodies and area of human activities, Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) and the vegetation type were taken into account. Logistic regression, multi-criteria decision analysis and weighted overlay approaches were used to assess fire risk zones. The empirical model was based on previous fire occurrences and the other two based on expert opinion. The area was divided into five risk zones viz. very high, high, medium, low and very low risk, using the models defining the fire vulnerability of the region. The three models were validated and compared using previous fire occurrence events. Results showed that the regression model is the best among the three with 88.89% accuracy, then multi-criteria decision analysis with 74.6% accuracy and then weighted overlay method with least accuracy of 68.24% for the specific study area. The obtained risk maps can be further used for management of the area.

Keywords: Forest risk zone, NDVI, LST

Assessment of landuse change implication on carbon stock of subtropical forests of East Khasi hills, Meghalaya

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Study was carried out with an aim to analyze the community characteristics, biomass and its validation with remote sensing and GIS. Altogether 71 woody species were recorded from subtropical broadleaved (SBL) and pine forests (PF). Stand density was 558 stems per ha and 585 stems per ha with basal area of 34.43 m^2/ha to 38.10 m^2/ha in SBL and PF, respectively. Bulk density ranged from 0.55 g/cm^3 - 0.85 g/cm^3 in SBL, 1.27 g/cm^3 in PF and 1.06 g/cm^3 in the abandoned lands. Soil moisture content ranged from 55.93% to 19.86% in surface (0-25 cm) layer and from 15.99% to 45.78% for subsoil layer (25-50 cm). Soil of upper layer was slightly more acidic than the lower depth and soil pH varied from 3.89 to 6.6 in upper depth 4.25 to 6.96 in lower soil depth. Generally, upper layer having more soil organic carbon than the lower depth of the soil and values varied from 1.14% to 2.87 % in the surface layer and 0.82% to 2.13% in subsurface layer. Available nitrogen ranges from 0.168 t/ha to 1.075 t/ha. Total biomass estimated in the SBL is 300.5 t/ha whereas it was 195. 89 t/ha in the PF. Predicted AGB was 235.4 t/ha in SBL forest and 125.2 t/ha in PF. However, calculated AGB was 300.28 t/ha in SBL forest and 215.8 t/ha in PF. Finally, spatial carbon map of the selected forest type was prepared. Based on the land use / land cover map, total estimated AGB for SBL was 17.6 Million Tonnes and 9.43 Million Tonnes for PF with an average of 165.2 t/ha and 107.2 t/ha, respectively. Implication of the land use change revealed that an amount of 86.36% carbon will be emitted in the situation when SBL is converted into abandoned land. However, an amount of 86.36% carbon will be emitted when PF are converted into abandoned land.

Keywords: Land use \ Land cover, Soil, Carbon, GIS, Emission

Measurement and analysis of spectral signatures of arid vegetation from Jodhpur area

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Spectral signature provides unique characteristics of a tree species due to chlorophyll content and leaf structure. Arid regions have many varieties of vegetation species which are useful for livelihood and environmental equilibrium. Objective of this study is to acquire, process and analyze spectral signatures of the prominent vegetation viz. *Azadirachtaindica*, *Senegalia senegal*, *Capparis Decidua*, *Calotropis procera*, *Acacia nilotica*. In-situ spectral signature measurement were carried out using Handheld Hyperspectral Spectroradiometer (SVC HR 1024) in the spectral range of 350-2500nm. Spectral signatures after pre-processing were analyzed statistically and percentage reflectance for each sample was graphed to gain a visual appreciation of variability of the reflectance curves of different tree species. Various statistically techniques were also used for discrimination and analysis of spectral data.

Keywords: Spectral signature, Arid vegetation, Hyperspectral Spectroradiometer

Morphological parameters and their implications in forest watershed

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Morphometric analysis, which refers to the science of quantitative analysis of land surface, was carried out on Kamleshwar watershed of Hiran River in Gujarat using remote sensing and GIS techniques. The land use/land cover map generated shows the catchment area of 78.19 km^2 mainly covered by forest. Digital Elevation Model (DEM) of 30 m × 30 m resolution was used to prepare the detailed drainage map in GIS environment. Stream order in the study area has trunk order of five. Total seventeen morphometric parameters including linear, areal and relief aspects were estimated. Mean bifurcation ratio of the watershed calculated to be 3.84, which indicates slightly dissected drainage basin. Low drainage density of 2.18 km/km^2 explains high infiltration in soil and less runoff due to dense forest cover. Drainage texture of 4.08 km^{-1} is coarse to moderate leading to reduce soil erosion. Form factor ratio and elongation ratio are 0.35 and 0.67 respectively, which favors lower peaks of longer duration with elongated watershed, considered good for avoiding the floods in downstream. Relatively low relief ratio of 0.016 translates low intensity of erosion processes. Low drainage density and relief results in moderately low ruggedness number of 0.52. The study shows potential usefulness of GIS techniques in determining geomorphological landforms of forest watersheds, which can be useful in various hydrologic modelling studies.

Keywords: Morphometry, Watersheds, DEM, Floods

TS - 4/2
Coastal Applications

Offshore wind farm site suitability and assessment for Tamil Nadu coast using RISAT-1 SAR and synergistic scatterometer data

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The possibility of expanding the wind power production to the offshore regions is viable, especially in the regions where winds tend to be higher and consistent. Out of all the coastal states of India, Tamil Nadu coastal region is having higher and persistent winds throughout the year. This study focusses on the utilization of satellite remote sensing in identifying most suitable sites favorable for installing offshore wind farms. Four years (2012-16) of RISAT-1 SAR and long-term synergetic scatterometer (QuikSCAT, OSCAT, ASCAT-A and ASCAT-B) data for 16 years have been processed to generate mean wind speed maps at 80 m hub height. A Geographic Information System (GIS) based methodology was developed to characterize the offshore wind power potential along the study region within the Exclusive Economic Zone (EEZ) by using ten site suitability parameters, viz. mean wind speed, bathymetry, distance from the ports, electrical transmission lines, cyclone risk, seismic risk, avian exclusion, visual exclusion, ecosystem exclusion and potential shipping lane exclusion. After assigning suitable relative weightages to each parameter, the offshore wind power potential sites of Tamil Nadu coast have been evaluated, using heat maps with ranking score between 1 and 10, where 10 denotes the most suitable site. Based on the analysis, it has been observed that the offshore region between Kolachel and Tuticorn has good potential for wind power generation. The overall electrical power generation in the most suitable sites have been estimated using Vestas 3MW and Gamesa 5MW offshore turbine curves. This methodology can be adopted for identifying potential sites of wind farms for the entire Indian coast.

Keywords: Offshore winds, Site suitability, RISAT, Scatterometer

A numerical modelling approach for beach erosion forecast during monsoon season

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Prediction of coastal erosion in advance along a beach during recurring events like monsoon shall be a significant information to the coastal management community to bring out proper management plans based on prior identification of coastal stretches likely to get effected. The present study has developed an approach towards numerically predicting the beach erosion at Ramakrishna (RK) beach, Visakhapatnam using XBeach modelling system. Wave parameters from the operational wave forecasting system at INCOIS, with a lead period of 10 days, is used as the forcing parameter. Initial beach topography was generated using DGPS profiles surveyed during August 2018 at regular spatial intervals. Forecast of beach erosion for 10th June is provided on 1st June, corresponding to a lead period of 10 days and such beach erosion forecast is provided for alternate 10 days up to September 30, 2018, which spans the monsoon season over the Indian Peninsula. Monitoring of beach using dumpy level at regular interval of time is carried out and the observed beach profiles are used to validate the model performance. Area under erosion observed from the model result is in homologous with the in situ observed beach profiles. The study highlights the importance of modelling studies for understanding the beach response under monsoon waves and for prior identifying vulnerable sectors of a beach so that appropriate measures can be taken to prevent coastal erosion and loss of land.

Keywords: DGPS, Beach profile, Modeling, Erosion

Morphodynamics of spit along Durgarajpatnam estuary, Andhra Pradesh, India

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Coasts are dynamic systems, undergoing changes in forms and processes in time and space in response to oceanographic conditions. Among the varieties of the coastal landforms, spit plays a vital role in modifying estuarine environment. Sand spits near river inlets or estuary mouths are accumulation of sediment that are formed and developed by longshore sediment transport. Their setting within the coastal landscape and anthropogenic influence leave them vulnerable to profound physical, ecological and associated societal disturbance from global climate change. Expected shifts in physical and ecological conditions and subsequent modifications lead to inundation and concomitant loss of natural and human communities. In the present study, the evolution of shoreline and spit at the mouth of the Durgarajpatnam Estuary, Nellore district, Andhra Pradesh, India has been investigated for last 30 years at different time intervals using High Resolution Satellite Images. The dynamic nature of the morphology of the spit has been examined and it has been observed that cyclic nature of the spit has led to shifting of the inlet very frequent. Even in the year 2009 and 2017 at some period of time it was also observed from the satellite images that the inlet was completely closed by coastal accretion which has been opened up with extreme weather condition at different location with a shift of 1 km. The spit has been very dynamic from 2013 to 2014 with a shift of 1.75 km. The spit being a north oriented in nature, plays a vital role in shoreline oscillation. Due to this dynamic nature of the spit, the proposed Durgarajpatnam Port location was shifted to Vagarru at Tupilipalem village located 20 km north of Dugarajapatnam, still referred as Dugarajapatnam Port.

Keywords: Coast, Spit, Morphodynamic, Estuary, Accretion

Seasonal variability of rip current probability along a wave-dominated coast using Hi-Res satellites and wave data

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Rip currents at RK Beach, Visakhapatnam in the northern coastal Andhra Pradesh are causing havoc to the beach users. Recent studies revealed that rip currents are responsible for most drownings happened along this beach. This creates an interest in the public and raises a research challenge on what factors are favorable for such dangerous currents. It has been well established that waves and beach morphology play an important role in the formation mechanism of the rip currents. However, due to limited studies, their variability with the season is less understood. In this paper, we have utilized high-resolution satellite imageries and wave data from the nearby buoy to establish a relationship between beach stage and wave parameters. RK beach is a wave-dominated coast and receives persistent swells during south-west and post monsoon seasons. The strong swells during monsoon season and extreme events induce changes in the beach morphology and thereby changes the beach stage from dissipative type to reflective type followed by an intermediate stage. High-resolution optical satellite imageries have been processed in GIS environment. Beach types have been identified in satellite imageries to understand the beach response to the prevailing waves for the period 2013-2017. The study revealed that the rip current probability is higher during intermediate beach stage, and is responsible for major drowning cases along the study area.

Keywords: Rip currents, Beach stage, RK Beach, Satellite data, Buoy data, GIS

Satellite observation of mudbank and its spatio-temporal dynamics along Kerala coast

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Mud bank, the unique coastal phenomenon of the Kerala coast, has been intriguing coastal researchers over decades for its formations, extent, migration and coastal impacts. During monsoon, the mud bank region dissipates high monsoonal waves (> 3 m) due to the presence of highly concentrated fluid sediment in the bottom layers, which leads into the formation of calm pool of coastal ocean surrounded by high wave activity. SAR images and cloud free multi-spectral images are used to study the possible satellite observation of mud bank. The delineation of mud bank region from the satellite data is based on identification of calm coastal region due to the dissipation of waves from the surroundings. Textural analyses of individual bands in multispectral images and VV polarized SAR images were carried out from the Grey Level Co-occurrence Matrix (GLCM) and homogeneity was estimated. Coastal region with sharp positive homogeneity has been identified as mud bank region, where the roughness due to the ocean waves were significantly reduced due to dampening of waves. Analysis have been carried out on temporal satellite images for the period 2015 to 2018. Periphery of mud banks were marked using *in situ* GPS observations and validated with that of satellite imageries. The temporal variations in the spatial extension of mud bank region observed by satellite images has been used to understand the dynamics of the active mud bank. The present study shall help in understanding the genesis of mud bank which can lead to decipher the processes involved in the formation of mud bank and to study the temporal dynamics, which is otherwise onerous task using in situ observations.

Keywords: GLCM, Mud bank, SAR

Thermal plume dynamics along the Chennai coast: A study using Landsat-8 TIRS data and numerical simulations

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Thermal plumes in the coastal ocean areas are associated with the discharge of water with temperature higher than the ambient coastal waters, where the main sources of thermal plumes are from coolant water discharges from thermal or nuclear power plants, sewages, effluents and natural processes like submarine ground water discharge and river discharges. The rise in coastal water temperatures due to the thermal plumes is a cause of concern for the marine ecosystem. The present study uses satellite based Sea Surface Temperature (SST) observations to monitor the thermal plumes and its dispersion along the coastal waters located near Kalpakkam area, Chennai coast, Tamil Nadu. Sequential Landsat-8 TIRS data for the period 2014-2017 has been used to study the seasonal and inter annual dynamics of the thermal plume structure. An anomaly in SST of 2.5°C - 3°C was observed during the study at the discharge location. The thermal plumes are observed to have seasonal dynamics in the dispersion direction with the seasonal change in the East Indian Coastal Current (EICC). It has been found out that the thermal plume disperses in the south direction during winter monsoon period and in the north direction during summer monsoon period which is also the dispersion direction of EICC from north-west to south-east between the two monsoons period. During the transient period, the plumes are observed to have an offshore extent. To understand the dispersion characteristic of thermal plume, numerical simulations are carried out under various discharge scenarios and with varying seasonal coastal currents. The study shows importance of synergetic use of satellite observations and numerical models in understanding the thermal plume structure and process of dispersion.

Keywords: Thermal plume, SST, Landsat-8, EICC

A study on impacts of wind movement upon shoreline changes along the south-east coast of Thiruvallur, Tamil Nadu, using geospatial technology

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The present study explores the effect of wind energy upon shoreline along the south-east coast of Thiruvallur district, Tamil Nadu, India. The multi temporal Landsat TM and ETM+ images acquired from 1996 to 2017 analyzed using Digital Shoreline Analysis System (DSAS). A detailed transect classification technique was used to attain accurate changes along the coast. The shoreline change rate (m/year), End Point Rate (EPR) and Linear Regression Rate (LRR) identified and the coastline progressions were noticed in the study area. The movement of wind and its impact on wind energy been mapped using the geospatial technology. The changing wind action along the coast was accounted and the shoreline change recorded. A timely study of the wind changes along the coastal tract ensures the change in the climate and to take precautionary methods and ensure safety using the geospatial techniques.

Keywords: Shoreline changes, DSAS, Wind movement, Coastal management

TS - 4/3
Hyperspectral Applications

Inversion of bio-optical properties using hyperspectral data in optically complex waters of Chilika lake

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Remote sensing reflectance (Rrs(λ)) above water surface is related to the ratio of total absorption coefficient (a(λ)) and total backscattering coefficient ($b_b(\lambda)$) of the water column (where λ refers to wavelength). These quantities are known as inherent optical properties (IOPs), which depend on three main constituents, namely phytoplankton, suspended particles and colored dissolved organic matter (CDOM). In this study, IOPs for Chilika lake were modelled using the in-situ measurements. IOP models were then used to simulate Rrs spectra using forward modelling. The simulations were done for all possible combinations of water absorption and scattering properties, which might prevail in the lake. Result of the simulations is a look up table (LUT) consisting of several Rrs spectra at 61 wavelengths equally spaced between 400 to 700 nm. Each Rrs in the LUT corresponds to a known set of water properties (a(λ) and $b_b(\lambda)$). To check accuracy of the simulations, in-situ measured Rrs (λ) were compared with those from the LUT to get a closest match. Water IOPs from the LUT, corresponding to the matched spectra, were considered as the retrieval. The retrieved IOPs were validated against in-situ measured dataset.

Keywords: Chlorophyll, Chilika, IOP, Phytoplankton

Knowledge based hyperspectral image classification using object oriented spectral library with CNN

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Modern hyperspectral imaging sensors acquire imagery at finer spatial and spectral resolutions so as to enable unambiguous discrimination and characterization of surface materials. The existing statistical and pattern recognition approaches of classification which depend upon image based reference do not exploit the rich spectral capability of hyperspectral imagery. Spectral knowledge discovery and knowledge transfer methods are sought after to exploit and recurrent use of spectral knowledge from hyperspectral imagery. Library based knowledge is one of the direct ways of image classification base on the spectral knowledge discovery and mapping. Transferring knowledge from spectrally overlapping imagery of similar land cover classes has recently proposed. To retrieve spectral information, with increased dimensionality of the feature vector, making the hyperspectral data larger than expected, it is challenging to apply discriminative information from library based training data to testing data that are not in the same feature space and with different data distributions. The development of deep learning greatly improved the performance of hyperspectral image (HSI) classification in recent years. The proposed method is built on a combination of a deep CNN strategy and an object-based classification for the interpretation of high-resolution hyperspectral images. In this paper, we train the deep CNN with required number of hyperspectral image objects. It creates a library of different objects in the form of CNN model. The trained CNN along with the segmentation model is used to detect the objects in the hyperspectral image dataset and segment them. To train the model, ResNet based CNN is used. Terrestrial hyperspectral data and drone-based hyperspectral data are used as the datasets to implement this model. As we considered the object based properties along with pixel properties, we can classify the image more meaningfully with high accuracy compared with pixel based classification.

Keywords: Object-based classification, Terrestrial hyperspectral image, Convolutional Neural Network, ResNet

Spectral unmixing of hyperspectral data in an agriculture system

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Spectral unmixing is one among the most challenging and active area of research in the domain of hyperspectral remote sensing. It is categorized as a blind source separation problem focusing on decomposing the mixed spectral signature into pure spectral signatures known as endmembers and estimating their approximate abundance or proportion. In most of the applications, the classifier often fails to classify hyperspectral imagery (HSI) effectively because of the mixing problem attributed in a single pixel. In-situ observation is not always possible to collect due to unavoidable constraints hence, it is required to develop a robust unsupervised strategy to address spectral unmixing. In this paper, we advocate an unsupervised fully constrained least square linear unmixing technique for material abundance estimation in HSI. Methodology based on orthogonal subspace identification to estimate the number of possible endmembers in HSI, along with strategies for band selection were investigated. For validation and testing, a series of computer simulations were conducted on AVIRIS-NG datasets over the region of Maddur, Karnataka and synthetic datasets. Fractional abundance maps were generated corresponding to each endmember with the aforementioned fully constrained least square method, further root means square error and spectral angle distance measures have been calculated to measure the effectiveness of the technique.

Keywords: Hyperspectral data, Spectral unmixing, Endmembers, Fractional abundance

Discrimination of mangrove and non-mangrove vegetation using spaceborne AVIRIS-NG hyperspectral data

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Mangroves are one of the world's most luxuriant forest with enormous ecosystem services. They are also the most vulnerable forest worldwide, as a consequence, in most of the countries they have been declared as protected forest. For the sake of the protection and proper management of this forest-ecosystem, an accurate demarcation of the mangrove forest area is most important. In many areas mangrove forest situated in close proximity of other vegetation classes. The present study attempts the discrimination of Mangrove and Non-mangrove vegetation using hyperspectral data. In the fringe of Indian Sundarbans, there are so many areas where mangroves stay in the close proximity of other vegetation. Two of these areas have been chosen as the study sites i.e. Ramganga and Frazer-Ganj with three sampling locations each. Airborne Visual Imaging Infrared Spectrometer- Next Generation (AVIRIS-NG) hyperspectral image have been used for the present study. The Mangrove Recognition Index (MRI) and recently developed Combined Mangrove Recognition Index (CMRI) have been used to differentiate Mangroves and Non-mangroves. After field validation, it has been confirmed that the AVIRIS-NG with finer spatial and spectral resolution gives an accurate discrimination of Mangroves and non-Mangroves. The same methodology has been adopted with LANDSAT and Sentinel data. The results show AVIRIS-NG provides most accurate discrimination.

Keywords: Discrimination, Mangroves, AVIRIS-NG, MRI, CMRI

Hyperspectral studies of flowers

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Flowers are the reproductive structures of angiosperms. Flower color is an important plant trait that regulates plant-pollinator interaction and undermines the reproductive success of angiosperms (flowering plants). Despite substantial progress in the objective representation of color (and light), the qualitative description continues to remain the norm. The Commission Internationale de l'Eclairage (CIE) has defined the relation between colors and perceived human colors using different tristimulus models. The CIE (L*a*b*) color model is a device-independent, non-linear transformation of the Red, Green, and Blue (RGB) color space, modelled on human perception. From an organic point of view, the perception of flower color by insect pollinators are more important for plants. The locus of photoreceptor excitation within the bee color space (chromatic hexagon) denotes insect-pollinator perceived color of a flower.

In this paper, hyperspectral remote sensing is used to measure floral spectral reflection across the wavelength from 350 nanometers(nm) to 700 nm, to objectively represent human and insect pollinator perceived floral colors. CIE (L a b) model and chromatic hexagon were used to represent the human and insect-pollinator perceived floral colors. Further, we illustrate the perceptible temporal change in human and insect-pollinator perceived floral colors and highlight the need to include time as a fourth dimension to holistically represent floral color. Floral spectral reflectance from seven freshly bloomed angiosperms were measured during February 2018 at 30 minute interval from 9.00AM to 4.00 PM using Analytical Spectral Device (ASD Inc. Field spec® 3). The analysis was carried out on both human (400 -700 nm) and insect pollinator (350 - 600 nm) visible range respectively. While temporal changes of human perceived floral colors were estimated using the CIE delta E (Empfunding) (CIE ΔE) 2000 model, the Euclidean distance was used for insect-pollinator perceived flowers. The present study uses hyperspectral remote sensing to represent human, and insect pollinator perceived floral colors and illustrated their perceptible temporal changes. We recommend inclusion of time as the fourth dimension to precisely represent floral color.

Keywords: Hyperspectral remote sensing, Flowers, CIE Lab, CIE ΔE (2000)

A study on retrieval of surface reflectance from hyperspectral data using artificial neural network

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Retrieval of surface reflectance from hyperspectral data is most useful and challenging task. Surface reflectance is being derived from the at-sensor radiance using different type of atmospheric correction techniques for its subsequent use in various applications and geophysical parameter retrieval. The effect of atmospheric correction directly determines the subsequent computable remote sensing quality of parameters by inversion and the accuracy of classification. In recent scenario the atmospheric, correction consists of two major steps: atmospheric parameters estimation like aerosol, water vapor, spherical albedo, Rayleigh scattering, aerosol scattering etc. and surface reflectance retrieval. The retrieval of surface reflectance through the atmospheric correction of hyperspectral observations is a challenging task. In this study, we retrieve surface reflectance from hyperspectral data using Second Simulation of the Satellite Signal in the Solar Spectrum Vector (6SV) radiative transfer (RT) model inversion through Artificial Neural Network (ANN). In order to retrieve atmospherically corrected surface reflectance, we employ an error back-propagation feed-forward fully connected neural network program. Using 6SV model we perform the forward simulations by varying atmospheric parameters

(aerosol optical thickness, columnar water vapor, ozone content) and viewing geometry parameters over different land covers to compute top-of the atmosphere reflectance (TOA) for training the network. Approximate 12,000 simulations have been carried out in forward simulation exercise. The ANN is applied to the AVIRIS-NG dataset of Ahmedabad (data acquired on February 11, 2016) acquired under NASA-ISRO collaborative air-borne campaign over India. Surface reflectance computed by the proposed ANN method over Ahmedabad region has been compared with the results of two independent methods developed by SAC and JPL. Preliminary comparative analysis of surface reflectance derived from ANN has been carried out with two independent methods.

Keywords: ANN, AVIRIS-NG, 6SV, Radiative transfer, Surface reflectance

Retrieval of target features using spectral curve simplification algorithm for airborne hyperspectral data

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Recent advancement in remote sensing research brings a new trend of using hyperspectral reflectance for pixel-wise classification. The richness of hyperspectral data in terms of spectral information due to presence of large number of narrowly spaced bands can be used as an effective tool for classifying target features present in a remotely sensed image. There can be two approaches for working with hyperspectral dataset. One approach is to address classification of hyperspectral image in feature space. But the issue of limited training dataset can pose a problem and do not fulfill the requirement of training sample as in case of the maximum likelihood classifier. Dimensionality reduction, to overcome the Hughes phenomenon is required before carrying out classification which makes the process cumbersome. The other approach is based on spectral space, and includes distance measures like Euclidean distance, Spectral Angle Mapper (SAM), city block distance and Spectral Information Divergence (SID) and absorption pattern as in case of Spectral Absorption Index (SAI). This approach can exploit the rich spectral information present and can be used without dimensionality reduction in the classification process. In this paper the spectral curves obtained from airborne hyperspectral image of AVIRIS-NG is utilized to derive a novel similarity assessment index for classification of target features. Douglas–Peucker algorithm is applied for simplification of spectral curves present in hyperspectral image. It is difficult to set threshold criterion so Spectral-Reflection Absorption Index (SRAI) was used for restricting curve simplification. Similarity assessment is done by matching the feature points of the curves simplified and are compared with traditional spectral similarity measures. The result showed that the proposed index is able to achieve higher precision than the traditional spectral similarity assessment measures like SID and SAM and gives a clear distinction between various target features.

Keywords: Hyperspectral, Spectral Reflection-Absorption Index(SRAI), Curve simplification, Douglas–Peucker algorithm, Similarity assessment

Estimation of chlorophyll content of some crop plants using airborne hyperspectral remote sensing and ground data: A case study of Maddur, Karnataka

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Precision farming and smart systems for agricultural resource management are relatively new approaches to increase the productivity, optimize the profitability and protect the environment. In order to develop sustainable and efficient agricultural practices, remote sensing is seen as a key tool to provide valuable information that is still lacking or inappropriate. Recent studies have demonstrated the usefulness of narrowband hyperspectral vegetation indices from imaging spectroscopy in the assessment of vegetation biochemical and biophysical variables like chlorophyll content and leaf area index (LAI). Maddur, Karnataka was one of the major site of AVIRIS-NG air and ground campaign carried out at various sites all over India as part of NASA-ISRO Hyperspectral Mission. This study presents, narrow band hyperspectral vegetation indices based approach for the quantification of chlorophyll content using ground and image based hyperspectral remote sensing data of Maddur, Karnataka. In this study, NDVI based masking techniques were used to mask non-agricultural patches in airborne hyperspectral image. Two narrowband hyperspectral indices, viz. Chlorophyll Ratio Absorption Index (CARI) and Modified Chlorophyll Ratio Absorption Index (MCARI) were computed using ground and image based data. Regression models were developed for both the indices computed from ground and image data. They were further validated using independent datasets and the models applied to airborne image data to generate bias corrected indices maps. Further, regression models for CARI and MCARI were developed using ground measured chlorophyll content by SPAD-502. Both the indices showed linear correlation with r^2=0.64 for CARI and r^2=0.76 for MCARI. Relatively better correlation achieved by MCARI is due to band ratio used in the index, which reduces the effect of non-photosynthetically active objects and background soil exposure.

Keywords: Precision farming, Chlorophyll content, Hyperspectral remote sensing, Chlorophyll Ratio Absorption Index (CARI), Modified Chlorophyll Ratio Absorption Index (MCARI)

Airborne hyperspectral remote sensing of inland water

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One of the challenging issue in satellite remote sensing using visible and near-infrared (VNIR) bands is to retrieve the water leaving radiance (L_w) with a desired accuracy. The situation becomes more critical in the case of inland waters as compared to clear oceanic waters. For inland waters the amount of backscattered water-leaving signal, reaching the space-borne sensor at the top of the atmosphere (TOA), is only about 15% of the total recorded signal. The complexity of atmospheric correction increases due to enhanced concentration of chlorophyll and other particulate matter in the water column. For satellite sensors, spatial and spectral resolution are typically low, thus, by using hyperspectral airborne sensors with spatial resolution of few meters it is intended to retrieve and characterize the biogeochemical properties of optically complex inland waterbody. The present study highlights the application of an atmospheric correction of inland water bodies for airborne hyperspectral AVIRIS-NG sensor data recorded over the Indian subcontinent. This method determines aerosol radiance using Rayleigh corrected NIR band at 745 nm and uses an extrapolation method to calculate aerosol radiances (L_a) at the visible bands. A significant improvement is achieved in retrieved L_w when compared to FLAASH correction used in ENVI software. Retrieved L_w is then converted into normalized water leaving radiance (nL_w) and subsequently Chlorophyll concentration is estimated based on the nL_w values using the ABI

algorithm. The proposed atmospheric correction method can be further tuned for correcting airborne hyperspectral data with better accuracy.

Keywords: Atmospheric correction, AVIRIS-NG, Inland water, Chlorophyll concentration

Built up construction material identification and classification from hyperspectral imagery

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Hyperspectral imagery contains abundance of information, both on spectral and spatial terms. Most application of hyperspectral imagery require a few processing techniques which achieve some fundamental goals. 1. Identifying and classifying existing material from pure pixels in the scene; 2. Reducing the dimensionality without compromising on the information present. The authors have proposed a technique which not only reduces the dimensionality of the data while ignoring mixed or unwanted spectral signatures, but also isolates pure pixels for the classification of hyperspectral data for urban application. The dataset has been processed from earlier stages of pre-processing to dimensionality reduction. After a reduction of the dimensionality, the final classification is achieved by using a support vector machine classifier. The proposed approach is tested and validated using an accuracy matrix. The results obtained on Airborne Visual Imaging Infrared Spectrometer – Next Generation (AVIRIS-NG) shows promising results with a limited training set.

Keywords: Support Vector Machines, Hyperspectral, PCA, Urban

TS - 5/1
Urban Applications

Building rooftop extraction and estimation of solar energy capabilities using machine learning

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Indian cities are experiencing rapid urban growth, requiring government to implement multiple redevelopment schemes addressing growing needs of citizens. Schemes to encourage renewable energy are among multiple initiatives of the government. India aims to reach solar rooftop energy target of 40 GW by 2020 and as of 2016, 1.25 GW has been achieved with an outstanding of 38.5 GW. Implementation of such programs requires identification of suitable locations and area available mostly on rooftops and to eventually achieve the capacity to generate targeted production. This paper addresses the extraction of rooftop area for Bengaluru city of Karnataka state in southern India, a fast growing Indian city, often referred to as Silicon Valley of India. It has been reported widely that high transmission losses in the state of Karnataka, are resulting into major energy crisis in the state. Various types of industries and domestic users in the state further make the task of energy distribution companies difficult. The study covered the Greater Bengaluru Municipal Area spread over an area of about 741 km^2. Object oriented approaches, Support Vector Machine (SVM) and Random Forest (RF) classifiers were used for extracting building rooftops from high resolution satellite imagery. Triplesat data of 0.8 m spatial resolution was used for the extraction of building roofs in the study area. Accuracies are compared with manual methods of digitization and selected building rooftops were visited in the field to validate results. This analysis would help to understand the area available in the city and the potential of tapping such regions for solar energy harnessing, thereby ensuring equitable distribution of electrical energy to all other stakeholders in the state.

Keywords: Building edge extraction, Support Vector Machine (SVM), Random Forest (RF)

3D volumetric change analysis in urban areas

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With rapid economic growth and consequent expansion of urban areas, municipal governance has become more challenging, thereby necessitating technological aids for effective decision-making and planning for the sustainable futures of cities. Integrated GIS and three-dimension (3D) volumetric analysis serves as important tool for analyzing the built environment comprising urban structures such buildings, towers, roads etc. for ensuring sunlight availability and air circulation, rooftop solar energy potential tapping and built-up density planning. Since the growth of the city is happening in both two and three dimensional space, i.e. horizontal as well as vertical growth, the temporal change in urban structures using 3D city models offer improved visualization and better understanding of the city. In this study, 3D volumetric change analysis of urban built-up area is done using data acquired by Indian remote sensing satellites. The building footprints were extracted from Cartosat 2 series panchromatic data fused with Resourcesat-1/2 LISS-4 data using Object Based Image Analysis (OBIA). The building footprints for the year 2015 were subsequently used to derive the building footprints for year 2005 and 2010 using temporal inversion or backdating approach. Digital Elevation Model (DEM) of the study area was generated using Cartosat-1 stereo pairs for three time periods, viz. 2005, 2010 and 2015. The building footprints and DEM were subsequently used to estimate building heights and the 3D city models for three timeframes was thus generated. The temporal data of 3D city model was used for volumetric change analysis of part of Ahmedabad city. Furthermore, the change in Floor Area Ratio (FAR) was estimated by integrating town planning scheme plot boundaries with the 3D city model.

Keywords: Volumetric analysis, GIS, Floor Area Ratio, Digital Elevation Model, OBIA

Simulation of urban growth using SLEUTH model: A case study on Ranchi city

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In the context of rapid urbanization, especially for the capital cities such as Ranchi in Jharkhand, the assessment of changing urban area is the very first step for better sustainable city planning in near future. Using remote sensing and Geographic Information System as a tool, the broader landscape of change in city area with significant accuracy can be achieved. In present study, using supervised classification technique on the data acquired by three different LANDSAT sensors MSS & TM, ETM+ and OLI, the urban scenario of Ranchi city during 1994, 2005, 2010 and 2016 have been estimated with overall accuracy of 82%, 86%, 87% and 90% respectively. Thence, four-fold of urban extent with significant increase in road network is divulged during 1994-2016. Furthermore, SLEUTH model was utilized to get the future estimate of urban area in the context of 2030. The imported layers in the model have resolution of 90m, 60m and 30m and henceforth calibrated in coarse, fine and final mode respectively to predict for 2030 by setting the number of Monte Carlo iterations equal to or greater than 100 with also defining best fit growth coefficient obtained from final phase of calibration. ASTER DEM was used to prepare slope and hillshade layers as required as input in model. The water bodies, forest area and airport were digitized from the LANDSAT images and assigned as excluded area layer to put as a constraint of spread. Using prediction best fit values derived from the forecast run, the projected urban area is 283.5 km^2. during 2030 as high as approximately two-fifth of current Bangalore city. With high spread coefficient defined by edge growth prediction mode, it was inferred that the changing pattern of city structure is highly road influenced during 2005-16 unlike centrifugal spread out before 2005.

Keywords: SLEUTH model, Growth modelling, DEM, Landsat

Detecting the growing urban heat islands of Ahmedabad city using satellite data and GIS

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Rapidly growing population has fueled the process of urbanization in terms of anthropogenic modification of land surfaces viz. replacement of green cover by concrete structures, paved constructions, etc. The alteration in the LU/LC, in general, alters the thermal properties of the land which changes the energy budget at the ground surface that affects the surrounding atmospheric circulation characteristics and results into a series of changes in the urban environmental system. These development lead to the formation of 'Urban Heat Islands', whereby, urban regions experience warmer temperatures than their rural surroundings. UHI is an important phenomenon given its direct and indirect impacts on human populations including increased mortality and morbidity of urban inhabitants, human discomfort etc. Urban Heat Island effect has been studied using both directly measured and remotely sensed temperature datasets. Satellite derived multi-temporal high resolution Land Surface Temperature (LST) datasets are able to capture at greater detail local differences in temperature originating from varying meteorological conditions, environmental differences and/or active heat sources (e.g., urban areas, land cover classes). With this background, the present study is undertaken for Ahmedabad city, Gujarat which has seen a substantial urbanization and rapid industrialization in the past two decades. Terra and Aqua MODIS daily day and night time LST product available at 1 km × 1 km spatial resolution has been analyzed for the period 2001 and 2017. The heat island intensity is computed at all points for the entire duration and spatial patterns are studied using Geographic Information System (GIS). The heat island intensity maps generated for few specific days and at seasonal (winter, summer, monsoon and post monsoon) and annual scales along with the respective anomalies have provided comprehensive insights to impacts of urbanization and detection of growing heat

islands in Ahmedabad city. The study would provide decisive inputs to the urban planners and policy makers for undertaking heat island mitigation strategies.

Keywords: Urban heat island, MODIS, Land Surface Temperature, GIS, Ahmedabad

Remote sensing based time-series analysis for monitoring urban sprawl: A case study of Chandigarh capital region

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Urban growth is a global phenomenon which is happening at unprecedented rates. According to the United Nations, the current world population of 7.6 billion is expected to reach 8.6 billion in 2030 out of which 5 billion will be urban population. Much of this urbanization will unfold in Africa and Asia, bringing huge social, economic and environmental transformations. The main reasons for urban growth are an unorganized expansion, increased immigration, and population explosion. In this context, changes in land use/land cover are considered one of the central components for managing natural resources and monitoring environmental impacts. In the present study, a supervised classification applied to three Landsat images collected over time (1990, 2001 and 2015) gave an insight into the urban sprawl patterns in the Chandigarh capital region. The results show an increasing trend of urban sprawl in the outskirts of the city, especially in the north-western and southern directions as a result of the development of an international airport, new sectors and approach roads. Post-classification change detection points to the fact that maximum changes were seen in the vegetation cover as it has rapidly changed to built-up/urban areas. Based on the results of such studies, the city and town planners may be able to take timely and appropriate steps to minimize the environmental implications associated with such urbanization.

Keywords: Urban sprawl, Land use/ land cover, Environmental impact, Chandigarh

Urban sprawl monitoring using multi-temporal built-up indices: A case study of Ahmedabad city

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From last few decades, urban areas of various parts of the world are experiencing an unprecedented growth in both built-up area and population. The UNESCO declared the historic walled city of Ahmedabad as India's first World Heritage City and also Ahmedabad has been selected as one of the hundred Indian cities to be developed as a smart city. The present study was carried out in Ahmedabad Municipal Corporation (AMC) area with a major objective of monitoring urban sprawl from 1976 to 2017 using multi-temporal Landsat data. The multi-spectral indices like Normalized Difference Vegetation Index (NDVI), Built-Up Index (BUI), Normalized Difference Impervious Surface Index (NDISI), Normalized Difference Built-Up Index (NDBI) and Normalized Difference Impervious Index (NDII), were generated. Spectral variations in built-up, open spaces, urban vegetation and water areas were studied by generating two-dimensional spectral plots of NDBI and BUI. The spectral response of built up areas like dense urban and sparse urban land cover are quite distinct. The results of urban sprawl monitoring indicate that the dense-urban built-up area in AMC has increased by 97.2% and sparse-urban area has increased by 43.8% over the period of 41 years from 1976 to 2017. However, open space has decreased by 353% and water bodies have decreased by 52.2% over the same period. The urban vegetation,

which includes parks and gardens in the city, has shown an increasing trend (9.8%) during the period of 1976 to 2017. It was observed that various built-up indices were very useful for mapping different urban land use/ land cover classes in Ahmedabad. The urban land use change map indicating changes in urban land use classes was also prepared. The detailed transport network in AMC was mapped using NDISI. These types of information are very useful for the urban planners to chalk out sustainable management plans for the city.

Keywords: Urban Sprawl, Landsat data, Built-up indices, Change monitoring

Forecasting urban growth for Chalakudy city using geoinformatics and statistical model

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Urbanization is a process of rapid transformation of rural area to urban characteristics. This process begun with the industrialization and globally all the economies, both developed and developing, are on rapid urbanization path. To predict the rate of urbanization in future is a very essential part in planning process. The present study was undertaken with the main objectives to analyze the land use change during past 18 years in Chalakudy city and predict the urban expansion till 2030 and suggest measures to plan city effectively. The study utilized the capabilities of remote sensing and GIS to obtain the urban boundaries for four different time periods and predict the growth of the cities during 2030 using Urban Growth Margin Model. Traffic forecasting is done based on the available traffic data. Validity of the model is ascertained using Kappa indices. The results reveals that the city had only 2.88 km^2 urban area during 1995 and it predicted that by 2030, 17.10 km^2 will become urbanized. Based on traffic projection, a long term Transportation Development Plan has been formulated. It is expected that these long term plans would enable a balanced development of the urban center in the coming years.

Keywords: Urbanization, GIS, Urban Growth Margin Model (UGM), Kappa index, Transport Development Plan (TDP)

Analysis of causative factors of urban growth in Gwalior city using multi-date remote sensing data

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This paper attempts to understand the causative factors of urban growth in the rapidly expanding Gwalior city of Madhya Pradesh. The expansion of the built-up area was estimated using multi-date remote sensing data acquired by LISS-IV sensor onboard Indian remote sensing satellites for years 2004, 2011 and 2017. The study observed an increase in rate of growth of built-up land from 11.96% during 2004-2011 period to 23.71% during 2011-2017 period. The new development was further classified as infill, leapfrog and extension development using Urban Landscape Analysis Tool (ULAT). The urban density gradient analysis of Gwalior city indicated a radial pattern of growth in built-up area, with an apparent sway towards industrial areas located in the North-Eastern direction. Shannon entropy was applied to derive the zone of influence of Central Business District (CBD) on the growth of city as well as to understand the directional bias in growth due to regional road network. It was observed that the CBD of the city had an influence up to 8 km radial distance and the growth of the city largely extended towards the North Eastern direction. The study indicated occurrence of dispersed and haphazard urban growth, particularly in the outer zones of the city. The study further assessed the effect of

various causative factors such as distance from national highways and state highways, proximity to industrial center and CBD, land characteristics such as slope, soil and natural drainage, and surface and sub-surface water resources, in promoting urban development in the city.

Keywords: Urban growth, GIS, New development, ULAT, Shannon's entropy, LISS-IV

Spatial and temporal variations of urban heat islands of Hyderabad city using high resolution Landsat 8 satellite data

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With the onset of urbanization, there has been a significant change in the land-use / land cover which has changed the microclimates of the cities. With the replacement of soil and vegetation by concrete / asphalt surfaces, high release of the anthropogenic (waste) heat, trapping of heat due to compact development and reduced sky-view-factor, cities are experiencing a warmer climate, which is also referred as Urban Heat Island (UHI). Due to the relevance in the regional climate, human comfort / health and urban air quality, UHIs studied extensively across the world in the last 20 years. Most of the studies attempted using long-term ground observations and short-term field campaigns, however, of late satellite data has been used to study the Land Surface Temperature (LST), which is a valuable metric for many earth-monitoring applications. The present study attempts to use the Landsat 8 satellite data for deriving Land Surface Temperature (LST) of Hyderabad city, the fourth most populous city of India with a population of 6.9 million and spreading over an area of around 650 km^2. A database of the LST for Hyderabad city was prepared for specific days for the different seasons of the year 2014-2015 and 2017-2018. The database was used to compute the UHI intensity at each point, which was subsequently mapped using Geographic Information System (GIS). The present study is one of the first few studies done using the high-resolution Landsat 8 satellite data for LST over Indian region. The study of UHI using high-resolution data provides valuable clues for developing mitigation strategies for Hyderabad city.

Keywords: Landsat 8, Urban heat island, Hyderabad, Land Surface Temperature

Building vulnerability assessment in urban area

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Buildings are the immediate environment in and around a city, wherein the population live, work, study, play, etc. A sound building stock will ensure towards contributing to better quality of life of its occupants and those moving around/passers by the stock. Building materials used in contemporary times has a definite life span, and over time, there is a probability that the building stock becomes vulnerable to various physical and social reasons. A study conducted in Dehradun, India wherein the oldest part of the city studied to determine the building vulnerability. The results revealed that there is a need to look in depth and determine the condition of buildings in terms of their vulnerability using a GIS based platform so as to not only safeguard the building's condition, but also that of the people associated with the buildings in terms of spatial and temporal proximity and/or use.

Keywords: Vulnerability, Building stock, Probability, Proximity

TS - 5/2
Marine Sciences

Algal blooms detection and associated phytoplankton absorption coefficient in Arabian Sea using in-situ and satellite data

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Algal bloom refers to an increase in concentrations of phytoplankton from hundreds to thousands/hundreds of cells per milliliter, depending on marine environment. This process happens when deeper nutrient rich waters rise to the top replacing surface waters. The bright sunlight in the surface waters, along with the nutrient enrichment, triggers the minute floating plant cells to multiply and concentration reaches hundreds of cells per milliliter. Algal blooms are often green, yellow-brown or red, depending on the species of algae. The excessive increase in the phytoplankton biomass can be studied by either apparent optical property (e.g. radiance/reflectance detected by ocean color sensors) or by inherent optical properties, (e.g. absorption and backscattering properties by ocean color sensors). In this study inherent optical property (phytoplankton absorption coefficient at 443 nm i.e. $a_{ph}443$) of the Arabian Sea is studied using *in-situ* and Oceansat-2, Ocean Color Monitor (OCM) data. Phytoplankton absorption coefficient at 443 nm has been retrieved using semi analytical inversion from reflectance data collected during Sagar Sampada cruise in 2011 (SS-286). The analysis of phytoplankton absorption coefficients ($a_{ph}443$) of algal bloom stations on 7,9,10 and 13 March 2011 respectively show very high $a_{ph}443$ (>0.07 m^{-1}) values. Similarly the bloom data of the cruises during 2007, 2009, 2010 and 2017 were also analyzed and it is observed from the *in-situ* data that $a_{ph}443$ >0.07 m^{-1} correspond to bloom stations. Phytoplankton absorption coefficient at 443 nm ($a_{ph}443$) of Eastern Arabian Sea is retrieved from Oceansat-2, OCM data acquired on March 8, 2017.

Keywords: Algal bloom, OCM, Inherent optical properties, Arabian sea

Development and validation of partial pressure of carbon dioxide algorithms in the southwest Bay of Bengal

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Satellite remote sensing is an alternative for mapping pCO_2 at large spatial and temporal scales using the available remotely sensed chlorophyll and sea surface temperature (SST) products. The seasonal regression analysis of calculated pCO_2 with in-situ SST showed the significant relationship for the cubic function during post monsoon season with a R^2 of 0.537 and SEE of ± 36.543. Validation of satellite derived pCO_2 with calculated pCO_2 showed R^2 of 0.498 and the root mean square error (RMSE) of ±30.922µatm. However, 75% of overestimation of calculated pCO_2 is observed in the satellite derived pCO_2. Hence, it directed to the addition of chlorophyll into the algorithm by considering the importance of biological activity in chlorophyll distribution. Three dimensional seasonal pCO_2 algorithms using in-situ SST, chlorophyll and calculated pCO_2 for plane, paraboloid, Guassian and Lorentzian functions are developed. Among the four functions the paraboloid function found to be better fit and significant regression (R^2 = 0.666, SEE = ±28.333) is obtained for post monsoon season compared to other seasons. The validation of pCO_2 map showed the better agreement than SST based estimations with calculated pCO_2 with a R^2 of 0.851 and RMSE of ± 23.441µatm. Thus, the addition of chlorophyll as a predictor variable improved the retrieval of pCO_2 than SST alone and confirms the predominant role of both SST and chlorophyll on the distribution of pCO_2 in the southwest Bay of Bengal.

Keywords: SST, Chlorophyll, pCO_2, Regression, RMSE, SEE

Isostasy and crustal structure of the Chagos-Laccadive Ridge: Geodynamic implications

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The Chagos-Laccadive Ridge (CLR) is a N-S trending important morpho-tectonic feature in the western Indian Ocean and believed as a part of the Reunion hotspot chain. The nature and mode of emplacement of this ridge has been analyzed in the present study through 3-D flexural gravity modeling. The analysis of satellite-derived gravity and sediment corrected bathymetry data of several overlapping grids revealed variation of the Effective Elastic Thickness (*Te*) along the CLR. The northern most part of CLR (Laccadive Ridge) is associated with low *Te* of 3 km with subsurface to surface loading ratio (*f*) of 1. However, towards south the Maldive Ridge and Chagos Bank has fairly uniform *Te* of 8-10 km with very low loading ratio of 0.1-0.2. We interpret Laccadive ridge as a continental sliver possessing underpalted magmatic rocks caused by Reunion hotspot volcanism. The Maldive Ridge and Chagos Bank appears to have emplaced on a lithosphere of intermediate strength possibly on the flanks of the Central Indian Ridge.

Keywords: CLR, Isostasy, Effective Elastic Thickness (Te), Laccadive Ridge

Computational methods for long term monitoring of new production and f-ratio variability in Bay of Bengal

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MODIS Aqua derived primary production and SST data are used for calculating the f ratio and new production using previously developed models. Developed models were validated with *in-situ* new production and f ratio reference values from published literature for the fall inter-monsoon (2002) season. The regression between derived and bottle measured P_{new} value showed R^2=0.478, SEE=±65.266, MNB=-0.114 and RMSE=214.426. Similarly f ratio is validated with *in-situ* derived value showed the clear underestimation with a R^2=0.271, SEE=±0.020, MNB=-0.6441 and RMSE=0.4416. The seasonal and inter-annual variation of primary production, f ratio and new production showed the clear seasonal pattern between the seasons. The high (133.64 $mgCm^{-2}d^{-1}$) and low (31.69 $mgCm^{-2}d^{-1}$) new production ranges are observed during pre-monsoon and summer seasons. The integrated primary production and f ratio of all the seasons provide a significant R^2=0.585. This is used to estimate the total annual primary production of Bay of Bengal as ~11%. The minimum (0.028 $GTCyr^{-1}$) and maximum (0.037$GTCyr^{-1}$) annual new production observed for the years of 2014 and 2006. In the entire processes of primary production, new production rate was less and it indicates Bay of Bengal largely as the regeneration based basin than the new production.

Keywords: New production, F ratio, Bay of Bengal, Sea Surface Temperature (SST), MODIS Aqua, Primary production

Cyclone Ockhi induced ekman pumping and associated change in primary productivity in Arabian Sea using Scatsat-1 wind fields

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In this paper the effect of tropical cyclone Ockhi on the wind induced Ekman pumping and the associated biological changes have been investigated from multi satellite data. Cyclone Ockhi was a severe cyclonic storm that originated 425 km south-south east of Sri Lanka on 30 November 2017 and traversed in the eastern Arabian sea causing heavy damage to life and property. The very high wind speeds (100-150 km/hour), the rotating storm system resulted in turbulent mixing, and wind stress curl induced Ekman pumping. Winds from Scatsat-1 was used for estimating Ekman pumping velocity and the resultant upwelling. The Ekman pumping velocity was found to be as high as 6-7 m/day during the event of the cyclone. An Ekman pumping parameter was also computed based on the Ekman pumping velocity and the duration of the pumping to quantify the upwelling. SST data from GHRSST analyzed on a daily basis for a 25-day period to confirm the cooling of sea surface in response to upwelling. The average values of SST and chlorophyll for a rectangular area which is most influenced by the cyclonic storm is analyzed on a daily basis to study the time series. The Ekman pumping velocity maps showed prominent areas of possible upwelling activity surrounded by prominent down welling areas. SST and salinity profiles of the area upto a depth of 200m was analyzed from NOAA data for pre cyclone and post cyclone change analysis. There was a marked decrease in surface SST and a deepening of the mixed layer after the cyclonic event. The mixed layer deepened from 42 m just before the cyclone to 67 m, 5 days after the cyclone has passed. There was also a deepening of the thermocline and halocline. Oceansat-2 ocean color L1B and SUOMI NPP VIIRS data was also processed to retrieve chlorophyll concentration prior and post the cyclone event to study the change in productivity. It observed that there was a significant phytoplankton bloom like concentration in the high Ekman pumping area in response to the cyclone. The SST and chlorophyll had an inverse correlation during this period of study with an inverse correlation coefficient of -0.68. The fall in SST was evident from the time of occurrence of the cyclone and it kept falling even after the cyclone has passed. The SST dropped at 0.18 °C/day for a period of 10 days, remained near constant for another 5 days and then started increasing. The chlorophyll concentration started increasing a day after the passage of cyclone, reached a maximum of 2.90 mg/m^3 after 7 days and started decreasing thereafter to pre cyclone levels. Gridded sea level anomaly data obtained from Copernicus marine environment also showed lowering of sea surface height during the cyclone event. The two-threefold increase of phytoplankton concentration in response to cyclones have crucial significance for the marine ecosystem as they can adversely impact aquatic species and thus need to be monitored using remote sensing observations.

Keywords: Ockhi cyclone, Ekman pumping, SST, Chlorophyll, Scatsat-1, Oceansat-2

Influence of sea surface temperature and chlorophyll on the distribution of particulate organic carbon in the southwest Bay of Bengal

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Particulate Organic Carbon (POC) plays a vital role in the ocean carbon cycle. POC is responsible for large fluxes of carbon and is linked to many important ocean biogeochemical processes. Nowadays, improved ocean color sensor provides better understanding of the Sea Surface Temperature (SST), chlorophyll and POC distribution in the oceans with good spatial resolution. Better retrieval of POC from satellite imagery would improve our ability to study the ocean biogeochemical cycle. In this context, the present study was carried out

to understand the spatial and temporal changes of POC in the year 2017. Validation of Visible Infrared Imaging Radiometer Suite (VIIRS) derived SST (R^2 = 0.7708, MNB = 0.004, RMSE = 0.2321 and SEE =0.4193), chlorophyll (R^2 =0.7444, MNB = 0.035, RMSE = 0.1315, and SEE =0.2395) and POC (R^2 =0.7328, MNB = 0.011, RMSE =89.415, and SEE =29.53) with *in-situ* measurements showed the better retrieval of SST, chlorophyll and POC in the southwest Bay of Bengal respectively. The basin average of monthly composited VIIRS data showed the maximum chlorophyll (0.54 μgl^{-1}) and POC (108.72 $mgCm^{-3}$) during monsoon and minimum chlorophyll (0.25 μgl^{-1}) and POC (62.60 $mgCm^{-3}$) during summer. In contrast, monthly composite SST showed the minimum basin average (27.77°C) during monsoon and the maximum (30.76°C) during summer due to increased incoming solar radiation with cloud free sky during summer compare to monsoon which experienced dense cloud cover with decreased light intensity at the surface of the ocean. The multiple regression analysis between POC, SST and chlorophyll demonstrated the better agreement between the variable with R^2 of 0.663 [POC= -5.310 (SST) + 110.059(Chl)] and suggested the strong positive influence of chlorophyll on the distribution of POC while the SST acted in a reverse manner in the southwest Bay of Bengal.

Keywords: SST, Chlorophyll, POC, Validation, Regression, Southwest Bay of Bengal

Change detection and trend analysis for Oceansat-2 Ocean Color Monitor (OCM-2) time series data

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Satellite ocean-color observations are now widely recognized as an important component of international remote sensing programs. Ocean Color Monitor (OCM-2), one of the payloads aboard Oceansat-2 (2009), is designed to obtain quantitative information of ocean color variables e.g. chlorophyll-a concentration, etc. The two important tools for analyzing multi-temporal data obtained from EO satellite are Change Detection and Time Series Trend Analysis. The remote sensing data has become the heart of change detection and trend analysis techniques because of its high temporal frequency and wider selection of spatial and spectral resolution. The general objectives of change detection in remote sensing include recognizing the geographical location and type of changes, quantifying the changes, and assessing the accuracy of change detection results. Change detection is useful in many applications such as land use changes, habitat fragmentation, rate of deforestation, coastal change, urban sprawl, and other cumulative changes. In time series analysis, the goal is to estimate the future value using the behaviors in the past data. Trend Analysis predicts the values over cloudy and missing data, thus helping in generating a uniform time series. This paper discusses remote sensing techniques namely differencing, PCA etc. for change detection and ARIMA based method for Trend Analysis on multi-temporal OCM-2 data.

Keywords: Change detection, Trend analysis, PCA, OCM-2, ARIMA

Bio-optical characteristics of Trichodesmium bloom in the Eastern Arabian Sea: Ship and satellite studies

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Trichodesmium, the major nitrogen fixing cyanobacteria, are known to form extensive blooms in the tropical and sub-tropical seas. They have a significant contribution to the marine and global nitrogen cycle. The present study provides the in-situ analysis of Trichodesmium bloom observed in the Eastern Arabian Sea during FORV-359 Sagar Sampada Cruise conducted during the inter-monsoon period (April-May 2017). Massive blooms of Trichodesmium erythraeum were observed to be floating on the surface aligned approximately parallel to the shoreline and distributed over the continental shelf of the eastern Arabian Sea. The surface occurrence is due to the presence of gas vacuoles in the cells of Trichodesmium. Surface waters appeared pale brown to green in color. Samples were collected from bloom and non-bloom stations for spectral absorption measurements, phytoplankton pigment analysis as well as for microscopic examinations. An underwater radiometer was deployed to study the apparent optical properties of bloom waters. High Performance Liquid Chromatography (HPLC) method was used to determine Chl-a concentration. Images of Oceansat-2 OCM corresponding to the period of ship campaign were processed in order to locate the area of bloom. Microscopic study revealed Trichodesmium cell density to be 7.30 x 10^6 cells l^{-1}, contributing 77 % of the total cell count (8.33 x 10^6 cells l^{-1}). The concentration of total Chl-a analyzed using HPLC ranged from 0.2-4.8 mg/m^3. Zeaxanthin and traces of Chlorophyll-c2 MGDG considered as the marker pigments for CYANO-1, the class to which Trichodesmium belongs was also detected using HPLC. Rayleigh corrected OCM-2 images were related to bio-optical properties of Trichodesmium and discussed.

Keywords: Trichodesmiun erythraeum, Phytoplankton pigments, Trichodesmium bloom, Remote sensing, Arabian Sea

Phytoplankton pigment composition and community structure in the Eastern Arabian Sea investigated using in situ data - an aid for remote sensing of phytoplankton functional groups

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Oceans have a complex composition of phytoplankton which highly varies over a wide range of space and time. The pigment assemblages vary among species of phytoplankton, a trait developed for optimizing light absorption, both for photosynthetic and photo-protective purposes. Different pigment assemblages have their corresponding absorption spectra, which can be used to characterize phytoplankton populations. To improve our understanding of the role of phytoplankton for marine ecosystems and global biogeochemical cycles, information on the distribution of major phytoplankton groups is essential. Therefore, the main focus of this study is to characterize the vertical and spatial variability in phytoplankton pigment distribution in the Eastern Arabian Sea and thereby to understand their community structure. The samples were collected during inter-monsoon period (April-May) when the water column becomes highly stratified and devoid of nutrients. Samples were analyzed using reverse-phase HPLC (High Performance Liquid Chromatography) for identifying different algal groups based on their pigment composition and presence of biomarker pigments. Vertical distribution of phytoplankton pigments displayed varying patterns over spatial scales of thousands of kilometers. The open

ocean regions of eastern Arabian Sea were observed to be dominated by Prochlorophytes and Prymnesiophytes indicated by the presence of Divinyl chlorophyll a, Chlorophyll b, Zeaxanthin and 19' hex-fucoxanthin. Diatoms identified by the presence of fucoxanthin, dominated the continental shelf regions. Results from this study can provide the database required to develop bio-optical algorithms for retrieving phytoplankton size class and functional types using remote sensing data and study their role in ocean biogeochemical cycles.

Keywords: Phytoplankton pigments, HPLC, Biogeochemical cycles, Phytoplankton functional types

Studies on new production using in situ based model and satellite datasets over the Bay of Bengal and Arabian Sea

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Nitrogen is one of the key elements in the biogeochemistry of the oceans. Nitrate, the most oxidized form of nutrient and the largest inorganic nitrogen reservoir, limits the marine phytoplankton production in the oceans. Phytoplankton growth supported by external nitrogen sources like nitrate has been termed as new production (nitrogen fixation and external inputs), whereas growth supported by recycled nitrogen primarily in the form of ammonia, has been termed as regenerated production. The sum of the new and regenerated production gives the total production while the ratio of the new to total production yields the 'f-ratio'. The f-ratio also defines the strength of the biological pump, the magnitude of the rate of export of organic matter. The relationship has been established between in situ measured nitrate and f-ratio datasets (n=18, R^2=0.85). The model has applied to generate f-ratio images based on nitrate images. The nitrate images have been generated using modelled nitrate algorithm and satellite derived SST and chlorophyll using Modis-Aqua datasets. Using the f-ratio images and primary productivity images (Epply products), the monthly scale new production images were generated over the Bay of Bengal and Arabian Sea during the year 2016. The monthly chlorophyll ranged 0 to 5.0 mg m^{-3}, SST ranged 24 to 32 °C and nitrate concentration ranged 0 to 12µM. F-ratio images ranged 0 to 0.50, the primary productivity ranged 0-12000 mg C m^{-2} m^{-1} and new production ranged 0-2000 mg C m^{-2} m^{-1}. There have been observation of nutrient fluxes and enhanced productivity in the northern Arabian Sea, southern peninsular Indian waters and off the river mouths in the Bay of Bengal. These features monitored in monthly scale nitrate, f-ratio, primary productivity and new production images precisely, covering the southwest and northeast monsoon seasons. Hence, more accurate estimation of these parameters and the validation would improve the technique in upcoming studies to have synoptic scale monitoring of marine productivity of the coastal and offshore northern Indian Ocean adjoining Indian sub-continent.

Keywords: Nitrogen, Phytoplankton, Primary productivity

Chlorophyll fluorescence images for monitoring Diatom bloom in the coastal waters at Kakinada

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A successful application of Fluorescence Line Height (FLH) images from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite which provides a strong argument for the use of FLH in monitoring surface phytoplankton blooms in coastal waters. The present study aims at studying the initiation / seeding of a phytoplankton bloom namely the Diatom bloom in the coastal waters off Kakinada, East coast of India using chlorophyll fluorescence. A Diatom bloom appeared on March 2012 in the coastal waters off Godavari, covering Kakinada and Yanam region in the East coast of India in the Bay of Bengal. MODIS satellite data along with

in-situ bio-optical measurements were used to detect the Diatom bloom. MODIS fluorescence line height (FLH in $Wm^{-2}\,\mu m^{-1}\,sr^{-1}$) data showed the highest correlation with near-concurrent *in-situ* chlorophyll concentration (r = 0.93). In contrast, the band-ratio chlorophyll product of MODIS showed more inconsistency with *in-situ* chlorophyll data due to the interference of other water constituents. High FLH value patches > 0.2 were confirmed to be located at the medium to high concentrations of diatom species of *Skeletonema Costatum* with a high concentration of *Fucoxanthin* as the biomarker for diatoms from the HPLC pigment analysis. The study was carried for a period of five years from 2007 to 2012, clearly showed a recurring pattern, which suggests seeding of the early Diatom bloom in the region of Kakinada, Bay of Bengal. Such seeding has been suggested before, but never observed. FLH images show the blooms more clearly than images of surface chlorophyll based on the ratios of water-leaving radiances in the blue and green spectral range (440-560 nm).

Keywords: MODIS-A, FLH, Diatom bloom

TS - 5/3
Microwave Applications

Urban land subsidence retrieval using PsInSAR based remote sensing technique

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In recent years, urban land subsidence has become one of the common hazards. It is also highly frequent due to the rapid urbanization and growing cities. Various factors such as population explosion, urban sprawl, and large infrastructure projects in cities, are resulting in over utilization of the aquifers for ground water extraction, thereby causing urban land subsidence. This induces a risk of cracks and damage in the urban infrastructures like urban roads, buildings, tunnels and also causes shrinking of the building foundation. Therefore, there is an immediate need for continuous urban land monitoring and subsidence estimation. In this study, the focus has been made on the development of an advanced approach for the urban monitoring and retrieving land deformation with a great precision. Synthetic Aperture Radar (SAR) technique has been utilized for the urban land subsidence monitoring. The time series InSAR techniques like PsInSAR utilizes the permanent scatterer candidate information to provide urban deformation monitoring at millimeter-scale accuracy. The improved PsInSAR technique is developed in this work, which utilized both ascending and descending pass datasets to retrieve multi-dimensional subsidence monitoring. The Sentinel-1 IW mode 58 ascending and 59 descending mode datasets from July 2014 to November 2017 are used in this study. The study area is selected as Lucknow, the capital of Uttar Pradesh state in India. The least square estimation is implemented for retrieving East-West component and vertical land subsidence velocity components from line of sight velocity (LOS) components. The retrieved land subsidence velocity per year was in the range of -40 mm/year to +30 mm/year. The retrieved results of the land subsidence velocity were validated by correlating it with the ground water level datasets.

Keywords: Disaster monitoring, Land subsidence, Microwave remote sensing, PsInSAR

Unsupervised detection of forest regions and clustering of their possible categories using multi-spectral and polarimetric SAR images

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Rapid advancement in the technology of remote sensing has facilitated the availability of land surface data from a wide arena of choices. A plethora of satellite missions offer different perspectives of various parts of globe in distinct scales and frequencies, which has made a horizon of options available for imagery sources. With surplus amounts of image data, mapping vegetation and monitoring forest resources are carried out by various considerations, which involve several processes and techniques. Different modes of image acquisition provide us with different understanding of the characteristics of land features. We propose to map different categories of forest region by a combination of passive multi-spectral imagery and active hybrid polarized SAR data. Multi-spectral imagery is used to identify general vegetation region, which includes forest, dense grassland, and cultivated agricultural fields with spectral slope based rules for selecting reference pixels that represent vegetation cover. Then we train a one-class SVM using these reference pixels to map vegetation cover. Also, SAR images are clustered into three scatter classes, namely, surface, volume, and dihedral, using Stokes parameters based m-δ decomposition. With the vegetation and volume scatter pixels, forest cover is mapped by intersection of their region, which forms a community level classification of forest region. Further, through m-δ polarimetric characteristics of SAR data, we segregate possible categories of specific forest vegetation clusters within the mapped forest region to obtain a species level classification. In identifying forest regions and their possible types or categories, we exploit the discernible spectral and scattering characteristics of remotely sensed images. The proposed method is automated by freeing the manual supervision in selecting seed pixels for

training any machine learning technique. Experiments are carried out by using Resourcesat-2 LISS-III multi-spectral images and RISAT hybrid polarized SAR images on study sites from Kharagpur, Bankura, and Kolkata regions in West Bengal, India.

Keywords: Vegetation mapping, Forest monitoring, RISAT-1 hybrid polarized SAR

Land cover mapping using multi-temporal dual-polarized Sentinel-1 SAR data: A case study in Ashoknagar district, Madhya Pradesh

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Land cover information generated from remotely sensed data is a vital variable for several studies including hydrology, food security and climate. This study investigated the potential of multi-temporal co-polarized (VV) and cross-polarized (VH) backscatter for land cover mapping over Ashok Nagar district, Madhya Pradesh, India. Multi-temporal data acquired on five different dates during Jan-Apr 2018 have been used for this study. The study area has wide range of land cover features such are built-up, bare, water body and agricultural crops i.e., wheat, mustard and lentil. Class separability analysis using transverse divergence (TD) method has been performed for multi-temporal VV and VH backscatter. Analysis observed that the classes such as water body and bare soil are less separable using VH backscatter with TD of 1.21 whereas these classes are well separable using VV backscatter with TD of 2. Moreover, it is also observed that the class separability has significantly increased by using both VV and VH backscatter. Furthermore, land cover maps have been generated using support vector machine for multi-temporal VV and VH backscatter as well as validated the same. As anticipated from class separability analysis, multi-temporal VV backscatter has shown higher overall accuracy and Kappa coefficient with 95.34% and 0.94 respectively compared to VH backscatter with 90.94% and 0.88 respectively. It is also observed that the classification accuracy is significantly improved to 97.65% by using both VV and VH backscatter. The results suggest that C-band multi-temporal both VV and VH backscatter gave better result over VV backscatter then followed by VH backscatter for land cover mapping.

Keywords: Land cover classification, Synthetic Aperture Radar, Sentinel-1, Multi-temporal, Support Vector Machine

Assessment of spatial variation of soil moisture during maize growth cycle using SAR observations

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Spatial information about soil moisture over agricultural crops is required for efficient irrigation, which in turn helps in saving water and increases crop yield. Soil moisture is also required in prediction of flooded and drought regions. However, periodical field measurement of soil moisture for large area is not a practical approach. The main objective of the study was to track the soil moisture variation all along the growth period of maize crop in a semi-arid region of India. There are only a few studies carried out on soil moisture variation considering entire growth period of crops, specifically maize. During the crop growing period soil moisture field investigation was

conducted in synchronization with satellite pass. Sentinel-1a Synthetic Aperture Radar (SAR) satellite, with interferometric wide (IW) swath dual polarized (VH and VV) data with 5.405 GHz frequency and central incidence angle of 23° with repeat period of 12 days, was used in this study. Overall, during growth period six scenes were acquired and processed using standard procedure by Sentinel Application Platform (SNAP) software. The areal extent of the maize crop considered is 0.8 Acres, sampled at 30 locations. An attempt was made to relate backscattered energy values extracted from SAR scenes with soil moisture, soil roughness and vegetation parameters. The developed relationship was validated using observed and top model soil moisture measurements. The output of this study will be helpful in formulating strategies for irrigation water management.

Keywords: SAR, Soil moisture, Sentinel 1A, Crop management

Generation and validation of Digital Elevation Model using RISAT-1 SAR interferometry

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A DEM portrays the topographic information in the form of an array of numbers denoting location of features in terms of their x and y coordinates and the elevation. SAR Interferometry is one of the techniques used for providing three-dimensional information about the Earth's surface, which converts the absolute interferometric phase data of complex radar signal into topographic information. RISAT-1, India's first C-band indigenous satellite, launched on April 26, 2012 carries a multi-mode SAR system acquiring data in Coarse Resolution ScanSAR Mode (CRS), Medium Resolution ScanSAR Mode (MRS), Fine Resolution Stripmap Mode-1 (FRS-1), and High-Resolution Mode (HRS). The prime objective of the study was to explore the potential of the RISAT-1 data for interferometric analysis. In this study, an attempt has been made to generate DEM for a part of Bharatpur region, Rajasthan using InSAR techniques. Analysis was carried out using FRS-1 data of 3 m resolution and 25 km swath corresponding to February 21, 2015 and March 18, 2015 having a temporal separation of 25 days. The accuracy assessment of the generated DEM was compared with the extracted reference elevation information over 53 points from the Cartosat-1 DEM. The accuracy of the generated DEM is 11.8 m standard deviation and mean error is 2.3 m.

Keywords: RISAT-1, FRS, InSAR, Validation, Standard deviation

Snow cover estimation of microwave SIR-C SAR dataset and its implications on statistical parameters

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The microwave remote sensing is exceedingly useful, as it provides synoptic observation of the Earth's surface or planetary bodies, regardless of day or night and the atmospheric conditions, propagating through ionosphere with minimum loss. This ability has been demonstrated under a variety of topographic and land cover conditions using both active and passive microwave instruments. One of the best active microwave remote sensing technology for imaging system is the Synthetic Aperture Radar (SAR) remote sensing. It has its own energy

source for illumination. It receives the radiation reflected from the target on the ground surface. It generates a very high resolution imagery of the Earth or planetary bodies. This study demonstrates the application of image classification techniques on L-Band SAR data for estimation of snow cover. The classification techniques are based on Entropy (H), Anisotropy (A) and Alpha (α) parameters. SAR data was classified using H-alpha, Wishart H-α and Wishart H-A-α classifiers. The results of these three classifiers were analyzed and there implications on statistical parameters were compared. The statistical parameters includes mean (m_a), median, standard deviation (s_a), coefficient of variance (CV) and equivalence number of looks (ENL). The overall process is applied on microwave L-band SIR-C SAR dataset of Cerro Laukaru, Chile. The dataset is useful for snow cover estimation, as the large area is covered by both dry and wet snow. L band dataset are considered better for snow cover estimation application. The overall processing was done by using PolSARPro Ver. 5.0 software. This software, developed by European Space Agency (ESA), provides open source toolbox for polarimetric SAR data processing and education. The results of Wishart H-Alpha classifier were found better compare to H-Alpha and Wishart H-A-Alpha classifiers. There are 5% to 7% difference in snow cover estimation between Wishart H-Alpha and Wishart H-A-Alpha classifiers for dry and wet snow. The statistical parameters of these results were compared and it was found that the performance of Wishart H-Alpha classification is better compared to the other classification techniques. The paper concludes that the snow cover estimation of microwave SAR dataset on the basis of statistical parameters analysis is a realistic and novel method.

Keywords: Microwave SAR, Dry snow, Wet snow, Statistical parameters

Land cover classification using L-band SAR data

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Acquisition of data by various space-borne SAR systems like Radarsat-2, ALOS-PALSAR, ERS-1 & ERS-2 and corresponding results drawn by analysis of data streams generated by these systems, have come a long way after facing considerable challenges in the microwave remote sensing community. The intent of this research is to explore the application of earth observation data obtained from fully polarimetric SAR images. In this paper, full polarimetric L-band ALOS-PALSAR SAR data of certain region in Japan, acquired on July 1, 2006, has been used for the study of land-use classification as mathematically, synthetization can be done of data of any combination of transmit and receive polarizations from full polarimetric data. The study focused towards classifying the study area into three major land cover classes, specifically water, urban, and vegetation. Unsupervised learning technique, K-Means clustering, was applied in order to see possible differences among SAR observable backscattering modes, namely single bounce, double bounce and volume scattering. On analysis of the result, it was found that the study area consisted of 54.21% water region, 13.43% urban area and 32.36% vegetative area. The overall accuracy achieved by using K-Means clustering is 89.67%, signifying that the proposed approach performs with acceptable accuracy for classification of fully polarized SAR images.

Keywords: L-band, ALOS PALSAR, Classification, K-Means clustering

Application of ground penetrating radar for mapping of subsurface utilities: A case study of road collapse

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In urban areas, finding and defining various subsurface utilities is a major challenge. However, this is extremely important because any defects or damage in the pipelines or cables can cause hurdles in various aspects. Traditional methods such as digging soil and roads are destructive and time-consuming. Moreover, this activity only provides single point source information. In contrary, Ground Penetrating Radar (GPR) is an extremely useful technique to image subsurface in non-destructive and faster way for extracting information about buried utilities such as electric and telephone cables, water and sewage pipes and other infrastructure in dense urban areas. GPR signatures have been analyzed for various surface and subsurface utilities, like concrete road, peat road, underground pipes made of different material, manholes and various cables, and brought out in the present paper. Moreover, the present article also emphasizes on a case study carried out in Ahmedabad city, Gujarat, India to examine disturbances in the soil and road layers associated with the road collapse due to damages in the underground pipes. The case study demonstrates the immense utility of the GPR instrument in identifying most of the underground utilities made of different materials and the deformation features in the road and soil layers.

Keywords: Ground Penetrating Radar (GPR), Subsurface features, Urban areas, Pipelines

TS - 6/1
Advancements in Data Processing

An approach for generation of multi temporal co-registered optical remote sensing images from Resourcesat-2/2A sensors

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Multi temporal remote sensing data availability is one of the crucial information source for remote sensing community to study the planet earth. The multi temporal data can be used for scientific studies only after sub-pixel level image registration of all the multi date acquisitions. Multi temporal co-registered remote sensing data is essential step for many real time applications that includes crop forecasting, forestry, inland water mapping, change detection and time series analysis. Multi temporal co-registered data is the first pre-processing step for generation of Analysis Ready Data (ARD) cube that allows immediate analysis with minimum number of user efforts. Image registration at sub-pixel level requires optimal geometric transformation of all datasets such that data stack is geometrically aligned over each other. The major step in image registration is feature detection to generate collection of tie points by removing outliers, match the feature points and finally estimate the transformation parameters. In this paper, we have developed an approach for multi temporal image registration that employs Scale Invariant Feature Transform (SIFT) technique along with applying segmented affine based transformation model at image segments to correct the data at geographic coordinate space to achieve sub-pixel level geometric accuracy. The key purpose of this work is to generate co-registered data stack for image analysis. Resourcesat-2/2A (RS-2/RS-2A) LISS-3 data from Indian Remote Sensing Satellite (IRS) is used for multi temporal co-registration task. The RS-2/2A LISS-3 data have spatial resolution of 24 m and combination of both RS-2 and RS-2A LISS-3 gives better temporal repetivity to cover the same region in less number of days. The technique developed is tested with LISS-3 data of same region acquired during time interval from 2012 to 2018.

Keywords: LISS-3, SIFT, ARD, Affine transform, Image registration, Multi temporal

Development of Oceansat-2 OCM data cube over Indian subcontinent

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The number of Earth Observation (EO) data users and developers are growing and a number of challenges need to be solved to fill the gap of acquisition and use of ever-increasing satellite data acquired by ISRO. The majority of EO data still remains underutilized mainly because of their complexity, increasing volume and lack of efficient processing capabilities. However, the full information potential of EO data can be utilized by directly providing Analysis-Ready-Data (ARD) to the user community. The ARD has all pre-applied corrections for radiometry and geometry. EO Data Cube (DC) is a new paradigm aiming to realize the full potential of satellite data by lowering the barriers caused by these Big data challenges and providing access to large spatio-temporal data in an user and developer friendly form thereby fulfilling both visualization and analysis needs. Systematic and regular provision of Oceansat-2 OCM Analysis Ready Data (ARD) will significantly reduce the post processing burden on ISRO's Oceansat series data users. Nevertheless, ARD are not commonly produced as a part of standard data processing chain of Oceansat-2 mission (operational at IMGEOS/NRSC, Hyderabad) and therefore getting uniform and consistent ARD remains a challenging task. This paper presents an approach to enable rapid data access and pre-processing to generate ARD using interoperable services chains. The approach has been tested and validated by generating OCM-2 ARD while building the Oceansat-2 OCM Data Cube.

Keywords: Data cube, Oceansat-2, Ocean Color Monitor (OCM), ARD, Pre-processing

Evaluation of Cartosat-2 series merged product for AMRUT mapping

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A very high-resolution satellite data is crucial for various applications in urban areas such as in urban planning, infrastructure development and utility planning. Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is a centrally sponsored scheme with the main objective of providing basic services to households and build amenities in cities. One of its sub-scheme focused on formulation of GIS based master plan. The geodatabase for preparation of master plan is to be prepared at 1:4000 scale. It proposed to use high-resolution satellite imagery (0.5 m spatial resolution) for this purpose. Cartosat series satellite, launched by Indian Space Research Organisation (ISRO) recently in June 2017, captures very high spatial resolution panchromatic and multispectral images. The main applications envisaged using this data is cartographic applications for infrastructure development and large-scale mapping of urban areas. The present study assessed the planimetric accuracy of the Cartosat 2 series data for 1:4000 scale mapping and subsequently evaluated the potential of imagery for AMRUT base layer and urban land use / land cover mapping. To achieve this objective, Cartosat-2 series images of Dehradun and Rishikesh cities were procured and a Differential Global Positioning System (DGPS) survey was conducted for the assessment of planimetric accuracy of the image. Mean Absolute Error, Root Mean Square Error (RMSE), Circular Error (CE) 90 and NIMA CE 90 were computed to check the planimetric accuracy. It was observed that RMSE of Dehradun image is 29.03 m and of Rishikesh is 28.15 m, which is very high, and more than the planimetric accuracy requirement of 1 m (0.25 mm of scale) at 1:4000 scale mapping. After registration of the image by using DGPS ground control points, RMSE error came down to less than 1 m in both the areas. It necessitates the use of high accuracy ground control points for geometric correction of the imagery before it could be utilized for AMRUT mapping. Further, the AMRUT layers were also extracted from the data and it was observed that urban features can be extracted with ease, except in unplanned high density areas and slums.

Keywords: Cartosat-2 series, Planimetric accuracy, AMRUT mapping

Development of a modified split-window algorithm for retrieving land surface temperature over India using the data from Imager sensor onboard INSAT-3D & 3DR

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Land surface temperature (LST) is one of the key parameters in the land surface processes and climate studies on global and regional scales. It is needed as an input to a variety of climatic, agricultural, ecological, hydrological and biogeochemical studies. Retrieval of LST from the Earth observation satellite is quite challenging since the land surface is laterally inhomogeneous and is composed of various materials with different geometries. Surface temperatures are derived from satellite based measurements in the thermal infrared (TIR) window channels using either empirical method or physical algorithm. Indian Earth observation satellites such as INSAT-2E, Kalpana-1, INSAT-3A, INSAT-3D and INSAT-3DR have TIR channels for surface temperature retrieval purpose. A Single Channel algorithm for retrieving LST from the thermal channel (10.5-12.5 μm) of Kalpana-1 (K1) VHRR sensor has already been developed over India using a radiative transfer model at SAC, ISRO. In order to exploit the presence of two TIR channels in the INSAT-3D/3DR Imager sensor for better estimation of LST, a study has been carried out to retrieve LST through a modified split-window algorithm. Objective of the present work is to develop an algorithm to retrieve LST using two TIR channels of

the Imager sensor onboard INSAT-3D/3DR satellites using a radiative transfer (RT) model over the continental region around India. Study also presents the comparison of INSAT-3D/3DR LST to the in-situ measurements as well as to contemporaneous LST products available from the MODIS and K1 satellites. A modified Split-Window (SW) method has been developed in this study, which is based on computing the split-window coefficients related to the Atmospheric Functions (AFs) simulated by a radiative transfer model- MODTRAN for varying view zenith angle sub-ranges (0-30 degree, 30-35 degree, 35-40 degree, 40-45 degree, 45-50 degree, 50-55 degree) and known land surface emissivity. The AFs were computed from the RT simulations based upon various atmospheric, surface and sensor inputs. Moreover, specific atmospheric profiles pertaining to tropical region from the SeeBor dataset were used in the model simulations. The AFs were then used in the computation of split-window coefficients for various view-angle sub-ranges for operational purposes. These sets of SW coefficients were utilized for LST generation over a vast region surrounding Indian landmass from the INSAT-3D and INSAT-3DR Imager data. In order to provide an estimation of the theoretical error on the estimated LST and also the contribution of the different terms to that error, a sensitivity analysis was performed based on the classical error theory using derivatives. A validation of INSAT-3D/3DR Imager-derived LST with (a) in-situ measurements and (b) the MODIS-LST products showed a fairly good performance (with R2 ranging from 0.80 to 0.98 with the maximum root mean square error of 2.7K). Using this proposed method, an operational LST product is being generated routinely on the MOSDAC site.

Keywords: Land Surface Temperature, Split-window algorithm, INSAT 3D/3DR

Evaluation and monitoring the data quality of Scatsat-1

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Accurate wind products generation, depends on the accuracy of sigma-0 estimation from the scatterometer data. Similar to Oceansat-2(OSCAT) Scatterometer, Scatsat-1 scatterometer works on dual pencil beam (Inner beam HH and Outer beam VV) approach at 13.5 GHz frequency by conically scanning the Earth surface and collecting the backscatter. The data is radar processed onboard and radiometrically corrected on ground. Scatsat-1sensor is designed with advanced techniques and modified, for providing better sigma-0 than OSCAT. This work discusses the quality aspects of Scatsat-1 scan mode (Level-1B) data. Level-1B is the basic data and it is very significant to evaluate and monitor the quality of this data as it forms the basic input to the Level-2A cell-grid sigma-0, which in turn results to wind formation. The level-1B product carries information about the radiometry (sigma-0, SNR), geometry (azimuth angle, incidence angle, geolocation), calibration constant and sigma-0 quality flag at both slice and footprint level. For evaluation of data quality these parameters are categorized into static and dynamic parameters based on the sensor scan mechanism and the wave target interaction. Doppler frequency, X-factor, range, incidence angle and azimuth angle are the static parameters which varies systematically over the orbit data and shows consistency and are well within the specification. Dynamic parameters like Sigma-0, SNR and Brightness Temperature (BT) are observed for the scan mode data acquired for each orbit/revolution. For calibration/validation, Sigma-0 and BT of well-known calibrated sites (viz. Amazon Rainforest, Antarctica) are monitored and results show that variation in Sigma-0 over the Amazon rainforest is less than 0.3 dB, as expected. Results from trend analysis ensures that parameters are behaving well within the specifications and assures stability and consistency of system parameters. Analysis suggests that the products from the Scatsat-1 can be taken for climate studies.

Keywords: Sigma-0, Brightness Temperature, Footprint, Fore, Aft

Concrete volume loss calculation using Terrestrial Laser Scanner (TLS)

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Buildings are one the major structures which have to be monitored appropriately with much importance. Any damage in the structure could prove fatal if it is not rectified within the time. Over the course duration of time, the structural material loses its strength. Concrete loss is a major concern as this may be a reason for the collapsing of the building. Thus the amount of concrete volume loss is an important factor to be monitored. In this research, Terrestrial Laser Scanner (TLS) (RIEGL VZ-400) has been used to serve this purpose. TLS is an instrument which provides 3D point cloud of the targeted surface rapidly with more accuracy. The actual 3D surface is compared with the simulated 3D idle surface (generated manually) and used to find out the exact concrete volume lost and this is compared with the ground truth observations for validation. These results are helpful to remodify the building depending on the actual amount of materials required to compensate and to avoid further loss in the volume of the concrete building. Using this technique, 2 to 4 % error was observed.

Keywords: Terrestrial Laser Scanner, 3D Point Cloud, Mesh, Concrete volume loss.

Simulating airborne LiDAR data using advanced computing techniques: Limulator 4.0

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Laser scanning, one of the widely used methods to generate precise 3D topographic data, has numerous applications such as urban planning, transportation planning, flood modeling, navigation and mapping. These applications may involve multiple algorithms. Sample LiDAR data are required to develop and test these algorithms. However, LiDAR data capturing process is complex, time-consuming and expensive. Therefore, its simulation has the potential to fill the need of frequent data availability at an insignificant cost. This paper is about the development of a simulator for airborne altimetric LiDAR data, i.e., Limulator 4.0, which is a newer version of an earlier development, i.e., Limulator 1.0. In this simulator, the data collection process is divided into three sections: 3D model component, laser component and LiDAR data generation. Limulator provides a user, the facility to input 3D models of different types (.obj format), which can be created using software like SketchUp, Autodesk, etc. In the laser component, scanner movement and flight trajectory simulations are done to compute the equations of lasers as per the user-defined details. These lasers are fired on the 3D model, created by a scanner mechanism, attached to an airborne platform, which computes its intersection with 3D mesh to generate LiDAR data. Octrees are used to increase the search speed of relevant triangles in the mesh. The effects of external and internal forces on flight movement and error simulation are also modeled using mathematical equations. This software is developed in C++, and its user-friendly GUI is developed using QT Creator 5.6. Limulator can be the ideal tool for understanding LiDAR data generation process with varying parameters.

Keywords: LiDAR, Simulator

High resolution DEM generation using airborne TMC data

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Chandrayaan-1, the Moon mission satellite, was launched in 2008. It had Terrain Mapping Camera (TMC) and Hyperspectral Imager (HySI), which captured triplet and multispectral images over Moon surface at a resolution of 5 m and 80 m respectively. The same TMC and HySI sensors were flown in an aircraft over Cuttack region. Along with Airborne Terrain Mapping Camera (ATMC) and Airborne Hyper Spectral Imager (AHySI), Airborne Nano Payload (ANano) was also operated. Performance of the sensors were assessed after carrying out various processing and analysis of the data. The airborne instruments were operated in different configurations and datasets were recorded. Data were captured on two dates with nadir and oblique views with flying height of 10.24 km. ATMC acquired triplet data i.e. same area was viewed by AFT(A), NADIR(N) and FORE(F) cameras with 0.56m resolution. This ATMC triplet data was analyzed for its attitude behavior before using the OAT parameters for image processing. Digital Elevation Model (DEM) is generated with various stereo imaging combination i.e. AF, FN, AN and triplet case (FAN). All combinations were analyzed to choose the best combination. DEM is generated with 10 m grid interval. It can be observed that FAN combination leads to better quality DEM. ATMC DEM is checked visually and geometric quality was compared with the available Cartosat-1 derived DEM. High resolution ATMC ortho-images were generated with best combination DEM and evaluated with respect to the available Cartosat-1 ortho-images. Data processing algorithms and software were developed to process full strip triplet data and generate full strip DEM and ortho-image. Strip ortho- image accuracy is found to be less than 10 m in location accuracy in planimetry and less than 6 m in internal distortion (in both X and Y) with respect to Cartosat-1 ortho-images.

Keywords: Terrain Mapping Camera (TMC), DEM, Stereostrip, Orthoimage

Estimation of building height of San Francisco city using different interpolation techniques on Lidar image

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The main objective of this study was to extract the height of a building by applying different interpolation techniques on the part of San Francisco city. The study further compared the results of different interpolation techniques to get the best fit. The study used the LAS dataset of the study area. Inverse distance weighted (IDW) and natural neighbor methods was used for interpolation of LAS data. Every input subset was interpolated in GIS environment by different algorithms. Digital terrain models are key tools in land analysis as they are directly employable in GIS systems and other specific applications. Triangulated Irregular Network (TIN) generation, from different kind of measurement techniques, is ruled by specific regulations. Interpolation techniques were used to compute a regular grid from a TIN. TIN interpolation produces a triangulated network that builds connections between each known elevation points. The elevation has been calculated at any location on the TIN using the geometry of the triangle faces. The normalized DSM (nDSM) is calculated using first pulse-derived DSM and the calculated DTM. Two separated classifications are applied on the nDSM. The final results of classifications are a set of nDSM pixels belonging to building roofs. In the nDSM, we categorize into the two categories: High and low. The pixels of High-rise class are the input to the last step of our building detection procedure which resulted with the height of the building and helped differentiating between the built-up and non-built- up phenomenon.

Keywords: TIN, LAS dataset, IDW, nDSM

Tree parameters retrieval and volume estimation using TLS data

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LiDAR remote sensing is one of the fast growing remote sensing technique. Terrestrial Laser Scanning (TLS) provides faster and precise information in the form of 3D point cloud. An approach to extract tree parameters like diameter at breast (dbh), height etc. followed by volume estimation has been discussed in this study. The area selected for the study is Barkot Forest Range in Dehradun district of Uttarakhand. The main tree species in this region are Shorea robusta (Sal), Tectona grandis (Teak), Mallotus philippensis (Indian Red Wood) and Terminalia alata (Saj). Four laser scans were collected using Riegl vz- 400 laser scanner. Ground measurements were also recorded which included tree height and dbh. These field parameters when compared with parameters retrieved through TLS showed excellent correlation. The Forest Survey of India has published site and species specific volumetric equations, where dbh is an input. However, the present study took into account three parameters: dbh, stem length and form factor to estimate the same. Excellent correlation was achieved between the two approaches for Sal and Teak. However, for Indian Red Wood, one of the estimations using FSI equation showed negative value but the present approach produced no such anomalous outcome. The reason may be attributed to the fact that FSI based volumetric equation is valid only for Assam, due to unavailability of Barkot specific equation. Finally, empirical equation for volume estimation was developed for Terminalia alata (Saj) as there is no FSI equation available for this particular species. The study also highlights an inverse relationship between Form Factor and dbh. This new approach may prove to be indispensable for volume estimation of those tree species whose volume equations are not available.

Keywords: TLS, Tree parameters, Tree volume, Form factor, Stem length

Topographic survey of open-pit mine using rotary-wing Unmanned Aerial Vehicle

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Unmanned Aerial Vehicles (UAVs), popularly known as drones, have gained special attention by remote sensing scientists in recent years because of the systematic acquisition of geo-tagged, very high resolution (mm-scale) aerial images at comparatively low cost and time with large surface coverage (hundreds of meters to kilometers). It facilitates more accurate, human-risk free and cheaper aerial surveys for natural resource management, damage assessments, mining, etc. In the present study, an industrial grade Rotary-wing Unmanned Aerial Vehicle (UAV) was used for topographical survey of a medium scale Open-Pit Mine at Dachepalli Mandal, Guntur district of Andhra Pradesh, India. A total 869 geo-tagged images were obtained after performing a dual mission operation for 2.30 hrs. During processing of the data, a 100 % calibration of the images was achieved with BBA ratio of 3D points to 2D points more than 1:3. A total number of 557 million dense cloud points were extracted with X, Y; Z coordinates from the aerial images after processing and correction. A detailed comparison of X, Y, Z coordinates with Ground Control Points (GCPs) measured using DGPS and GAGAN enabled Bluetooth dongle and those determined by UAV Photogrammetry revealed that the Root Mean Square (RMS) errors were around 5 cm. The process of data collection using the same UAV was repeated after three month time for monitoring the changes and estimating the difference in volume of the materials excavated. More than 95% degree of accuracy was achieved in terms of topographical survey like pit bench height, contouring, leases area demarcation, etc. Therefore it is validated that UAV remote sensing techniques can effectively be used for open-pit mines as a standard technology and has potential to supplement the present topographical survey techniques.

Keywords: UAV, Drone, BBA, Dense Points Cloud, DSM, RMS

Optimisation of total number of scanning stations for Terrestrial Laser Scanner (TLS) Survey

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Surveying techniques have always played a primary role in engineering surveying. Recent advances and development in new instruments and methods of data capturing and processing have introduced the chance to increase the accuracy and the amount of information obtained. This research is focused to optimize the number of scanning positions for Terrestrial Laser Scanner (TLS) data acquisition. More scanning positions in Laser Scanning increases the size of the data collected by the instrument and covers all the portions of the target with increasing the point density. In this work, the number of TLS scanning stations were optimized depending on the 3D Shape file of the target, terrain features, Line of Sight Visibility and the scanning parameters of the instrument. This work reduces the bulkiness of the TLS data by reducing the scans and repetition of the overlapping regions between the scans are reduced.

Keywords: Terrestrial Laser Scanner, Optimization, Surveying

Spatial enhancement of SWIR band from Resourcesat-2A by preserving spectral details for accurate mapping of water bodies

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Monitoring of inland water bodies using multi spectral images is an important application of remote sensing. Resourcesat-2A (RS-2A) launched on December 7, 2016 provides data at multi-tier imaging scheme to map land surface water bodies and delineating their spatial distribution to understand the hydrological processes and managing water resources. Short Wave Infrared (SWIR) band from RS-2A LISS-3 sensor is available at best observed spatial resolution of 24 m and wavelength range of 1.55 µm-1.70 µm plays a vital role for spectral water index determination especially for Modified Normalized Difference Water Index (MNDWI), which is calculated from green and SWIR bands. The water index accuracy can be enhanced further by improving the spatial resolution of SWIR band from RS-2A platform. In this paper, SWIR band spatial enhancement techniques are described in detail and is divided mainly in two major processing stages. In the first stage, SWIR band spatial resolution is improved directly by combination of Laplacian operator to highlight the finer details with smooth gradient to enhance the prominent edges and downscale the image to 12 m with Lanczos based resampling kernel without affecting much the dynamic range of the gray level of SWIR band. In the second stage, spatial enhanced SWIR band of LISS-3 is used for overlap region extraction with same time acquisition data of LISS-4 having spatial resolution of 5 m and perform weighted average using Brovey based image fusion technique to generate SWIR band of RS-2A at spatial resolution of 5 m by preserving the spectral information. The processing workflow developed can increase SWIR band spatial resolution from 24 m to 5 m and improve land surface water bodies mapping performance.

Keywords: SWIR, MNDWI, Resourcesat-2A, Spatial enhancement, Image fusion

Solar power nowcasting using diurnal observations from Indian geostationary meteorological satellite: A case study over Ahmedabad

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Solar irradiance forecasting at 15 minutes to one-hour time scale is essential to forecast solar power generation in addition to inputs on air temperature and configuration of solar power plant. This is important for the integration of photovoltaic plants into an electrical grid and helps the grid operators to optimize their electricity production for grid balancing and to reduce additional costs or penalties by preparing an appropriate strategy. Half-hourly Global Horizontal Solar Irradiance (GHI) is an operational product at 4 km spatial resolution from two Indian Geostationary Satellites, INSAT 3D and 3DR. The combination provides an opportunity to construct time series solar irradiance at 15 minutes time interval. The present study was conducted over 40km×40km region in Ahmedabad city, where solar panels are installed on the rooftops within 1.5 km^2 area and the corresponding 15 minutes electrical power data are used for validation. A solar power model based on solar irradiance and rated efficiency based on power temperature coefficient and solar panel configuration is used in present study. Artificial Neural Network (ANN) approach using non-parametric Gaussian Process Regression (GPR) technique was used to forecast half-hourly solar irradiance from clearness / cloudiness index from INSAT 3D observations followed by solar power forecast from the efficiency-based model using hourly high-resolution (5 km spatial resolution) air temperature forecasts interpolated to generate half-hourly air temperature forecast. GPR model has been trained using historical time series data over past three years (2014 to 2015) for summer, south-west monsoon and winter months. The trained coefficients have been further used to forecast solar irradiance and power at half-hourly and hourly scale. The ANN-based GPR model irradiance forecast was compared with persistence model forecast. GPR model was found to show lesser error during morning (1 - 8%) and evening (up to 17%) hours for both clear and cloudy skies than persistence model forecast for 2016. However, both models showed substantially less and similar magnitude of error (within 3%) at noon hours. At any given time in a day, GPR model performance is better than persistence model. Though intra-day solar power showed wide difference between satellite-driven and recorded power, the shape diurnal transition of power from both the sources matched quite well. The difference in magnitude is due to difference in representative footprint, inaccuracies in weather forecast temperature, dust deposition on solar panel.

Keywords: Clearness index, Indian Geostationary Satellite, Solar PV, Power, Irradiance

Inventory of ridge-valley watershed treatment using Unmanned Aerial Systems

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Lightweight, portable Unmanned Aerial Vehicles (UAVs) or drones have been gaining enormous popularity for many applications including watershed treatment inventory. In Geospatial context, there is a growing need for finer scale responsive data, which cannot be delivered from satellites or aircraft for smaller areas in a cost-effective way. UAVs can be used efficiently to collect highly detailed geospatial information. Compared to satellite-based or traditional manned photogrammetric surveys, UAV system provides high operational flexibility in terms of costs, place, platforms, time and repeatability. High spatial and temporal resolution imagery acquired from Unmanned Aerial Systems (UAS) provides new opportunities for inventory of treatment works in watersheds in large scales. The possible results derived from UAS are exceptionally useful for planning, monitoring and assessment of Ridge-Valley type of watershed. The present study an attempt is made to investigate the use of UAV remote sensing techniques to evaluate the watershed development works in

Guruvajipeta watershed having an extent of 2.30 km^2 in Prakasam district of Andhra Pradesh. The UAV images acquired with 5 cm Ground Sample Distance (GSD) on an average were ortho-mosaicked and the DSM was derived. The details of watershed treatment works such as check dams, percolation tanks, loose boulder structures, farm ponds, greening of hillocks, horticulture plantation, staggered trenches, etc., which are executed in the watershed are extracted from UAV derived ortho-images. Accurate assessment derived from this technological advancement allows for more effective monitoring and management, and provides synoptic view of the watershed at finer scale.

Keywords: Ridge valley watershed, Unmanned Aerial Vehicle, Drone, Watershed Treatment

3D modelling from airborne LIDAR point cloud data

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LiDAR (Light Detection and Ranging) is a surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Airborne LiDAR scanners are becoming one of the most efficient methods to record geographical information in three dimensions. The 3D point cloud data collected by airborne LiDAR scanners consists of densely spaced points representing XYZ dimensions of the objects that are being surveyed. Euclidean segmentation has been applied to the input point cloud dataset to divide it into different clusters. Then the equivalent 3D mesh representation of the segmented clusters was computed using greedy projection triangulation technique. Finally, from the 3D meshes obtained in the previous step, 3D models have been derived using poison surface reconstruction method. The input point cloud dataset of Vaihingen area, Germany was used in this study. This work aims at developing 3D model from airborne LiDAR point cloud data. 3D mesh structure corresponding to the building structures in the input point cloud data have been successfully created. 3D surface reconstruction from the obtained meshes is a future work in this research.

Keywords: Point cloud, LIDAR, 3D Modelling, Segmentation

TS - 6/2
Cryosphere

The melting cryosphere in the north-western Himalaya, India: Past, present and future scenario

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There is lack of credible knowledge about the melting Himalayan cryosphere as is evident from the contradictory reports about the status of the glaciers in the region. Cryosphere of the Jammu and Kashmir Himalaya has undergone significant changes since the last several decades and the same has to be understood in light of the multiple driving factors, namely topography, climate, and Anthropocene. The use of satellite images, DEM and altimetry data, supported by detailed and extensive field-based glaciological, Ground Penetrating Radar (GPR) and other studies to assess the changes in glacier geometry, dynamics, debris cover, mass balance, thickness etc., shows that the melting cryosphere across various mountain ranges in the J&K Himalaya shows varied responses. It was observed that the glaciers in the Karakorum are more or less stable primarily due to the extreme cold winters and low average winter temperatures (-18°C). The glaciers in the other ranges across the northwestern Himalaya with varying topographic and climatic setting are behaving differently. For example, in the Pir Panjal range almost all the glaciers have vanished during the last 6-7 decades due to various reasons including the increasing winter temperatures. The glaciers in the Kashmir valley showed recession, which is one of the highest reported for the Himalaya. The investigation revealed the highest glacier recession of ~-8% in the Greater Himalaya range during the observation period while as the least recession (~1.5%) was observed in the Karakoram range. Moderate recession is observed in Ladakh (5.65%) and Zanaskar (5.42%) mountain ranges. Similar trend observed in other parameters including ELA, volume and thickness. From the satellite and field-based glaciological observations, the glaciers in the Kashmir valley showed an average reduction of ~1 m in ice thickness while the Karakoram glaciers showed the least reduction in ice thickness. A detailed study of the Durung Drung (clean glacier) and Pansila (debris-covered glacier) in the Zanaskar region showed the impact of debris thickness on the glacier melting with the former melting 2.5 m/year and the latter melting 1.35 m/year due to their different debris cover extent and debris thickness. Climate change is loud and clear in the region and the higher rates of glacier recession are due to the significant increase in the observed winter temperatures. In the region, precipitation is occurring more in form of rain than as snow due to the warming in winter. Compared to the present observations, the mass balance in the Kashmir basin is projected to decrease by more than four times by the end of the century. It is predicted that 47% and 67% of the glaciers cover in the Kashmir basin may disappear by the end of century under RCP4.5 and RCP8.5 scenarios respectively. Furthermore, the concentration of black carbon in the valley is highest compared to the other Himalayan stations (5.9 mg m^{-2}). All these factors are responsible for the melting of Cryosphere in the J&K Himalaya. The stream flows have significantly declined in the river basins particularly since 1990s and it is likely that the tipping point of the maximum glacial-melt was reached in mid 1990s. The depleting cryosphere and stream flows have potential to adversely impact the food, water and energy security in the region and downstream.

Keywords: Himalayan Cryosphere, Climate change, Glaciology

Operational snow cover product using INSAT-3D data from geostationary platform

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Snow cover is a crucial parameter in hydrological and climatological applications at regional and global scale. Remote sensing has provided operational product on snow cover areal extent at 5 and 10 days using Resourcesat satellite sensor AWiFS from polar platform since 2004. INSAT-3D, a meteorological geostationary satellite

launched in July 2013, carries Imager Visible, SWIR and Thermal channels. NDSI alone is not able to mask all clouds and mixes with snow in few cases. INSAT-3D derived top-of-atmosphere reflectance were estimated for visible and SWIR channels (0530_L1C_ASIA_MER) and used in developing the algorithm along with additional criterion of brightness temperature from TIR-1, geography and topography. Daily snow cover product at coarse resolution was operationally generated using INSAT-3D satellite data and made available on IMD through IMDPS routinely. Validation of snow cover mapping algorithm was carried out using spectroradiometer based ground observations, visually identification on ground using False Color Composite image, manual mapping and with available high resolution product such as from AWiFS. However, as INSAT-3D is a coarse resolution sensor, fractional snow cover product will also be made available to user in future derived from INSAT-3D/3DR.

Keyword: Snow cover, INSAT-3D, AWiFS

An automated feature tracking based algorithm for estimation of ice flow and glacier surface velocity using Resourcesat-2A data for Himalayan terrain

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Determination of ice flow and glacier surface velocity plays a pivotal role in the study of glacial geography, its sensitivity to climate change and its impact on water cycle of the area. This study becomes of utmost importance in case of Himalayan Cryosphere, which is a source of water to many regions in Asia. In this paper ortho-rectified image pair data of Resourcesat-2A are used, which are further processed using a land and cloud based mask to enhance the visibility of the requisite area. This in turn is used as a input to the first level Principal Component Analysis (PCA). Further a common area raster is extracted and then moving chip based sub-pixel correlation is performed to find the ice shift. Post processing algorithm are exploited to remove spurious matches and false positives. In the analysis, we observe considerable difference in velocities during different season. Average glacier surface velocities ranging from 30 m/year to 45 m/year were observed. This study shows that optical image based correlation is suitable and efficient for measurement of ice flow in the fast moving glaciers of the Himalayas.

Keywords: Ice flow, Glacier surface velocity, Cryosphere, Sub-pixel correlation, Resourcesat

Retrieval of glacier ice velocity and thickness: A case study in Chandra basin, NW Himalayas

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Glacier velocity and ice thickness are important parameters in understanding the glacier dynamics of the Himalayas. Estimation of these parameters using conventional field based techniques is quite difficult and sparse due to rugged terrain and harsh climatic conditions. In this study an attempt has been made to estimate glacier surface ice velocity using optical remote sensing images utilizing Co-registration of Optically Sensed Images and Correlation (COSI-Corr) technique. Surface displacements of glaciers in Chandra sub-basin, North West (NW) Himalayas was retrieved using ASTER time series data acquired during 2007-2009. Horizontal displacements of two major glaciers in the study area, namely Bara Shigri and Chhota Shigri, were observed to vary between 20 m and 70 m and, these displacements were converted to glacier surface velocities. It is observed

that the upper glacier zones have shown higher velocities of the order of ~77 to 90 m/year, which reduced to ~32 to 50 m/year towards the lower part of the ablation zone. Glacier ice velocity was utilized to derive ice thickness based on laminar ice flow model. Glacier valleys of Chandra Basin has ice thickness variations of ~50-400 m from the snout to the accumulation zone. Sensitivity analysis suggests that slope of the glacier surface has significant influence on the accuracy of ice thickness retrieval.

Keyword: Glacier, Ice velocity, Ice thickness, ASTER, Chandra basin

Satellite based characterization of spatio-temporal trends in the surface ice velocities of the glaciers in central Himalaya

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Glaciers move down slope under the influence of gravity and their movement is influenced by factors such as topography and climate. Mass input in the accumulation zone of the glacier is transported to the ablation zone by deformation and sliding, relating glacier velocity directly to the glacier mass balance. Moreover, the Surface Ice Velocity (SIV) also regulates the debris-transfer mechanism of glaciers and development of supraglacial lakes. Thus, systematic monitoring of SIV is important in understanding the overall glacier dynamics. Considering the inaccessible nature of the mountain glaciers, remote sensing has obvious advantage in this regard. Current study attempts at deducing the SIV (for 1990, 2000 and 2015) of the 18 selected central Himalayan (CH) glaciers by applying the Co-registration of Optically Sensed Images and Correlation (COSI-Corr) algorithm on the Landsat data. Results show that almost all the selected glaciers experienced a substantial slowdown during study period (1990-2015). The average SIV of all glaciers was 22.63 ±5.81 m/year in 1990, which decreased (by 23%) to 17.32 ±3.06 m/year in 2000 and further declined (by 35%) to 11.10 ±1.65 m/year in 2015. Considering the total study period, the average SIV has substantially decreased by ~50%. Though a decline in average SIV has been observed, but rates of slowdown are considerably heterogeneous for the studied glaciers. This may be because of the differences in geometry, slope gradient, rate of melting and debris cover characteristics of glaciers which requires a thorough investigation. This progressive slowdown of the glaciers suggests negative mass balance conditions in the area which is likely to increase the debris accumulation on the CH glaciers, increasing the probability and pace of glacial lake development.

Keywords: Glacier surface ice velocity, Remote sensing, Glacier slow-down, Central Himalaya

Spatial and temporal variability of Accumulation Area Ratio (AAR) of glaciers in Nubra, Chandra and Bhagirathi sub-basins in the Himalayan region (2008-2013)

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Accumulation Area Ratio (AAR) is the ratio of accumulation area to total area of respective glacier. AAR can be used to determine the mass balance of glaciers at a reconnaissance level without going to field. In view of the above, a study was taken up to compare the AAR of glaciers in three sub- basins viz. Nubra, Chandra and Bhagirathi. The objective of this study is to understand the spatial and temporal variability of AAR of glaciers

three sub-basins in the Himalayan region. Identification of snow line at the end of ablation season requires multi-temporal satellite data with high frequency. AWiFS is a highly useful sensor for this work. Reflectance of bright surface like snow is not saturated over snow due to high radiometry of AWiFS data. In this study, snow line at the end of ablation period was delineated using AWiFS data. AAR was estimated for more than 333 glaciers in identified sub-basins such as Nubra (a part of Indus Basin), Chandra (a part of Chenab Basin) and Bhagirathi (a part of Ganga Basin). These sub-basins are located in different climatic zones. Eighty glaciers from Nubra basin covering 419 km^2, 106 glaciers in Chandra basin covering 265 km^2 and 141 glaciers in Bhagirathi basin covering 715 km^2 were used in this analysis. The AAR was generated from year 2008 to 2013. The date of end of ablation season also varies on spatial and temporal scale. The maximum, minimum, mean and standard deviation of AAR for each year was calculated for each basin. These statistics indicated more variability in the Bhagirathi sub-basin than in other two sub-basins. The mean AAR of the glaciers of the Chandra and Nubra basins indicate the positive mass balance whereas the glaciers of the Bhagirathi sub-basin indicated negative mass balance in all years except in year 2010-2012. The variance has been noted minimum in Nubra sub-basin in all years; however, no significant trend of increase or decrease in AAR of glaciers of Chandra and Nubra sub-basins has been noted.

Keywords: Accumulation Area Ratio (AAR), Mass balance, Snow line, AWiFS, Resourcesat

Glacier ice surface velocity using interferometry

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Movement of ice within a glacier system is central to all the processes which are governed by glacier-climate interactions. It is embedded in the definition itself of glaciers. This movement of ice varies in time and space and differs from one glacier to another. The primary reasons of variability are the total mass of the glacier, slope of glacier bed, melt water system and conditions of stress and strain developed within a glacier. So ice velocity becomes an obvious parameter, monitoring of which can help in understanding of glacier dynamics and understanding the effect of climate forcing on glaciers. This parameter is also used to retrieve ice thickness of glaciers. Ice velocity can be measured on the ground using GPS measurements made on the markers or stakes drilled into ice. However, the ground methods are very difficult to be employed in Himalayan terrain. It is not feasible to measure ice velocity of several thousands of glaciers in a short span of time. Therefore, the need of knowing velocity of ice has driven development of newer techniques utilizing images acquired by orbiting satellites. Two major approaches retrieving velocity from images have evolved over the years; first the techniques based on image correlations mainly utilizing optical images and other is based on SAR interferometry. Both the approaches have their own advantages and limitations related to imaging radiometry and geometry. SAR images are known to be more useful even in cloud cover conditions. SAR signals can also penetrate through dry snow, so SAR interferometric pairs can be utilized to find velocity even in winters when glaciers covered with dry snow. Most of the work carried out so far in determining velocity in Himalayan or in other mountain ranges are based on image correlation techniques utilizing optical and SAR images. In SAR images it is called Intensity tracking. SAR Interferometry is much less explored area of finding velocity.

We present here a case study utilizing SAR data and interferometric technique for retrieving ice velocity of Samudra Tapu and Bara Shigri glaciers of Chandra basin in Himachal Pradesh. Two Sentinel images with interval of 6 days of ablation period were used and processed for interferometry using GMTSAR software. Probably this is the best pair for getting coherence in SAR image pairs. Moreover, the changes in surface characteristics in an interval of 6 days are normally so less that we can get good coherence in interferometric pairs, a primary condition for good results. Since the image pairs are of ablation time, the time of imaging for finding surface velocity is very optimum. Normally various research groups find the velocity which is average

of one or two years. The results show that a velocity varies from 3.23 cm/day to -5.06 cm/day for Bara Shigri and for 3.9 cm/day to -3.56 cm/day Samudra Tapu glacier respectively. Similar results in two glaciers indicate the coherence of results in two nearby glaciers. The Line of Sight (LOS) surface velocity component is positive when the surface movement is along the LOS of satellite direction and exhibits negative value when surface movement is towards satellite. One of the reason for negative values is amount of debris cover over ice. The velocity has differential movement between ice and overlying debris cover. These results also match with the order of velocity found in other glaciers. Ice velocity of glaciers in different basins can't be compared as the effect of climatic forcing vary from one basin to other. The results suggest more and more utilization of this approach for finding ice velocity of glaciers and comparative studies on the variability of this parameter in time and space. This study also demands launching of SAR sensors with interferometric capability.

Keywords: Interferometry, Ice velocity, Phase, SAR

Estimation of glacier thinning using Cartosat-1 stereo data of 2005 and 2015

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Mapping and monitoring of glaciers and ice sheets have acquired a very crucial role in recent years due to their high sensitivity to climate variations prevailing in Earth's environment and its implications on water resource availability, sea level rise and disasters of cryospheric origin. The paper describes a case study of finding change in thickness of a Himalayan glacier using Digital Elevation Model (DEM) extracted from Cartosat-1 stereo data of ablation season of 2005 and 2015. It is the first study of its kind in which data from the same stereo sensor, Cartosat-1 here, has been used for two different time periods. SAPHIRE-C software developed at Space Applications Centre, Ahmedabad for processing of stereo data from Cartosat-1 sensors has been used. GCPs were taken from Google Earth images giving high accuracy of models. Fifteen areas or polygons on various geomorphological and sloping terrains of the DEM under consideration were selected to evaluate the difference image of DEMs on the assumed stable areas. In an ideal case, the difference of DEMs should be zero on stable areas provided other parameters of stereo data remain the same. A statistical relationship of mean slope and mean DEM difference was established. Based on this relationship, DEM difference on glaciers was estimated. This mean difference was compared with actual difference of elevations on the glacier. The mean difference in estimated value and observed value in elevation differences was taken as a change in thickness of glacier. The interval of 10 years is good enough to note changes. Glacier thinning in ablation zones of the order of 0.922 m was observed. The uncertainty in the study is ~15% of the estimated number of thinning which related to slope-elevation bias relationship.

Keywords: Cartosat-1, Stereo, DEM difference

Surface ice dynamics of Siachen glacier, Central Karakoram during 2008-2016 derived using image correlation of Landsat imagery

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The glaciers in the Karakoram are among the largest outside the polar region. The 72 km long Siachen glacier is the longest in Karakoram and the second longest outside the polar region. In this study, image correlation using optical data of LANDSAT 5 and 8 is used to determine the surface velocity of Siachen glacier in central

Karakoram for the period of 2008-2016. The velocity fluctuations along a profile in the ablation region of glacier is observed for the period 2008-2016. The velocity varies from 50 m/year near the glacier's terminus to 150 m/year in the lower ablation region of the glacier about 25 km from the terminus. During the 2011-2016 period, the velocity in the lower ablation region (2-15 km from terminus) increases about 20-40 m/year. The ice thickness of the glacier is calculated using surface velocity, slope and a simple ice flow law involving laminar flow equations. The slope along the profile is estimated using SRTM Digital Elevation Model (30 m). Ice thickness varies from 400 m (4 km from terminus) to 750 m (25 km from terminus) The bedrock profile is also generated using the ice thickness derived. The surface strain rate is derived from the surface velocity to observe the area having positive and negative strain.

Keywords: Ice velocity, Image correlation, Ice thickness, Siachen glacier, Landsat

Optimizing ship route in Antarctic Sea-ice region by multi-objective evolutionary algorithm

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Safe, fuel efficient, time efficient, economical and eco-friendly ship operation in sea ice is need of the hour for successful expeditions, both commercial and scientific. Managing all the goals simultaneously is challenging and leads to a non-linear, multi-objective, constrained problem with conflicting objectives in an uncertain environment. Heuristic approach of optimization using evolutionary algorithms is most appropriate way to deal with such problems. In this paper sea-ice region covering Indian research stations, namely Bharti and Maitri at Antarctic, is partitioned into grids to analyze level ice concentration, level ice thickness, ridge density, ridge thickness and wave parameters for each partition. These parameters are modeled to get resistance and hence actual power required to overcome the resistance in each partition is determined. Finally, fuel consumption optimized for a sea-ice route problem with safety and time constraints by identifying Pareto-optimum routes using multi-objective genetic algorithm in order to make decision-making process more reliable and accurate for safe and efficient Indian scientific expeditions to Antarctic, was determined.

Keywords: Sea ice, Route optimization, Pareto-optimum, Genetic algorithm

Assessment of 1-day and 3-days Scatsat-1 L4 products for studying different sea-ice zones in the Antarctic

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The Antarctic is the high latitudinal region around South Pole, which influences Earth's global climate immensely. The region is non-favorable for human activities and is inaccessible due to the extreme weather conditions. Satellite remote sensing techniques are therefore employed to better explore the region. Scatterometry is one of such remote sensing techniques. Primarily, scatterometer is used to retrieve winds over the ocean surface. Using geophysical model function, radar cross section (Sigma-0) measured wind indirectly. Scatterometer has pervasive contribution in the field of polar studies. It is useful in sea ice mapping, snow cover, iceberg detection and supports navigation. In this paper, we have used Scatsat-1, a Ku-band Indian scatterometer super resolution Level-4 data. These products are available as Sigma-0 (σ^0), Gamma-0 (γ^0) and Brightness Temperature (Tb) in Horizontal (H) and Vertical (V) polarizations. The temporal composite data products of

two durations i.e. 24-hours (daily product) and 72-hours (3-days product) are also provided. We have analyzed three basic zones (inner core, intermediate and outer or marginal) of the Antarctic region for different polarization data for each product. These zones are described as Marginal Ice Zone Top (MIZ_T), Marginal Ice Zone Bottom (MIZ_B), Intermediate Ice Zone Top (IIZ_T), Intermediate Ice Zone Bottom (IIZ_B) and Core Antarctic (ANT). Statistical analysis of various parameters (σ^0, γ^0 and Tb) derived from daily and 3-days products for each of the zonal pockets (MIZ_T, MIZ_B, IIZ_T, IIZ_B, and ANT) has been carried out. It was found that for the marginal sea ice zones, where temporal dynamics plays an important role, 24-h data products perform better than 72-h data products. For the core sea ice region, both the data products give almost similar results.

Keywords: Sigma-0, MOSDAC, Scatsat, Brightness temperature, Sea-ice, Scatterometry

A semi-automatic tool for generating sea ice maps for Bharati and Maitri from Scatsat-1 data

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Antarctic continent is a laboratory for climate change studies. A large number of countries established their research stations in this virgin continent. These research stations mainly depend on ship navigation for meeting their day to day needs for food, fuel and various equipment for running the research station in the harsh environs. Antarctic environments are hostile to ship navigation due to various reasons such as rough sea, high wind conditions, blizzards, white outs and the formation of thick sea ice. The sea ice, oscillates between approximately 4 million km^2 to 20 million km^2 between the summer and winter, pose a real threat to the ship navigation. The Ivan Papanin, engaged for Indian Scientific Expeditions for the past several years, doesn't have ice cutter. Hence require prior information of the sea ice extent and thickness for the easy passage. Remote sensing platforms provide various information on ice concentration/thickness, polynya and leads for ship navigation in the form of a map. Scientific expedition as well as commercial expeditions require this information. The present study aims at utilizing Scatsat-1 data for generating the sea ice maps in a semi-automatic way. The Scatsat-1 gamma0 HH (horizontal), vertical (VV) and Polarization ratio were used for generation of the sea ice maps with a broad categories of low concentration, medium concentration and high concentration areas. It also provides information on ice deformation and formation of polynyas. A tool is developed in MATLAB environment which fetches the back scatter data (Gamma H and Gamma V), converts into logarithmic scale, generate the ratio, make a layer stack, enhances linearly, mask the land area and generate the sea ice map specific to the area of interest. The tool is aimed towards automatic sea ice advisory for Indian Scientific expedition to Antarctica with deliverables in the form of Sea Ice Maps. MOSDAC daily ascending/descending composite product of Scatsat-1 data from Oct 2016 were used to generate the maps. Three-day composite will not give an exact status of sea ice conditions required for ship navigation. The module will be made available in VEDAS. After the geo-referenced tiff file is generated, it is automatically ingested in an online database and made available to users in the form of interactive web based map. The interactive map will enable the users to view maps for the desired date, view temporal animation and perform temporal pixel drill operation on a particular location. The users will also be able to download the temporal profile in Comma Separated Values (CSV) format. The map in the form of JPG format also can be accessed by the voyage leader / ship captain to navigate along the least resistant path.

Keywords: MOSDAC, Scatsat, VEDAS, Antarctica

Characterization of snow properties over the Central Himalayan region

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Characterization of snow properties such as snow cover and snow grain size using advanced satellite datasets is important to understand the Himalayan hydrological issues due to inaccessible terrains. The remote sensing datasets are most promising for monitoring and retrieving the snow properties in micro to macro level. In this study MODIS MOD10A2 snow cover composite products are used to monitor annual variation of Snow Cover Area (SCA) in the Bhagirathi basin of central Himalayan region. Total 345 scenes are used for daily snow cover mapping using interpolation technique for the period 2010-17. Snow grain size are also estimated by the Spectral Angle Mapper (SAM) technique and validated with the grain index method. The spectra of snow cover features are generated from the Hyperion images and compared with the spectra of snow mixed objects using SAM technique. A finest match was observed between the class-wise (i.e. fine, medium and coarse) grain-size classes using SAM and grain index methods. The overall accuracy was 84 % among different snow grain size classes using SAM and grain index method. The present study also reveals the capacity of Hyperion data for snow grain size mapping over the Himalayan region. The estimated parameters will be used as input for climatology, hydrology and mountain hazard mapping over Himalayan region.

Keywords: Snow cover, Snow grain size, MODIS, Hyperion, Himalaya

Investigations on glacier fluctuations using Indian remote sensing and Landsat data of Naradu Glacier, Western Himalaya

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Himalayan glaciers are an important source of fresh water to the Himalayan region as well as people living in the adjoining plains and also known as the major indicators of changing climate. The present study gives detailed observations based on the space data of varying resolutions and the assessment of the glacier in terms of the temporal change in area and length of Naradu Glacier. The baseline data of this glacier has been taken from the Survey of India topographic maps (1962) as the base layer and the glacier layers prepared based on visual interpretation from LISS III and LISS IV sensors having spatial resolution of 23.5 m and 5.8 m respectively from 1999 to 2013. A total reduction of 1.35 km^2 has been observed during 1962-1999 while 0.02, 0.06, 0.04, 0.10, 0.05 and 0.05 km^2 during 1999-2001, 2001-2004, 2004-2005, 2005-2007, 2007-2011 and 2011-2013 respectively. Analysis of linear movement of the glacier using LISS-IV satellite data suggests that the total length of the glacier has been reduced from 6731.53 m (in 1962) to 4539.90 m (in 2013). This loss of area and length is further supported by the vertical thinning as loss of ice mass observed by the glaciological mass balance study conducted on this glacier. The continuous negative specific mass balance for the three years 2011-12, 2012-13 and 2013-14 of Naradu glacier has be calculated as -1.09, -1.15, -0.85 m respectively, which further suggest that this glacier indicates a retreating trend in its mass.

Keywords: Naradu Glacier, LISS-III, Linear movement, Glaciological mass balance

Monitoring of ice velocity and frontal position of Mertz's and Ninnis glacier, east Antarctica

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The glacial surface ice velocity is one of the important parameters of glaciology. The Mertzs glacier and Ninnis glacier are important glaciers of East Antarctica. These glaciers are situated next to the largest ice shelf of Antarctica i.e. Ross Ice shelf, with ~ 472,960 km^2. The two main processes that remove mass from the ice shelves are Basal melting and iceberg calving events. The large iceberg calving events tends to occur as a part of a natural cycle where the front advances beyond the embayment walls and then retreat by the calving event. One large activity of calving noted in our study area at Mertz glacier. Mertz glacier is a heavily crevassed glacier in George V Coast of East Antarctica. It is the source of a glacial prominence, which historically has extended northward into the Southern Ocean, the Mertz glacial tongue. Mertz glacier is about 72 km long and averaging 32 km wide. It reaches the sea at the head of a 60 km fjord, where it continues as a large glacier tongue. The Ninnis glacier is a large heavily hummocked and crevassed glacier descending steeply from the high interior to the sea in a broad valley, on the George V Coast in Antarctica. The present studies deals with the ice velocity of the Ninnis and Mertz glaciers between 2000 and 2017 using MODIS (Moderate Imaging Spectroradiometer) data. The studies shows one iceberg calving events in our study area and then advancement in the Mertz glacier noted until 2017. However, on the other hand the Ninnis glacier shows nominal changes during the study tenure. The surface ice velocity measured using the ImGRAFT (Image Georectification Feature Tracking Toolbox) based on Normalized Cross Correlation (NCC) techniques.

Keywords: Mertz glacier, Ninnis glacier, ImGRAFT, Normalized Cross Correlation (NCC)

Modelling and optimizing ship route in sea ice areas: A review

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Transportation through sea route is ancient as an operational means of journey for long distances with heavy goods. Movement of ship in ocean as well as in oceans with ice areas is modeled with the help of metrological and oceanographic information. Researchers have made efforts in optimizing route for ship voyage in terms of minimum fuel consumption and shortest journey time. Still there is a constant demand to optimize energy efficiency with the management of safety and emission regulations simultaneously. This makes modeling and optimizing ship routes in sea, a non-linear, multi-objective and constrained problem with conflicting objectives. There are number of paper in literature that have proposed ship transit simulation through their models. Since last two decades, ice modeling and ship transit simulations have been integrated with different optimization techniques to develop a route optimization prototype system in ice-covered waters. Almost all the papers have studied Arctic sea-ice Ocean. This paper is an attempt to provide an up-to-date review of existing models and optimization techniques applied to analyze them in most structural and comparative way such that it can help in modeling and analysis for safe and efficient scientific expeditions at Antarctic precisely between Indian research stations, Bharti and Maitri.

Keywords: Sea-ice, Optimization, Dynamic programming, Stochastic approach, Heuristic algorithms

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Water Resources

Decadal changes in water level over major Indian rivers using Jason series of satellite altimeters

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Satellite altimetry was designed for sea level monitoring over Open Ocean, but with advancement of technology nowadays this technology is commonly used to retrieve water level in many inland water bodies. In this paper, an altimetry track based network of virtual stations were defined over major rives of India using Jason series of altimeters. These virtual stations work as the pseudo gauge installed at equal intervals and can be utilized to calibrate installed gauges for long-term deployment drafting issues. The water level was retrieved from year 2008 onwards by making use of waveform classification, waveform retracking and dedicated inland water bodies geophysical range corrections. Hydroweb (LEGOS) and DAHITI are the other two agencies that provides worldwide water level over inland water bodies using satellite altimetry. However, over Indian region the water level is available for only few locations, such as few major reservoirs (Bansagar, Gandhi Sagar, Ukai reservoir etc.) and large rivers (Ganga and Brahmaputra Rivers). We have compared our results with the available inland altimeter water level dataset over the coinciding locations and found good match. Seasonal trend was also estimated based on the long term dataset over the selected locations. In southern Indian peninsula, Krishna and Godavari River have shown sinusoidal inter-annual trend of monsoon, but Kaveri River shows a drastic negative trend in water level. Over Kaveri River, close to 5 m decrease in water level was observed in 2018, as compared to its value in 2008. That turns out to be an alarmingly decreasing trend of 0.48 m/year. Anthropogenic activities and associated climate change could be the possible reason for such alteration. This water level information can be integrated with hydrological and hydrodynamic models for the generation of various hydrological product such as seasonal water yield production in the major river catchment, discharge pattern, rating curve etc.

Keywords: Satellite altimetry, Waveform retracking, Geophysical range corrections, Inland water bodies

Estimation of chlorophyll a, coloured dissolved organic matter and total suspended matter in Satluj river in Punjab using Landsat-8 OLI satellite images

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The Satluj river in Punjab is getting contaminated by domestic sewage, agricultural runoff and industrial wastes, which are usually discharged into water or on land in its nearby areas. Many agencies are monitoring water quality of Satluj river with point measurements, which are insufficient for real time monitoring of water quality due to low frequency of measurements. Moreover, it is difficult and costly to develop in situ studies related to daily/fortnightly/monthly monitoring of water quality of the river. However, in recent decades, new technologies based on satellite remote sensing have been increasingly used to obtain accurate spatio-temporal information of water quality. In general, the directly measurable optical water quality variables from satellite data are chlorophyll-a, Colored Dissolved Organic Matter (CDOM) and Total Suspended Matter (TSM). In this study, Landsat 8 Operational Land Imager (OLI) satellite images were used to measure these variables across Satluj river in Punjab. Water samples were collected from 91 locations across the river in pre- and post-monsoon season of the year 2017, nearly synchronous to pass of Landsat 8 satellite and the samples were analyzed for optical water quality variables. Compared with non-contaminated sites, the chlorophyll-a and CDOM concentration were lower in the waters of contaminated sites, but TSM concentration was higher in the waters of contaminated sites. The surface reflectance values of Landsat 8 corresponding to sampling points were extracted and the linear regression equations were developed between reflectance values and optical variables.

Chlorophyll-a was significantly positively correlated with green (correlation coefficient, r > 0.8) and near infrared band (r > 0.8) of Landsat 8 in both the seasons. The correlation coefficients were lower with blue/red band for CDOM (r > 0.24) and with NIR band for TSM (r > 0.35). These results suggest that Landsat 8 satellite images can be used for remote monitoring of temporal and spatial changes in water quality independent of in situ data once site-specific spectral algorithms for water quality are developed and validated.

Keywords: Chlorophyll-a, Colored Dissolved Organic Matter, Landsat 8, Total Suspended Matter, Water quality

Hydrological modeling and flood vulnerability assessment in upper Jhelum basin using station and gridded precipitation datasets

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In this study, the flood vulnerability of the upper Jhelum basin (UJB) and the reliability of gridded precipitation datasets in the hydrological modeling was investigated. For the vulnerability assessment, influence of the watershed characteristics on the hydrological response of five watersheds of UJB which conjointly drain at Sangam was studied. The datasets used are: DEM, land cover, soil, rainfall, evapo-transpiration, discharge, census data and ancillary data. The HEC-HMS hydrological model simulation was carried out for 11 years by using the precipitation data from 3 rain gauges viz., Pahalgam, Kokernag and Qazigund. The combined impact of all the influencing factors on the hydrological response was modeled. The model was run for years during the period of 2004- 2014 and a good correlation (0.90) was found between the simulated and measured discharge. After calibration of the model, gridded precipitation datasets were used for the year 2014 to test the reliability of the gridded precipitation products. Five gridded satellite precipitation data products; CPC, IMERG, GSMaP, TRMM and INSAT-3D-IMR were used. Highest Pearson's correlation (0.99), Coefficient of Efficiency (0.97) and minimum Relative Bias (-0.61) was observed for the IMERG precipitation data by comparing the simulated discharge with the measured discharge. Thus, it is concluded that among all the gridded precipitation datasets IMERG is highly reliable. Moreover, using the 'vulnerability score' approach, it was observed that the Vishav watershed in the UJB is most vulnerable to flooding among the five watersheds as also evident from the September 2014 flooding event. About 11.31% of the Vishav watershed comes under floodplain, covering about 117 villages and affecting a population of 168,853 people. Also, the findings are of practical use in developing flood management strategies for Jhelum by opting best management practices.

Keywords: Hydrology, HEC-HMS, Gridded precipitation, Runoff potential, Vulnerability

Utility of Cartosat DEM in characterization and prioritization of sub-watersheds using geospatial technologies and morphometric analysis for better water resource management

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Characteristics of the watershed play a very vital role in developmental planning of water resources. Morphometric analysis has been investigated in this study to find out the most suitable locations for developmental planning by characterizing and prioritizing sub-watershed. Morphometric analysis of a

watershed provides a quantitative description based on drainage system and shape of watershed that have been considered as a vital parameter for characterization of watershed. Cartosat Digital Elevation Model (DEM) has been used in this study for extraction of drainage network, stream ordering and sub-watershed boundaries in the Tenughat reservoir catchment, which has been taken as case study. Tenughat reservoir catchment situated in the Jharkhand state and a part of Damodar river system, covers an area of 4501.9 km^2. Total 37 sub-watersheds were delineated using ArcGIS hydrology tool. Linear, aerial and relief parameters such as catchment length, bifurcation ratio, drainage density, drainage frequency, texture ratio, form factor, shape factor, compactness coefficient, elongation ratio, circularity ratio, length of overland flow, basin relief, ruggedness number and relief ratio were computed. Ranking was assigned to each parameter based on its erodibility factor and Compound values (Cp) for each sub-watershed was calculated. Further, priority fixation was carried out based on Cp value. Lowest Cp value was assigned as very high priority and highest value was assigned very low priority. Subsequently other priorities like high, medium and low were carried out.

Keywords: Cartosat DEM, Morphometric analysis, Sub-watershed, Prioritization, Tenughat reservoir catchment

Integrated hydrological modeling over upstream catchments of Himalayan rivers and assessment of extreme hydrological events

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Discharges from upstream river catchments of Himalayas are primary source of water to the downstream region. Abrupt increase in discharge amount due to extreme rainfall events cause flash floods in the upstream Himalayan catchments. Hence, estimation of spatio-temporal variation of discharge is of utmost importance for water resources management, flood control, irrigation and soil erosion. Hydrological modeling over upstream catchments of Himalayan river basins was performed using SACHYDRO model. It is a conceptual, distributed hydrological model developed from integrating different hydrological processes into the modeling framework. There are several hydrological processes solved within the model. These hydrological processes are formulated in such a way that maximum space based inputs can be ingested into modeling framework. The different modules such as infiltration, surface runoff, evapo-transpiration, runoff routing, ground water recharge and snow melt runoff are combined together. Hydrological simulations over Himalayan region were performed for the period of 2013 to 2017 using hydro-meteorological parameters at 5x5 km grid scale. Hydrological fluxes such as soil moisture, evapo-transpiration, snow-melt depth and discharge was estimated. The discharges for upstream catchment of the Brahmaputra, Indus and Sutlej rivers were compared with observed data set. Statistical evaluation was performed to estimate the model performance in terms of RMSE in annual discharge cycle. It was found that RMSE of 1600 m3/sec and 138 m3/sec for the Brahmaputra and Sutlej rivers, respectively. Model simulated peak discharge was also compared for the Uttarakhand flood disaster occurred during 13-17 June 2013. It was found that model could able to estimate the peak discharge over rivers in Uttarakhand region due to extreme rainfall event during this period. The model simulated peak discharges were also used to assess the flood vulnerability over Uttarakhand region. The model simulations have demonstrated its capability for long term and near real time hydrological simulations for water resources management.

Keywords: Hydrological simulation, Discharge, Upstream catchment, Uttarakhand

Application of geospatial technology for groundwater prospects and quality mapping in Huzurabad assembly constituency, Telangana state

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Groundwater is an essential source of drinking water for many Indian habitats. Water has become a scarce resource all over the world. Overuse of land practices for agriculture in command areas with increasing use of chemicals have undermined the quality of many tanks, reservoirs and aquifers, as well as the rapidly growing cities and industries also in turn significantly contributing for quality deterioration. Maintaining good water quality is a growing concern in water resources management around the world. Even though water quality deterioration is often not as visible as water scarcity, its impacts can be just as serious with significant economic consequences. The chemical contamination of drinking water especially fluoride and nitrate, which is directly related to the sewerage and fertilizers applied to the agricultural fields, are major concern in drinking water supply. The National goal is to provide every person with sufficient quantity of safe water for drinking, cooking and other domestic needs on a sustainable manner. The spatio-temporal variations in rainfall, local variations in geology and landform composition of various units have led to uneven occurrence and distribution of groundwater resources. The remote sensing imagery with its synoptic coverage, acts as a tool for finding suitable solution when combined with conventional data. An attempt is made to map the availability of ground water quantity as well as quality of Huzurabad Assembly constituency area using geospatial technologies. The study area covers 94 villages that spread over five Mandals and comprising a total population of 3.06 lakhs. The hydro-geomorphic maps prepared by integrating the lithology, landforms, structural fabric and hydrology layers using remote sensing and GIS techniques on 1:50,000 scale. The spatial distribution of hydro-geomorphic unit-wise ground water quality assessment for the parameters like pH, total dissolved solids, total hardness, total alkalinity, fluoride, chloride, sulphate, nitrate and iron, and its impacts are carried out in temporal (pre & post monsoon seasons) under integrated environment.

Keywords: Chemical elements, Quality, Spatial, GIS, Remote sensing, Temporal, Landform

Assessing the impact of debris cover on glacier melting in Kashmir Himalayas, India

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The Mountain glaciers are covered with varying amount of supra-glacial debris cover derived mostly from the local rock or sometimes from atmospheric deposition of particulates. Debris cover influences the melting behavior of a glacier. In this study the glaciers of similar size, aspect and elevation but with different debris cover were chosen for assessing spatio-temporal glacial changes in three different basins (Suru, Zanskar and Chenab) using remote sensing data for two decades (2000-2017). Glaciers covered with debris more than 30% showed minimum change in area and snout position as compared to the glaciers with debris cover less than 10%, which showed the maximum recession. As per the observations, clean glaciers showed very high recession of area and snout position. Despite high debris cover, certain glaciers showed a significant recession which in turn implies the role of debris thickness. A thin debris cover accelerates the melting rate of the underlying ice through increased absorption of solar energy by low-albedo debris and rapid transmission of this heat to the ice surface. A detailed study of Durung Drung (clean glacier) and Pansila (debris covered glacier) in the Zanskar region between the year 2017-2018 showed the impact of debris thickness on the glacier melting. The 22 stakes (each 3 m in length) drilled into the Durung Drung and 11 stakes were drilled into the Pansila glacier during the

year 2017. The Pansila has an average debris thickness of 40 cm along with large amount of huge boulders with average height of 5 feet. It was observed that Durung Drung, a clean glacier showed highest melting of 2.5 m/year as compared to Pansila which showed a melting of 1.35 m/year. The differential melting rate is attributed to their different debris cover extent and debris thickness.

Keywords: Melting rate, Recession, Absorption

An operational method for discriminating sea ice and water in the Antarctic using Scatsat-1 Level-4 data

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Sea ice exists in polar regions which are the farthest places on the Earth, but it affects the climate of the entire globe. This ice has a profound impact on the polar environment, ocean circulation, weather, and regional climate. Various types of sea ice are formed depending on different weather and ocean conditions. Sea ice has a bright surface, which means it reflects solar energy more. A little intensification of temperature can bring on a more prominent warming which affects the polar region. That makes the polar regions the most sensitive areas to climate change of the Earth. For the last few decades, scientists from all over the world are studying and monitoring sea ice for variety of societal and scientific reasons. Unexpected melting of sea ice has become potential threat to the Earth's climate. In this paper, an algorithm of sea ice extent retrieval using Level-4 data from Indian Scatterometer Scatsat-1 has been presented. Using hierarchical classification rules, threshold-based technique has been applied to generate sea ice images. In this technique, four parameters have been used to classify sea ice and open water. The sea ice area obtained from Scatsat-1 has been compared with Advanced Microwave Scanning Radiometer 2 (AMSR2) radiometer sea ice concentration data and National Snow and Ice Data Center (NSIDC) sea ice extent data. Accuracy assessment has also been performed between AMSR2 and Scatsat-1. Results shows Scatsat-1 super resolution data is capable of distinguishing sea ice from water and it is matching well with other datasets. The technique developed has been validated and applied to generate daily sea ice images of the Antarctic since January 2017.

Keywords: Sea ice, Sea ice extent, Scatsat-1, Scatterometer

Mapping of seasonal snow cover and snow melt area for Miyar and Bhaga basin in Western Himalayas for hydrological year 2017-2018

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Snow cover is the second largest component of cryosphere. It is one of the important parameter for hydrological and climatological applications. Occurrence and distribution of snow greatly depend on the altitude and latitude of a specific region. A large global effort is being carried out all over the world to monitor the snow cover continuously. In India, the Himalayan snow and glaciers feeds the major rivers such as Indus, Brahmaputra and Ganges by its melt water. Hence, the estimation of Snow Cover Area (SCA) is important. In this study, the seasonal fractional snow cover area mapping for winter accumulation period and area of snow melt for ablation period has been estimated for the hydrological year October 2017 to September 2018 in Miyar and Bhaga basin

of western Himalayas in Lahaul and Spiti district of Himachal Pradesh. The high resolution optical imagery data captured by Sentinel-2 with spatial resolution of 10 m has been used for this study. The snow cover has been estimated using NDSI, NIR/SWIR ratio and S3 index. Normalized Difference Snow Index (NDSI) is a generally used index to detect the snow cover but it has a limitation in detecting the water pixels and cloud pixels. In order to overcome the misclassification of water as snow, NIR/SWIR ratio has been used. For the exact classification of parameters and the threshold value selection, statistical analysis using the spectral response of the pixel has been used for NIR/SWIR ratio. The S3 index has been used to detect the snow cover under vegetation. Fractional snow cover area has been mapped using Sentinel-2A and 2B data, with the combined revisit period of 6 days for both Miyar and Bhaga basin. From this study, it has been estimated that the average snow cover area for the accumulation period (December, January, February and March) of the hydrological year 2017- 2018 is approximately 2073.25 km^2 for Miyar basin which is 85.9% of total basin area and 1210.26 km^2 for Bhaga basin which is 72.04% of total basin area respectively.

Keywords: Snow cover area, Sentinel 2, NDSI, Accumulation, Ablation

Application of geo-spatial tools for assessment of maximum storage potential in the watershed adopting continuous stream storage approach

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With the occurrence of frequent intense storm events and prolonged dry spells, the effects of climate change have started being visible in water sector. Water is the most stressed natural resource in India because of spatial and temporal variability of monsoon rainfall and rapidly increasing demands. Many areas in the country chronically face drought like situations during non-monsoon because of inadequate surface and ground water storages. Conventional watershed development methods adopt construction of mini/micro storages spread in the watershed. Such storages are discrete, inadequate and have several other limitations like land submergence, sedimentation etc. In this study, an attempt made to use innovative approach of *Continuous Stream Storage* (CSS) in the entire drainage pattern of the study watershed. Using the remote sensing data and GIS tools, various watershed characteristics such as physical, geo-hydrological and morphological parameters were studied including hydrology and the water demand pattern. This was used as base for estimation of the extent of surface and ground water storages presently available and its utilization. It was observed that, there has been severe water deficits in agriculture and PWS demands during non-monsoon months. To deal with the deficit scenario, in this study, surface water storage capacity is enhanced adopting *Continuous Stream Storages* (CSS) at locations on the steams of various orders in the watershed with variable storage depths. The location identification and total storage estimation is done for the drainage network in GIS environment. Adopting this approach, it was found that surface water storage capacity may be increased by more than 100%. Also, since the entire stream network will be rejuvenated, the ground water recharge and use will also increase substantially. Thus with substantial additional storage of surface water and the groundwater recharge made available, the simulation results indicate that the deficits during summer months may be reduced to almost nil. Thus it is inferred that CSS is very effective, practical, economical and environment friendly watershed development method which can be replicated in all watersheds.

Keywords: Watershed development, Geospatial tools, Continuous Stream Storage (CSS)

Flood inundation mapping of stretches of Brahmaputra river in Assam state using advanced geospatial data analysis

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The current study estimates the damage occurred due to flood wave recently affected in the entire stretch of Brahmaputra river course along Assam. During September 12-17, 2018 River was reportedly flowing high, above danger level all along the course of the channel from Neamatighat, Sonitpur (Tezpur), Guwahati, Goalpara and Dhubri. Daily accumulated precipitation of GPM from IMERG V5 (late run) Satellite derived data from combined microwave and Infrared (IR) estimate analyzed for the above dates shows continuous precipitation at a rate of 25-75 mm/day during September 9-16, 2018 with a lag of 2 days along the districts Lakhimpur, Dhemaji, Sibsagar, Jorhat and Sonitpur. Also intense precipitation at a rate of 76-126 mm/day during September 9-11, 2018 has been estimated in the districts of Dhubri, Bongaigoan, Goalpara, Barpeta, Nalbari & Kamrup. Flood situation reports of Assam State Disaster Management Authority and News from various source indicated that standing crops over an area of 115.32 km^2 was damaged in the districts of Dhimaji, Lakhimpur, Sibsagar, Sonitpur, Morigaon, Kamrup, and Barpeta, and 2000 km^2 cropland has been submerged in floods. The same are compared with the estimates derived from the present study. Sentinel 1 C-Band SAR, Landsat 8 and Sentinel 2 satellite images have been used for assessment of flood inundation mapping. Normal river flow has been quantified using October 2017 and May 2018 Sentinel 1 images. Flood event were estimated for 14th and 17th, September using Sentinel 1 SAR, 17th September Landsat 8 and 16th September Sentinel 2 optical satellite images, which shows an inundation area of 2101.88 km^2 in the 16 districts. Assessment of Sentinel 1 SAR vs. Landsat 8 and Sentinel 2 derived water body shows an accuracy more than 88% to 96% in 7 districts. Coefficient of determination between SAR vs. optical satellite image based flood inundation area in the overlapping 7 districts shows R^2 of 0.97. The junctions of tributaries (i.e., Subanshiri, Ranganathi, Danshiri, Jia Bareli, Kopili, Puthimari, Beki and Kulsi) and low lying areas along main river channel have been affected during the flood. The approach undertaken in this study is very useful to quantify the flooded/inundated zones very reliably.

Keywords: Flood, GPM IMERG V5, Sentinel-1 C Band SAR, Landsat 8, Sentinel 2, Brahmaputra River, Assam

Seasonal and time series analysis of terrestrial water storage for the Indo-Gangetic plain using GRACE data

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The GRACE satellite mission data is used to study the mass variability on the Earth surface. The major component to the surface mass variability is changing Terrestrial Water Storage (TWS). The GRACE mission data are used to analyze the TWS dynamics for the Indo-Gangetic plain which is one of the most water-stressed regions in the world. The dynamics of TWS is expected to have periodic behavior due to the seasonal pattern. Because of the vast study area, significant seasonal pattern changes are prevalent in the region. A seasonal and time series analysis of TWS is required for the plain. The entire study area was classified on the basis of seasonal behavior. For the classification of the study area, a Fast Fourier Transform (FFT) was applied to get the dominant frequency which represents the seasonality. The intensity of most dominant frequency varies spatially from a grid to grid and it actually increases from the upper Indo-Gangetic plain to the lower Indo-Gangetic plain. This intensity variation was used to classify the study area. Further, a time series models were established for each classified region. It shows that data at any point is highly correlated with the preceding

data but not the older one. The analysis further identified a major drought that hit the country (i.e. India) in the year 2009.

Keywords: GRACE, Indo-Gangetic plain, FFT, Classification

Mapping and demarcation of water bodies in the Jodhpur city using geospatial technology

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Jodhpur is the second largest city in the Rajasthan with the population of over 13 lakhs. The city experienced high urbanization in last one decade and therefore needs effective public amenities along with safe water. Presently water needs of the city is fulfilled through Rajeev Gandhi canal, which feeds into Kaylana Lake. The present study was carried out to identify and map the exposed water bodies spread across the city boundary. Presently 10 major and 20 minor water bodies are available in the study area. High resolution GeoEye satellite data with resolution of 2 m was used to demarcate the water bodies using pixel based index and object based method. The Normalized Difference Water Index (NDWI) technique was also used for extracting water bodies. The study shows the availability of alternate water resources, which shall also be useful during frequent maintenance work of Rajeev Gandhi canal, which supply water to whole city.

Keywords: Demarcation, Water body extraction, NDWI, Satellite data

Hydrologic simulations and water quality assessment of mined watershed in Jharia coalfield

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In this study, Soil and Water Assessment Tool (SWAT) was used for modeling hydrological processes in Olidih watershed of Jharia coalfield region in India. The calibration and validation of model performed using daily stream flow and sediment yield data for the period 2005 to 2008. The alternative scenario of no-mines modeled to assess the potential impact of opencast mines for the period from 2005 to 2010. Results show that the abandoned opencast mines alter the hydrologic processes of Olidih watershed. Increase in sediment yield by 14.29%, ground water flow by 11.34%, evapo-transpiration by 3.56% and decrease in surface runoff by 51.33% and water yield by 6.6% was observed as compared to no-mine scenario. Results also indicate that the SWAT model can satisfactorily applied in mined watershed to assess the effect of opencast mines on hydrological processes by defining large opencast mines as pothole. Water samples from study area were collected and analyzed to identify their suitability for domestic uses in pre-monsoon (PRM) and post-monsoon (POM) seasons. Results show that surface water from 53.6 % mine affected area in PRM and 28.2 % mine affected area in POM season is not suitable for drinking purpose.

Keywords: Opencast mines, Watershed hydrology, Water quality index, SWAT

Poster Session

Spatial variability mapping of macronutrients using geo-informatics technology across Patan and Vadodara districts, Gujarat

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Agriculture is one of the most important components of our society and GIS based soil fertility mapping can provide a cost effective strategy for an effective nutrient management. For this purpose soil macronutrient datasets of Patan (174 samples) and Vadodara district (276 samples) were obtained in spreadsheet format from Anand Agriculture University, Gujarat. Further, generated spatial distribution maps of macronutrients {viz. Nitrogen (N), Phosphorus (P), Potassium (K)} using IDW interpolation technique of GIS. Range and average variability status also estimated using Exploratory Spatial Data Analysis tool of ArcGIS10. Across Patan district available macronutrients viz. Nitrogen, Phosphorus, Potassium ranged from 113-220, 25-111 and 110-1827 kg/ha with mean value of 168, 48 and 408 kg/ha respectively. While across Vadodara district available macronutrients viz. Nitrogen, Phosphorus, Potassium ranged from 60 - 235, 12 -160 and 151-985 kg/ha with mean value of 147, 65 and 533 kg/ha respectively. Soil Nutrients Indices evaluate fertility class of soil. The results of SNI revealed low fertility class of Nitrogen and higher fertility class of Potassium across Patan and Vadodara district of Gujarat State, India. SNI also revealed medium fertility class of Phosphorus across Patan district while across Vadodara district SNI revealed higher fertility class of Phosphorus. Further, based on spatial distribution maps and SNI recommended fertilizer doses to improve crop productivity across Patan and Vadodara district of Gujarat State, India. GIS maps will not only be helpful for nutrient management and fertilizer recommendation but will also reduce the plot-by-plot soil testing activities.

Keywords: Geographic Information System (GIS), Inverse Distance Weighting (IDW), Soil Nutrients Indices (SNI), Spatial distribution, Macronutrients

Application of Geographic Information System (GIS) as a decision making tool to expedite Kala-azar elimination in highly endemic regions of Bihar, India

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Visceral leishmaniasis (VL or, kala-azar) is a serious public health problem in India for several decades. All VL endemic states, including Bihar, have struggled to achieve the VL elimination target [i.e. <1 case/10,000 population at block-level (by 2020) as per World Health Organization] due to injudicious application of chemical-insecticide in indoor residual spraying (IRS), and village selection criteria (i.e. endemic villages in the last 3-years, including the implementation year) for targeted spraying. This study demonstrates the use of geographical information systems (GIS) as a decision-making tool to identify and select the endemic and high-risk non-endemic villages for targeted IRS to expedite VL elimination in highly-endemic districts of Bihar. The second most highly-endemic district Vaishali in Bihar (India) was selected as the study area. A geodatabase was used to integrate VL-case data between 2012 and 2016. GIS analyses, such as layers integrating and mapping, were performed to explore the spatio-temporal distribution of VL-cases and villages' endemic-prolongation for hotspot identification across the district. A new basis for village selection was developed [i.e. all endemic villages in the last 3-years, including the implementation year, and the peripheral villages of the hotspot (during the period) and the newly-endemic (reported in the past year of the implementation year) villages] for IRS campaigns (i.e. two-rounds IRS of annually) during 2015 and 2016. Results showed that the number of cases and affected villages were reduced from 664 in 2014 to 163 in 2016 and 282 in 2014 to 142 in 2016, respectively. Percentage of case reduction was increased from 22.6% in 2014 to 58.8% in 2016. All the 16-blocks were

achieved the elimination target. VL incidence rates were ranged from 0.17 to 0.86. The developed method has been adopted by the state health society of government of Bihar for VL vector-control in other highly-endemic districts.

Keywords: Visceral leishmaniasis, Indoor residual spraying, Spatio-temporal analysis, Geographical information systems, Elimination

Effect of zoom factor and surface heterogeneity on sub-pixel mapping of glacier facies

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Glacier facies maps are valuable input datasets for hydrological, climatological, calibration and/or validation of distribution mass balance models. Remote sensing technology has greatly facilitated the per-pixel mapping of glacier facies at low/no-cost. Notably, their mapping at sub-pixel level is yet to be explored. In sub-pixel mapping (SPM) process, proportions of each glacier facie within the coarse pixel are first estimated using a soft classifier and then a higher resolution map is created depending upon the choice of zoom factor is a key factor in SPM that determines the spatial resolution of super resolved map. This study aims at exploring the impact of and surface heterogeneity on the SPM accuracy. Synthetic image was first created and degraded by different integral factors to obtain four synthetic fraction images. Support Vector Machine (SVM) classifier was then used to extract the fraction images of glacier facies using ablation and post-ablation Advanced Wide Field Sensor (AWiFS) images of Gangotri and neighboring glaciers. Synthetic and AWiFS derived fraction images were inputted to the developed modified pixel swapping algorithm (MPSA) to generate super resolved maps at various . Synthetic images were used to test the efficacy of MPSA before its implementation on AWiFS data. The Sentinel-2A Multispectral Instrument data has been used as reference here. Results show that both and surface heterogeneity significantly control SPM accuracy. Increasing the from 3 to 7 led to 3% reduction in SRM accuracy besides introducing noise and distortion in the resultant map of synthetic data. For AWiFS data, 6% and 10% decrease in OA, besides noise in the form of isolated pixels appeared in the resultant maps on varying from 3–6 and 6–10 respectively. OA increased by 2% on reducing the number of glacier facies to three in post-ablation AWiFS data.

Keywords: Coarse resolution, Sub-pixel mapping, Glacier facies, AWiFS, Sentinel

Close range photogrammetry: An innovative technique for morphometric study of cities

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Close Range Photogrammetry is a technique of using terrestrial photographs for the spatial study while 3D modelling is the process of developing a mathematical representation of any three-dimensional surface of an object via specialized software. Our study area is the Buildings along the Garhi Cantt road, Dehradun near IIRS Campus. And purpose of this study is to get clear picture of the morphology of this area. For this, three research objectives were finalized to prepare road map of this study. These are (1) To generate 3D Modelling using the close range photogrammetry. (2) To assess urban morphology through 3D Visualization and data query. (3) To visualize 3D street scenario with walk through. The software which is used in this project is TRIVIM, developed

by Indian Institute of Remote Sensing (IIRS), Dehradun, India, for morphometric analysis of the study area. This software provides a visualization and decision support tool by creating geo-referenced, photorealistic models attached with attribute data base for variety of applications. 356 photographs have been snapped in field from a distance of approximately 1meter at every consecutive photograph to maintain a 60-80 per cent overlap between the photographs. Out of them 177 were found suitable for this study. 123 shorted photographs are being used to generate the right hand side view of the street, while remaining 54 photographs has been used for left side street visualization. 3D visualization of the study area can be displayed on Google Earth Pro and a Walk Through was made to enhance the final result presentation. Final result is categorized under three sub heads- Regarding Urban Morphology, Regarding Software and Regarding Database Query. Future perspective of this study is also mentioned in the end of this paper.

Keywords: Close range photogrammetry, Urban morphology, 3D visualization

Time-series bigdata naïve Bayes classification for Agriculture, Forest & Other (AFOLU)

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Time-series big data analysis is uneasy complex processing using traditional techniques. Time-series data are voluminous, but useful for mapping dynamic nature of land use assessment. Usage of remote sensing data for rapid assessments of global land use are important for country and regional planning. MODIS MOD13Q1 product NDVI, 250m spatial resolution, monthly time series data are used in between 2004 to 2005. Study region South Asian Association for Regional Cooperation (SAARC) nation is considered. It covers area of 5006711 km^2 and fall into varying agri-climatic regions. Time-series monthly data anomalies and noise are filtered using Satvizky-Golay algorithm, then data redundancy and multi-collinearity are check using Variance Inflation Factor. Time-series data are identified as redundant, so multi-collinearity are removed using Principal Component analysis and data components are PCs(PC1, PC2, PC3) independent images, which are used for classification. Principal component image PC1, PC2 considers more than 98.5% of time series image information, so it is used for classification. Random points are created all over SAARC region and its randomness checked using Average Nearest Neighbor (ANN) method. Using Python-Spark package spark-2.0.2-bin-hadoop2.7 in environment of Jupyter notebook with anaconda python library. Seventy five percent of random referenced points used to train Naïve Bayes classifier. PC1 and PC2 values used to get classified values for agriculture, forest and other (AFOLU) land use classes. Using 25% of random referenced point used for accuracy assessment of Naïve Bayes class output. Along with Naïve Bayes classifier accuracy its working performance on Big data is also checked in respect to time. Naïve Bayes accuracy-based algorithm for classification assessment of agriculture, forest and other land use for SAARC countries with more that 65% with respect to (Food & Agriculture Organization) FAO data and NRSC 2005 for Indian region. Its reliability increased due time performance, whole analysis process gets completed into half hour of working on Quad-Core and 8GB RAM system configuration system.

Keywords: Big data analysis, Time series analysis, AFOLU, Naïve Bayes, SAARC nation

Remote sensing and GIS based site selection for water harvesting structures in Bilaspur forest circle

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The state of Chhattisgarh receives good amount of rainfall but due to the land topography, most of the water in the streams immediately gets drained off rendering the streams seasonal and causing extreme water scarcity during the summer months. Hence there is a need to retain water by increasing water storage capacity and building effective water harvesting structures such as farm ponds, check dams, gabions etc. For these structures to be functional, they need to be placed at appropriate position, in series, following the ridge to valley approach. Panning the entire terrain consisting of dense forest patches for suitable sites based on field survey alone requires tremendous effort. Remote sensing and GIS technology can facilitate such analysis encompassing large regions and multiple datasets. This study was done with two objectives. Firstly, to create and enhance water bodies for elephants and other wild animals and secondly to increase the irrigation potential of JFM villages. Cartosat DEM data with a resolution of 10m was used to obtain hydrology data. The catchment area of each structure, the expected area and length of water impound was also calculated. The shortlisted sites were handed over to the field team for verification. Initially temporary structures such as sandbags were used to test its efficiency before erecting permanent structures.

Keywords: Elephant habitat management, Joint forestry management, Forest health

Evaluation of the consistency of DMSP - OLS and SNPP-VIIRS Nighttime light datasets

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Night-time light remote sensing is used to monitor human impact on earth's surface. DMSP-OLS was the famous source of night-time light data until the release of a newer version of night-time light satellite SNPP-VIIRS which has several improvements over DMSP-OLS. However, the dissemination of DMSP-OLS datasets was ceased for public use after 2013. The SNPP-VIIRS satellite products are available from April 2012. Due to this unavailability of the datasets prior to 2012 for VIIRS and after 2013 for DMSP, raises the major importance of homogeneous long term datasets in understanding the impact of the past and to have a comparative and change analysis prior and later to 2013. Due to the need of a long term homogeneous datasets, the evaluation of the consistency of the DMSP-OLS and SNPP-VIIRS has been foreseen. For this, both the datasets are harmonized temporally, spatially and radiometrically. The study presents the inter-calibration between DMSP and VIIRS using pseudo invariant features (PIFs). PIFs are the regions of constant luminosity and are considered as spatially homogenous and locally stable. For extracting suitable PIFs, combinations of Getis ord statistics (Gi*) and coefficient of variation (CV) are used on 3×3 and 5×5 pixel window sizes. Various thresholds are applied to Gi* and CV and the optimal combination is selected to identify suitable PIFs. Logarithmic and power functions are used for DMSP and VIIRS to find the optimal fit. The calibrated (simulated) image is validated against socio-economic indicators: Gross State Domestic Product (GSDP) and Electricity consumption (EC). The model is found to be a good fit at national scale (India) but doesn't fit very well on regional scales. Significant improvements can be made to ensure better consistency by the application of different techniques of harmonization, selection of PIFs and application of the inter-calibration model.

Keywords: DMSP-OLS, Gross State Domestic Product (GSDP), Electricity consumption (EC)

Python development for geospatial applications

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Python is gaining a lot of popularity from developers these days due to its simplicity. A lot of libraries are available for all possible domains one can think of from neuroscience to astronomy. One such library called GDAL (Geospatial Data Abstraction Library) for geospatial applications is a boon to the developers of the said domain. GDAL when clubbed with NumPy, Matplotlib, Opencv, Scikit Image, Scikit Learn, and RSGISLib can be handy for any possible geospatial application development. This paper aims to introduce how the functionalities of GDAL can be exploited from installation to geospatial application development.

Keywords: PYTHON, GDAL, Scikit Learn, Opencv

Delimitation of priority zones for biodiversity conservation in Rajpipla forests using RS-GIS approach

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Despite of several protected forest areas persisting as a treasure trove for biodiversity, deforestation rate is unabated resulting in swift loss specifically in the dry tropical forests. Lack of effective conservation strategies calls for realistic and effective management strategies for forest biodiversity. This places great emphasis on delineating the priority conservation zones and the forest density classes prone to degradation using Geospatial technology in the forest areas. The present work was set out to use multi-criteria analysis in order to define priority zones for Biodiversity conservation in the forest areas of Rajpipla taluka of Narmada district using RS-GIS approach. Thematic layers (maps) such as forest change detection map, different biodiversity indices, elevation, slope, distance from urban centers, distance from road and rail systems, types of soil, and average annual rainfall accumulation etc. are created. Landsat-8 and sentinel-2 satellite images of year 2014 and 2018 were used to classify the vegetation density by applying Normalized Difference Vegetation Index (NDVI) technique and to generate forest change detection map. The generated thematic maps were categorized according to their weightage classes and overlaid in GIS domain to demarcate the Conservation Priority Zones (CPZ): very low, low, moderate, high and very high. The study highlighted the usefulness of satellite remote sensing and GIS for decision making and implementation of conservation of high biodiversity areas and also, restoration and rehabilitation programmes of such critical areas in forests of Rajpipla, thereby to achieve sustainable development of forest resources.

Keywords: Conservation priority zones, Biodiversity conservation, NDVI

Forest biophysical parameter estimation in Buxa tiger reserve, West Bengal

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Forest biophysical parameters like Fraction of Absorbed photosynthetically Active Radiation (FAPAR) and Leaf Area Index (LAI) are essential variables in ecosystem modelling. Leaf area index (LAI) was measured at

sample locations in Buxa tiger reserve (BTR), West Bengal. BTR is unique forest dominated with semi-evergreen forest and patches of evergreen forest in the core areas. This area situated on the edge of Eastern Himalayan forest and is biologically rich forest area, with highly important timber yielding species. LAI values were modelled using IRS Resourcesat 2 LISS 4 data for creating spatial map of LAI. Using field based instruments Fraction of Absorbed photosynthetically Active Radiation (FAPAR) was estimated at each sample location and was modelled using satellite data. The study reveals higher values of LAI and fAPAR, ranging upto 4.8 and 0.9 respectively, particularly in the core areas of BTR. It was found that the tree canopy was relatively less dense but under-growth in the forest was extremely dense, making it difficult to penetrate inside the forest areas. Results were compared with existing product from MODIS. Considerable match with the existing product was seen.

Keywords: FAPAR, Leaf Area Index (LAI), Buxa Tiger Reserve (BTR)

Assessment of classification accuracies for identifying priority forest sites by using RS-GIS approach: A baseline for biodiversity conservation

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Despite of several protected forest areas persisting as a treasure trove for biodiversity, deforestation rate is unabated resulting in swift loss specifically in the dry tropical forests. Lack of effective conservation strategies calls for realistic and effective management strategies for forest biodiversity. Nature requires adequate and accurate detection of environmental stresses which inevitably arise after implementation of such large construction projects. Hence forest mapping and analysis is pivotal for assessment and modelling of biodiversity of an area and it is needed at different spatial and temporal scales from local to global and from historic records to future models. Such information is also a prerequisite for spatial planning at local and regional levels. Considering these facts, an attempt has been made to select an eloquent classification method which is predominantly significant for improving classification accuracy to prioritize areas for sustainable forest land management and conservation to be restored in Panchmahal district of Gujarat that covers a span of 5210 km^2. The purpose of this work was to explore low-cost techniques for land-use mapping. Whilst an immense number of recent image classification algorithms have been developed, they are seldom tested with the corresponding classification task. Thus, different Supervised classification techniques available namely Maximum Likelihood (MLC), Minimum distance, and Support Vector Machine (SVM) supervised classification methods were applied to Landsat-8 and Sentinel-2 data set to accurately identify four different forest cover classes viz. Open Forest, Dense Forest Degraded Forest and Land use. Ground reference points collected for accuracy assessment were utilized to generate confusion matrices for all different classification techniques. Subsequently classification accuracy, results were compared to find out the best approach to generate current forest cover map of the area. The results of supervised classification showed that the proposed technique has achieved better results reaching an accuracy of above 83% and kappa above 0.82. The Support vector machine algorithm used to produce the multi-temporal land use data has proved to be very subjective in nature. It is important to note that along with different classification algorithms, improvement in results depends on the area, the quality of the initial classification and the data. The study highlighted the usefulness of satellite remote sensing and GIS for decision making and implementation of conserving high biodiversity areas, thereby to achieve sustainable development of forest resources.

Keywords: Supervised classification, SVM, SENTINEL-2, LANDSAT-8, Biodiversity conservation

Maiden detection of spinel at Maunder crater of far side using Chandrayaan-1 Moon Mineralogy Mapper

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Maunder crater (14.6°S, 93.8°W) is a 55 km diameter classic complex crater located at the northern end of the Mare Orientale. Analysis of hyperspectral Moon Mineralogy Mapper (M3) on-board Chandrayaan-1 reveals the presence of Mg-spinel mineral at crater wall of Maunder. Mg-spinel is identified on the basis of strong absorption signature near 2000 nm and absence or weak signature at 1000 nm. All exposures of Mg-spinel are located in feldspathic NW region of crater wall. Close association of Mg-spinel with mafic-free anorthosite or crystalline plagioclase is detected. In geological context the lithology of NW crater wall can be identified as Mg-spinel bearing anorthosite (Pink-Spinel Anorthosite, PSA). Confirmed locations include areas of dispersed exposures within the slumped terraced wall of crater. The composition of NW region of crater can be said to be spinel-rich, plagioclase-rich and low detectable mafic minerals (<5%). The rock type suggests that it is principally of lower crustal in origin. However, Low-Ca Pyroxene, High-Ca Pyroxene, Olivine and Spinel are observed at the central peak in association with OH/H2O signature indicating diverse mineralogical surface exposures of some deep parts of lunar interior. This study highlights the importance of mineralogical and geological remote sensing studies to assess the heterogeneity of the lunar crust and understanding its genesis.

Keywords: Moon Mineralogy Mapper, Spinel, Maunder crater, Far side

Mineralogical study of Mare Humorum using hyperspectral data from Chandrayaan-1 Mission

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Mare Humorum is Nectarian age (~3.95 to ~3.85 Ga) basin located towards the near side on the Moon. It occupies the southwest quadrant (24°S-39°W) at the southern end of Oceanus Porcellarum. Large craters like Gassendi, Doppelmayer, Vitello and Hippalus are situated in the North, South and East side of Mare Humorum respectively. This circular basin is characterized by large multi ring structure, wrinkle rillies, ridges, varied topographical features and flooded by basaltic flows. In the present study area, high-resolution datasets from Moon Mineralogy Mapper (M^3) and Hyperspectral Imager (HySI) from ISRO's Chandrayaan-I mission is used for studying the basaltic mineralogy of Mare Humorum for mafic minerals (especially pyroxenes). Both are Hyperspectral sensors designed to provide high-resolution imagery of entire lunar surface. HySI covers the wavelength range of 421-964 nm in 64 spectral bands while the M^3 covers the wavelength range of 500-3000 nm. Although the spectral coverage of HySI is less compared to M^3 its spatial resolution is much better (80m) as compared to M^3 (140-280 m/pixel) so more suitable for identification and characterization of pyroxenes and compositional mapping. The various basaltic units present in the region as defined by their respective ages are qualitatively analyzed for their composition. These lithological units corresponding to their chrono-stratigraphic units as provided by earlier workers were delineated on M^3 mosaic of the study area to understand the basaltic evolution through time. The units have been modified on the basis of visual observations. The mineral compositions of various basaltic units were analyzed on the basis of variability of spectral properties of pyroxenes.

Keywords: Mare basalts, Pyroxenes, Chandrayaan-1

Multi-model comparative assessment of meteorological parameters from GCM's over Jammu and Kashmir

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The present study aims selection of best fit model representing the climatic conditions over Jammu and Kashmir to better project the multi-model outputs for the future climate (2021-2050) under three different IPCC climate scenarios; RCP2.6, RCP4.5 and RCP8.5. The climate models used in the present study include; GFDL CM3, GFDL ESM2M, COSMO CLM, CCSM4, and CNRM CM5 available at 0.5^{o} resolution. Various statistical tests were performed to assess the agreement of the model data with the observed temperature and precipitation. The analysis revealed that the temperature simulations from GFDL CM3 are in good agreement with the observations (lowest relative bias 4% and RMSE of 0.1). GFDL CM3 performed well for precipitation compared to other models showing a relative bias of 25% and RMSE of 16.0. The suitability and appropriateness of temperature and precipitation projections from GFDL CM3 model over the state of Jammu and Kashmir are also supported by better NSC, an indicator of consistency of the simulations and the observations. The temperature projections from GFDL CM3 showed fairly well NSC of 0.34 while as the precipitation showed a limited NSC of -3.1. The study also revealed that the precipitation projections are generally less reliable than temperature projections. The GCM data was further downscaled such that the monthly averages and variability during baseline period matches the observations similar to the procedure described in (Aerts and Droogers 2004). It is believed that the research shall help in the choice of the most appropriate GCM for assessing the impacts of the changing climate on various sectors like water resources, glaciers, forests and other sectors.

Keywords: General Circulation Models (GCM), Downscaling, Climate change, Statistical indices

A study of seasonal separability of coal seam fires from other high temperature locations using clay mineral ratio in Landsat 8 OLI/TIRS

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There are two types of non-stop smoldering of raw coal seams i.e. coal seam fires, such as surface, and sub-surface coal seam fires. Coal seam fires have huge environmental, social, ecological, and economical adversity in the society. Detection and prevention of coal seam fires have several research challenges. In the past, coal seam fires detected from satellite images by analyzing land surface temperature (LST). In such procedures, high temperature regions computed to detect fire regions without considering the physical location, which is more likely to be a coalmine. This increase false positive as other high temperature regions cannot be separated from coal seam fire regions. In, coal seam fires detected by additionally removing water bodies, which provide thermal anomalies in summer. In this work, LST is computed through Land surface emissivity (LSE) using normalized difference vegetation index in Dhanbad region. Further, the histogram of LST image is analyzed to detect high temperature regions. These regions are treated individually by connected component analysis. Most of the coal seam fire regions are in the proximity of coal mining regions. Clay mineral ratios of these regions are different from other regions. Hence, a bounding box with 5-pixel padding computed over each connected component. Clay mineral ratios of such bounding boxes are analyzed. Coal seam fire regions and high temperature regions are separated by applying a threshold over the mean values of clay mineral ratios of these bounding boxes. The proposed method validated by t-test and ground truth data. Detection of subsurface fire regions, which are not located in the proximity of a coalmine region, treated as a future work.

Keywords: Land Surface Temperature (LST), Coal seam fires, Clay mineral ratio, Connected component, Landsat 8

Detecting signals of climate change through time-series thermal comfort analysis: A case study of Vadodara city, Gujarat

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The science is clear and the debate seems to be over: Climate change is happening and there is a need to act now. It is axiomatic that the more advanced the civilization becomes, the more complex the problems related to man's environment will be. There is no doubt that with the onset of development, the urban areas become the engines of economic growth and the magnets for new residents flooding in from rural areas. The rapid industrialization and urbanization with unsustainable development approaches deteriorate the living environment due to increase in energy consumption, elevated pollutants level resulting to increased health ailments as well as mortality rates. The probability of climate variability and climate change especially in fast developing cities is the cause of great concern among scientists, governments and lawmakers. Therefore, it is necessary to assess the long term impact of urbanization on the various climatic parameters which in turn affect the human beings along with the rest of the biosphere. With this background, the present study is an attempt to detect and quantify the signals of climate change in a fast growing urban environment of Vadodara city using the long-term climatic dataset. Vadodara is the third-largest city in the Western Indian state of Gujarat located in the semi-arid zone in India. The study presents a detailed analysis of long-term data of key climatological parameters like air temperature, wind speed and relative humidity for a period of 38 years (1969-2006). These parameters play a major role in determining the climate of an area and evaluating the thermal comfort in an urban environment. The present study attempts to quantify the artificially induced climatic trends affecting the human beings based on non-parametric test methods viz. Mann-Kendall Trend test, Sen's slope method on the meteorological parameters and analyzing the biometeorological indices for thermal comfort on multiple time steps. The long-term trend analysis of the changing climatological parameters and deriving biometeorological indices would provide significant insights for evolving the mitigation strategies to reduce the impacts of urbanization for sustainable development.

Keywords: Time-series meteorological data, Biometeorological indices, Thermal comfort, Climate change, Vadodara

Mapping of coral habitat in Neil Island of Andaman using SENTINEL images

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The coral reefs are one of the largest biodiverse ecosystems of the world characterized by a wide range of marine ecosystems that include intertidal zone, pelagic system, and deep benthos. The reefs provide a lot of ecosystem services and act as an indicator of coastal pollution, significant environmental and physicochemical changes. Popularly termed as earth' marine rainforest, coral reefs are extremely productive ecosystems with a high annual gross production rate. Accurate mapping and monitoring of diversity and health of reefs are therefore extremely essential for its protection and sustainable management. Recent advancements in sensor technology, data storage, and processing algorithms have aided the capability of remote sensing for precise coral reef mapping. In this study, we used SENTINEL images of the years 2015 and 2018 for mapping the coral habitat and also tried to detect any significant change. The analysis was aided with a field study which was conducted in the Neil Island of Andaman group of islands. All the images were atmospherically and radiometrically corrected using Fast Line-of-sight Atmospheric Analysis of Hypercubes, and water column correction using the Depth Invariant index algorithm respectively. With the help of ground sampling points and corrected images, the coral

beds were classified using the spectral signature using the Support Vector Machine algorithm. Through a temporal analysis of classified images, it was detected that the coral cover of the study site underwent destruction. The cause of this habitat loss may be attributed to various developmental activities related to tourism activity and coastal constructions. While analyzing the loss of habitat as well as the potential of the sensor in discriminating the coral from other classes, SENTINEL images stood out as a good data resource.

Keywords: Coral habitat, Neil Island, Andaman, SENTINEL

Estimation of optically active substance from in-situ data in the Hooghly River, Kolkata and satellite data product validation using Sentinel-2 data

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The Hooghly River is influenced by a complex mixture of seawater constituents and a wide variety of physical processes The study site is densely populated as well as one of the important industrial hub of West Bengal. It is of great importance due to its biogeochemical processes and marine hydrodynamics. The field measurements were carried for 20 stations using AOP Satlantic Hyperspectral radiometer and IOP wetlabs during the month of April to May 2018 for the estimation of Chlorophyll-a concentration (Chl-a), Total Suspended Sediment (TSM), Colored Dissolved Organic Matter (CDOM). The water samples were collected at the depth of 0.5m using the Niskin water sampler for laboratory analysis. We present here the in-situ, laboratory and remote sensed results of optically active substance in the Study area. The laboratory measurement values of Total Suspended Sediment (TSM) concentration varies from 92 mg/l to 610 mg/l and the Chlorophyll-a (Chl-a) concentration varies in the range from 1.73µg/l to 3.47µg/l. The Remote Sensing Reflectance (Rrs) value reveals the dominant peak in the range 460nm to 480nm which shows the suspended sediment is dominant in the water. The remotely sensed retrieval of optically active substance was derived from sentinel satellite data and compared with the in-situ measurements.

Keyword: Chlorophyll-a, Total Suspended Sediment, Hooghly river, Remote sensing reflectance

Tidal effects on bio-optical variability in Gulf of Khambhat using Ocean Colour Monitor on-board Oceansat

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Gulf of Khambhat, pertaining to its unique geography, encounters heavy sediment load from three major estuaries which download huge volume of sediments into the sea through its wide funnel shaped mouth. The area also encounters high tidal range, for most parts of the month. This causes the water here to be always turbid with high suspended load and also with domestic and industrial wastes. The combined effect is the degradation of the environment and decline in biodiversity. Therefore, regular monitoring of estuaries is important for conserving the aquatic life. So, in this direction data from Ocean Color Monitor, on-board Oceansat-2 was investigated for studying the optical variability of water color due to tidal influence. Geocoded radiance data from Ocean Color Monitor (OCM) onboard Oceansat-2, available every alternate day for the study site was used for this study for a period of two months (Jan-Feb, 2017). Land areas were masked using band 8. Tidal tables were generated using model WXtide32. The low as well as high tide were matched with the extent of

turbid area in the gulf, also in connection to the tidal range. Turbid water extent was also studied vis-à-vis bathymetry of the gulf where shallow water bathymetry map was generated using gridded data from GEBCO of British Oceanic Data Centre. TSM product was also used to study the distribution pattern of sediments. A total of five control points (taken at each of the confluence regions of rivers) were taken to observe the variation in turbidity and changes in radiance pattern with time and tidal effects. Clustering of the area was done. Consequently, class distribution analysis was carried out. In waters of low turbidity, high tidal amplitude exposes the massive tidal bars, verified through the bathymetry of the region. Spatial extents of highest and lowest turbidity were demarcated. For the highest extent, > 300 km of the gulf is covered with turbid water while for the other case ~150 km of the gulf is turbid, for the tidal amplitude of < 9 m. It may be implied that in case of high tidal amplitude (>9m), the turbid extent of the gulf may further reduce. Further, it was revealed that turbidity dominates in the regions having bathymetry between 0 to -30 m for the cases pertaining to case 1. In case 2, water remains highly turbid for bathymetry between 0 to -10 m. In future, this kind of study in larger time frames shall help in understanding the time dependent variability in marine productivity of this region.

Keywords: Gulf of Khambhat, OCM-2, Low and high tide, Bathymetry, Bio-optical

Remotely observed of advanced and retreating of glaciers in Zaskar valley, Bhaga river, Miyar valley, Parbati river, Chandra basin

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The Himalayas possess one of the largest concentrations of glaciers outside the Polar Regions in its high-altitude regions. The mountain ranges of the Himalayas stretch for a distance of about 2,400 kilometers from east to west direction in the shape of an arc along the northern border of India covering an area of about 500,000 square kilometers. The history of glacier fluctuations serves as a reliable indicator of the past climate. The front positions of Zaskar valley, Bhaga river, Miyar valley, Parbati river, Chandra basin all area situated in Jammu and Kashmir, Himachal Pradesh state is drained by a river having huge mass of ice in agreement with those followed. Glacier's changes has been monitored using IRS LISS-III and Landsat 8 data. There are total 361 glaciers accounted in the basin of Zaskar valley, Bhaga river, Miyar valley, Parbati river, Chandra basin. Twenty four glacier have been retreated in the year 2016 in comparison to year 2001 which is been interpreted through IRS LISS-III satellite images. Glacier variations were mapped and analyzed; discrepancies between images could be detected and removed from the integrated data using remap tables in Arc/Info grid both graphically and numerically. Our results show that glaciers in the region both retreated and advanced during the last 15 years; difference between year 2001 and 2016, average Bhagirathi basin glacier area decreased from 2.86 km^2.

Keywords: Himalayas, Glacier retreat, Remote sensing

Future Changes in glacier mass and area under changing climate in the Kashmir Himalaya, India

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The impact of climate change on the glacier cover of Kashmir valley was investigated in this study using projected IPCC climate change scenarios under different Representative Concentration Pathways (RCPs). The

glacier mass balance (MB) by the end of century was modelled using the temperature-index and accumulation models based on daily air temperature and precipitation projections from RCP4.5 and RCP8.5 scenarios. The MB model is calibrated against 4 years of annual altitudinal MB measurements of the largest glacier in the basin; Kolahoi glacier from 2015 and 2018. The relationship between the observed glacier thickness and glacier area was used to reconstruct glacier area from MB. A significant mass loss is predicted in the basin by the end of century. Compared to the present observations, the mass balance in the basin decreases by more than four times by the end of the century. It is predicted that 47% and 67% of the glacier cover in the basin may disappear by the end of century under RCP4.5 and RCP8.5 climate change scenarios respectively. Sensitivity analysis of the glacier MB to temperature demonstrated temperature sensitivity of -0.60 m w.e. a^{-1} $°C^{-1}$ whereas the sensitivity to precipitation is calculated as ±0.11 m w.e. a^{-1} for a 10% change. The predicted glacier mass loss and recession of glaciers in the Kashmir Himalayan region under the plausible climate change scenarios underscore the threat to the perennial water resources emanating from the region and thus, endangering the food, energy and water security in the region and downstream.

Keywords: Glacier mass balance, Climate change, Glacier dynamics modelling, RCP scenarios

Sea ice thickness distribution from Altika: A case study of the Indian ocean sector in the Antarctic

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Sea ice thickness represents an integrated measure of total sea-ice production. Although information on Antarctic sea-ice extent has been routinely available from satellite passive microwave remote sensing since 1979, no similar information is available on Antarctic sea ice thickness, let alone whether it is changing. This is a crucial knowledge gap. As stated by the IPCC Fifth Assessment Report, "without better ice thickness and ice volume estimates, it is difficult to characterize how Antarctic sea-ice cover is responding to changing climate, or which climate parameters are most influential". Better knowledge of these quantities is crucial to reducing climate model uncertainties to improve model performance. Satellite altimetry (both laser and radar) potentially offers the only practical means of measuring and monitoring Antarctic sea ice thickness over large scales, but is currently limited by a lack of suitable data for calibration and validation of the satellite-derived product, amongst other things. Major objective of the study is the generation of Sea Ice Thickness (SIT) spatial distribution by improving the AltiKa altimeter based retrieval technique of different Antarctic sectors. Sea ice thickness derived using the SARAL/AltiKa waveforms. SSMIS radiometer data were utilized for the measurement of snow depth over sea ice. Sea ice thickness derived for the September and October 2016 and discussed in detail for the different Antarctic sectors. Significant melting has been observed as Antarctic summer progresses. In the Indian Ocean Sector of the Antarctic, reveal the fact that observed thickness values are higher around the Indian Antarctic station Maitri as compared to that observed near Bharati station. Similarly, thickness values decreases in northward direction. Sea ice thickness nearby ice shelves found to be higher than those observed elsewhere, emphasizing the role played by ice shelves in the growth of sea ice. Sensitivity study highlighted the role of snow depth and density in the retrieval of sea ice thickness.

Keywords: Antarctica, Remote sensing, Radiometer, Altimeter

Antarctica snow and ice features signature from ground penetrating radar and satellite data

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In colder climate like Antarctica, every year freshly fallen snow buries older snow thereby exerting pressure and making it compact, leading to densification of snow giving rise to ice stratification. These stratigraphic layers were identified using amplitude vs depth graph (Radargram), acquired through Ground Penetrating Radar (GPR) profile. In the present study, we have utilized measurement taken during 35th Indian Antarctic Expedition from two GPRs namely, the in-house designed and developed Stepped Frequency Continuous Wave (SFCW) 500 MHz and Commercial (Time Domain) 1000 MHz GPR. GPR measurements were taken in both spot/point (1000MHz) and line (both GPR) mode over locations which were pre-selected based on variable RISAT-1 signatures and includes various Antarctic ice features like ice sheet, ice shelf, ice berg, sea ice etc.. Along with snow depth, which is uppermost stratum, two or more strata (Radargram based) were also identified and quantified using 1000 MHz GPR. Measured snow depth is found to vary between no snow over bare ice to few meters thick, measured 23 km inside from the Bharati (Indian Antarctic Station) coast. Further, various ice features like ice pipes, ice lenses, and crevasses were observed using both the GPRs. Profiles from both the GPRs were similar, while slight discrepancies can be attributed to difference in frequency and hence resolution of two GPRs.

Keywords: Ground Penetrating Radar (GPR), Antarctica, Radargram, Snow depth

Grounding zone and ice rise in Antarctica: A case study using SARAL/AltiKa repeat pass radar

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This study focuses on investigating the potential of unique Ka band in delineating the grounding zone, near Ronne Filchener Ice Shelf (RFIS). Elevation anomalies generated from the selected repeat passes of AltiKa (14 March 2013 to 4 July 2016) were utilized to accomplish the purpose. AltiKa repeat pass analysis yielded few centimeters precision over dynamically stable region (Vostok subglacial lake), allowing its utilization for observing elevation anomalies varying in meters. Further, difference between the elevation anomaly observed over an ice shelf (anomaly ranging from -2.5 m to 3 m, due to tidal motion of ocean beneath it) and grounded ice sheet (anomaly ranging in few centimeters) adjacent to it, reveals the potential of Ka band in detecting the grounding zone. Ka band derived grounding zone near RFIS, ranges between 3.7 km to 7.3 km. Subsequently, elevation anomaly observed over Berkner island ice rise indicates its vertical motion in few meters, adding novel information to the ice rise dynamics. This vertical motion can be attributed to the movement of ocean water present between the ice rise portion supported on two grounding or pinning point and grounded part connecting these pinning points.

Keywords: Antarctica, Ronne Filchener ice shelf, Grounding zone, Ice rise, AltiKa

Hyperspectral subspace identification using Eigen values Hyperspectral subspace identification using Eigen values

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Blind hyperspectral unmixing basically consists of three sub-problems. First is Subspace identification that is finding number of pure endmembers present. Second Endmember extraction and third is abundance estimation. There are many approaches for endmember extraction and abundance estimation in literature. But many approaches require number of endmembers a priori. We have found a new approach based on Eigen values of hyperspectral image for subspace identification. We have compared our result with other state of art algorithms on real and synthetic dataset.

Keywords: Hyperspectral, Endmember, Eigenvalue

Extraction methods for SAR imagery: A review for road extraction techniques

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SAR datasets provide abundance of information as they can penetrate clouds. Various techniques for feature extraction have been developed rapidly in the recent times. Linear features such as roads, canal, pipeline play a major role in city planning and development. The incessant development of roads in recent times has raised the amount of labor and finance required for maintenance of roads. Information from SAR imagery such as intensity, phase, backscattering, polarization are used to identify features depending upon its incidence angle and dielectric constant. SAR has a requirement of pre-processing of data before extraction of any useful information. This paper summarizes multiple methods for Road Feature Extraction such as Markov random field (MRF), Bayesian Tracking Framework using particle filter method, Multiple Views of imagery with different flight direction, Deeply Convolution Neural Network using Binary Segmentation and Regression, Various Transformation and Segmentation techniques etc. Various datasets required to process above extraction techniques and their applications has also been reviewed. Comparison of various models with its advantages and disadvantages has also been performed. Since no single feature extraction technique will not give satisfactory result, so clubbing of different methods can be done based on its characteristic and need. This can be beneficial to users who are interested in road network and its analysis.

Keywords: SAR, Feature extraction, Polarization, Road

Analysis of ground water quality surrounding area of Hindan river- A case study of Saharanpur district, Uttar pradesh using geospatial techniques

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Ground water is considered as one of the best sources of purest water available in the nature, meets overall demand of rural as well as urban population. Now days, groundwater pollution is one of the serious environmental problems in both urban and rural areas. In this regard, assessment of groundwater quality is very

needful act to preserve our natural ecosystem. Due to rapid growth of human population, urbanization, industrial activities and frequent use of chemicals, ground water is contaminated. One of the major factors is discharge of untreated & semi-treated effluents from industries like textile mills, distilleries, fertilizer factories, sugar factories, tanneries, mineral and metal processing industries. Untreated chemical waste from the industries contain harmful toxic elements that adversely affect the health of both human and animals. Saharanpur district has a large area under sugarcane cultivation. The advent of sugar industries has played a significant role in the socio-economic development, but at the same time, it could be a threat to the environmental pollution. Keeping this in view, the present work is an attempt to assess the ground water quality of Saharanpur district and its surrounding area near by Hindan river, Uttar Pradesh for drinking and irrigation purposes. Study carried out using remote sensing with physiochemical characteristics of the ground water and integration of relevant data. Geographic Information System (GIS) is used to demarcate contaminated zones. The groundwater samples have been collected and analyzed to measure suitability for both irrigation and drinking purpose. Analyzed water samples contained various harmful chemical parameters that are pH, EC, T.D.S, TH, Cl, HCo3, Ca, Mg, R.S.C, Cd, Zn, Fe, Ni, As, S.A.R etc. Analysis of water samples confirmed the presence of heavy metals in significant proportions. The overall analysis of groundwater samples has also confirmed with the help of U.S. Salinity diagram that water is good for irrigation purposes.

Keywords: GIS, Groundwater pollution, Human health, Remote sensing, Semi-treated effluents

Impact of grassland degradation on carbon dynamics: A case study of Banni

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In recent years, grassland degradation in India has become a serious environmental problem as it responsible for altering the carbon dynamics of the ecosystem. Most research on grassland degradation and its impact on carbon dynamics is conducted at the level of communities or at the scale of small regions. To better understand the spatio-temporal variation and driving factors of grassland degradation, monitoring and analysis at broad regional scales are needed. This study systematically describes the state and characteristics of grassland degradation at the Banni region of Gujarat and makes an in-depth empirical analysis of the natural and man-made causes leading to degradation, and analyses what driving factors have influenced degradation and carbon dynamics in this grassland region in recent years. Different biophysical and socio-economic variables, including slope, precipitation, temperature, soil conditions, distance to water body, distance to highway, population density, etc. were evaluated on their impact on observed patterns of degradation. Satellite data for Net Ecosystem Exchange (NEE) for the entire year of 2017 was acquired from the online resources to understand the carbon dynamics of Banni region. The results indicate that different factors had a significant influence on the process of grassland degradation and also on carbon dynamics. It was observed that the rate of degradation has decreased in recent years due to the measures taken such as fencing vulnerable areas, played an important role in this change. However, the capacity of the grasslands to uptake carbon has altered significantly due to increased invasion of Prosopis. The results advance the understanding of grassland degradation and contribute to constructing an empirical and theoretical base for grassland management and planning.

Keywords: Banni, NEE, Carbon dynamics, Ecosystem

Mapping of deforestation in Shoolpaneshwar wildlife sanctuary using multi-temporal radar satellite data

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Forest disturbance is a serious problem, environmentally, socially and economically particularly in developing countries. According to the United Nation, it is estimated that deforestation and forest degradation is 12.9 million hectares per year and the current area of degraded forest is 850 million hectares. Estimating the deforestation will aid in addressing the climate change. As 15% of all greenhouse gas emissions are directly caused by deforestation and up to 33% of climate mitigation efforts depend on preserving forests. Usually the forest disturbances or deforestations are mapped with the help of optical data. In the tropics, frequent cloud cover and the challenge of quantifying forest degradation remain problematic. The present selected site for determining the deforestation area is the Tropical Dry Deciduous forest of Shoolpaneshwar wildlife sanctuary forest in Narmada taluka. They are home to a variety of natural resources and a diversity of flora and fauna. Intensive patrolling of these areas is required as they are hilly and rugged. Inside the sanctuary, the locals resort to the cutting for house construction and other requirements. With the population going up, illicit cutting for domestic requirement also take up big toll on the forests. Our research demonstrates a method to detect forest cover change dynamics, including degradation, using multi-temporal radar images.

Keywords: Deforestation, Shoolpaneshwar wild life sanctuary, Radar backscatter

Extracting foliar traits using AWiFS data

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In tropical forests area, spatial information on forest functional composition is prerequisite to inform management and conservation practices. Canopy foliar traits emphasize the functional biodiversity of forests and have been shown to be remotely measurable using various spatial data. A robust approach for the extraction of the foliar traits using AWiFS data is proposed in this study. In the present study two foliar traits, chlorophyll content and relative water content, of dominant tree leaves of Shoolpaneshwar wildlife sanctuary are considered. The forest canopy chlorophyll content and vegetation water-related properties directly reflect the health and stress of forest. The accurate estimation of the forest canopy chlorophyll content is a significant foundation for researching forest ecosystem cycle models. It has been evaluated that which Vegetation Indices (VIs) can best retrieve canopy chlorophyll and water-related properties of plant so as to make the road map for optimized information extraction. Future mapping studies using this approach can advance scientific investigations and applications based on imaging spectroscopy.

Keywords: Forest, AWiFS, Foliar traits, Chlorophyll content, Relative water content

Landscape metrics for evaluating diversity in Fragstats using spatial data

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Abstract: Plants are the ecology engineer of the forest as they provide resource and habitat to all other organisms of the forest. Plant diversity features changes with respect to species type and location respectively. The species diversity is one of the most important indices for evaluating stability and productivity of forest ecosystem. This study was carried out in the forest area near Pavagadh, aim of this study is to evaluate diversity with help of landscape metrics. Certain index and parameters related to landscape diversity assessment were calculated from non-conventional data using FRAGSTATS software.

Keywords: Species diversity, Landscape metrics, Non-conventional data, FRAGSTATS

Comparison of different classification Methods using LISS IV dataset: A case study of Dahod

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Classification of satellite imagery plays an important role in many application of remote sensing. Classification is a method by which labels or class identifiers are attached to the pixels making up remotely sensed image on the basis of their spectral characteristics. Pixel based classification using digital number is done using various band combinations. Classification to monitor vegetation is the main concern for the sustainable development. Vegetation indices computed from satellite images gives a good indication of the presence of vegetation. It is an indicator that describes the greenness, density and health of vegetation. This paper illustrates the use of various classification techniques like Maximum likelihood, Spectral Angle Mapper (SAM) and decision tree method to classify the different land features in Dahod district. In this paper we evaluate the possibility of land use classification using an integrated approach methods based on property of object with different vegetation indices for single date LISS IV sensor with high resolution of 5.8 meter. Ten vegetation indices (NDVI, DVI, GNDVI, MSAVI2, NDWI, NG, NR, NNIR, OSAVI and VI green) was generated using green, red and NIR band and then image is classified using decision tree method. A comparison has been done between the different classification methods to check which one gives best results. The results indicate that inclusion of vegetation indices can be effectively implemented to produce classified maps with higher accuracy for Indian satellite IRS-P6, LISS IV sensor images and Maximum Likelihood gave the higher accuracy i.e. 0.91.

Keywords: Maximum likelihood, Spectral Angle Mapper, Decision-tree, NDVI

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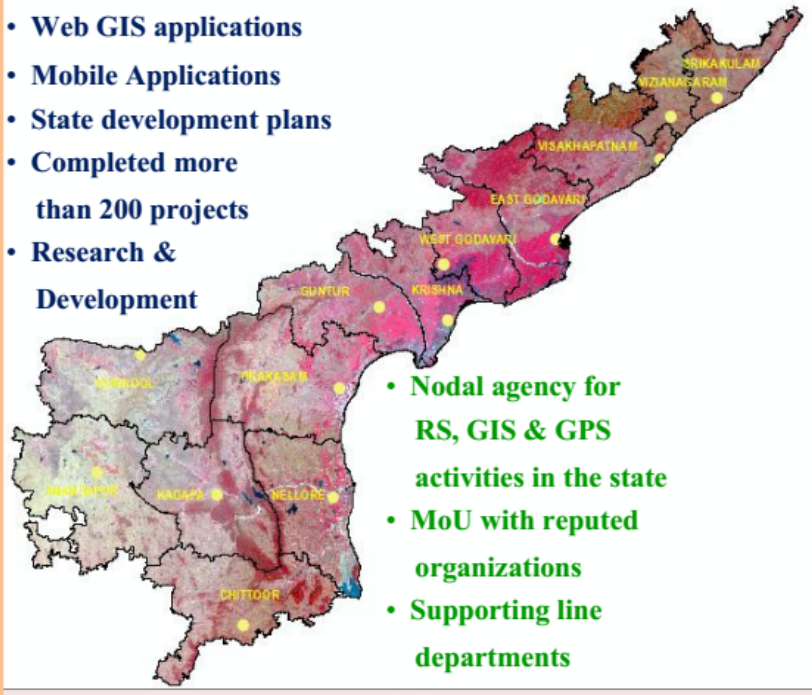

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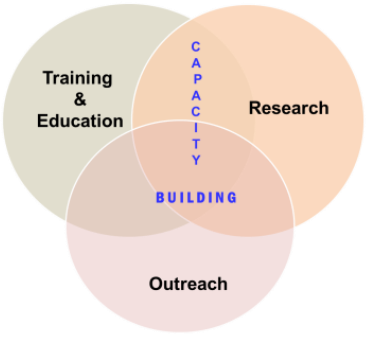
Indian Institute of Remote Sensing (IIRS), a unit of Indian Space Research Organisation (ISRO), Dept. of Space (DOS), Govt. of India is a premier training, education and research institute established to prepare professionals in the field of Remote Sensing & Geoinformatics and their applications.

Background

- Formerly known as Indian Photo-Interpretation Institute (IPI), established in 1966 under the aegis of Survey of India (SOI), DST in collaboration with Govt. of The Netherlands
- Merged with National Remote Sensing Agency (NRSA), Dept. of Space in the year 1976
- Renamed as Indian Institute of Remote Sensing (IIRS) in 1983
- Became an independent Unit of ISRO, Dept. of Space with effect from April 30, 2011



Vision

"Achieve excellence and remain in the forefront for capacity building in Remote Sensing and Geoinformatics and their applications"

Participation in National Mission Projects

- Landslide Hazard Zonation (Parts of Uttarakhand and Himachal Pradesh)
- National Biodiversity Characterization Project
- Geomorphological and Lineament Mapping at 1:50,000 scale (Northern States)
- National Urban Information System (Nahan, Solan and Shimla towns of Himachal Pradesh)
- Land Degradation Mapping at 1:50,000 Scale (Uttarakhand, Uttar Pradesh and Andaman & Nicobar Islands)
- National Carbon Project under ISRO-Geosphere Biosphere Programme
- Land Use/ Land Cover Mapping on 1:2,50,000 scale (Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttarakhand) and 1:50,000 scale (Haryana and Andaman & Nicobar Islands)
- Groundwater Prospects Mapping at 1: 50,000 scale under Rajiv Gandhi National Drinking Water Mission (Chhattisgarh, Madhya Pradesh, Himachal Pradesh, Rajasthan and Uttarakhand)
- Establishment of Village Resource Centres (Himachal Pradesh, Uttarakhand and Uttar Pradesh)
- Monitoring and Assessment of Ecosystem Processes in North West Himalaya

Education / Training Programmes

❖**Educational Programmes**

- ✓ M.Tech. in RS & GIS
- ✓ M.Sc. in GFM

❖**Training Programmes on RS&GIS**

- ✓ Post Graduate Diploma in RS & GIS (*10 months*)
- ✓ Certificate Programmes (*Sponsored by ITEC, MEA) - (8 weeks twice a year*)
- ✓ NNRMS–ISRO Sponsored Certificate Course for University Faculty *(8 weeks)*
- ✓ Decision Makers Course *(4 days)*
- ✓ User defined Special / Tailor-made courses (*1 to 8 weeks*)

Facilities

- State-of-the-art Digital Image Processing, GIS, Digital Photogrammetry & Thematic Applications Laboratories
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- Studio for Distance Learning Programmes
- Satellite Data Archives & Instrumentation Facility
- Central Library
- Carbon Flux Tower
- Spacenet
- Hostels

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- till November, 2018

- Professionals trained / enrolled: **11599**
- Foreign participants trained: **1175** from 96 Countries *(excluding CSSTEAP)*
- M.Tech. (**328**) / M.Sc. (**198**) students: **526** (*since 2002*)
- Customized courses: **4163** participants
- IIRS Outreach Programme (DLP)
  - Live & interactive Programme: **86624** participants (**880** Institutions)
  - E-learning: Learners- **5150**
    Registered for Certificates- **1623**
    Certificates Issued -**91**

Collaborations

- ITC, Twente University, The Netherlands
- Wageningen University, The Netherlands
- Collaborations with Premier Institutes in the Country
- WGCapD Committee on EO Satellites
- Kumaon University
- Doon University, etc.

Thrust Areas of Research

- Hyperspectral and Microwave Remote Sensing
- Satellite and Terrestrial Photogrammetry
- Geospatial Data Modelling, Geo-visualisation and WebGIS
- Monitoring and Assessment of Ecosystem Processes and Services in Western Himalaya
- Measurement, Modelling and Assessment of Carbon Pools and Fluxes
- Land Surface Processes Parametrization and Modelling
- Land Use and Land Cover Change (LULCC) Modelling and Assessing its Impact along with Climate Variability/ Change on Water Recourses
- Mapping, Monitoring and Modelling of Geological Hazards and their Vulnerability and Risk Assessment
- Planetary Geoscience
- Climate Change impact on Biodiversity
- Biomass/Carbon assessment using LiDAR, Hyperspectral and Microwave data
- Forest Ecosystem services

Hosting of CSSTEAP

- Hosting Headquarters of CSSTEAP (Affiliated to the United Nations)
- Conducting PGD/ M.Tech. in RS&GIS and Short courses

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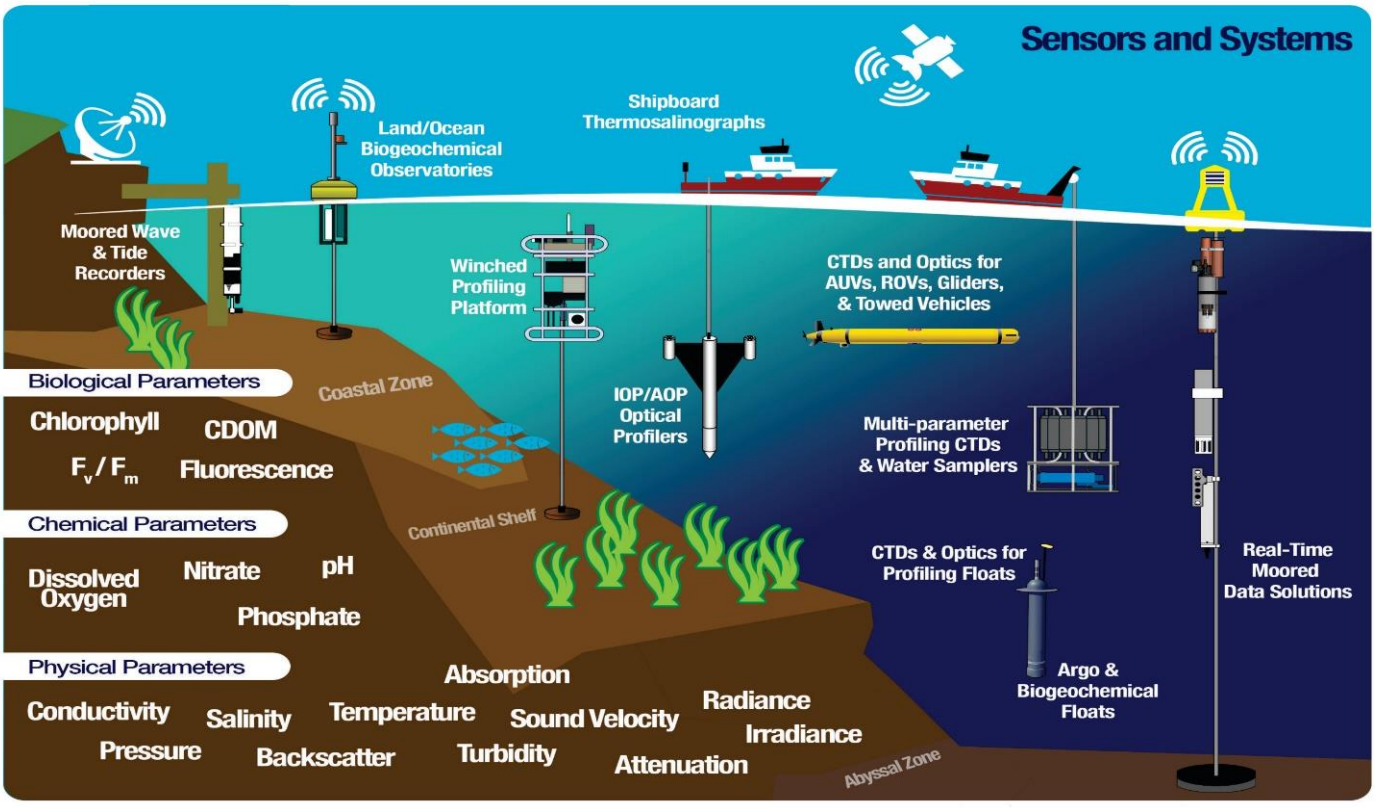

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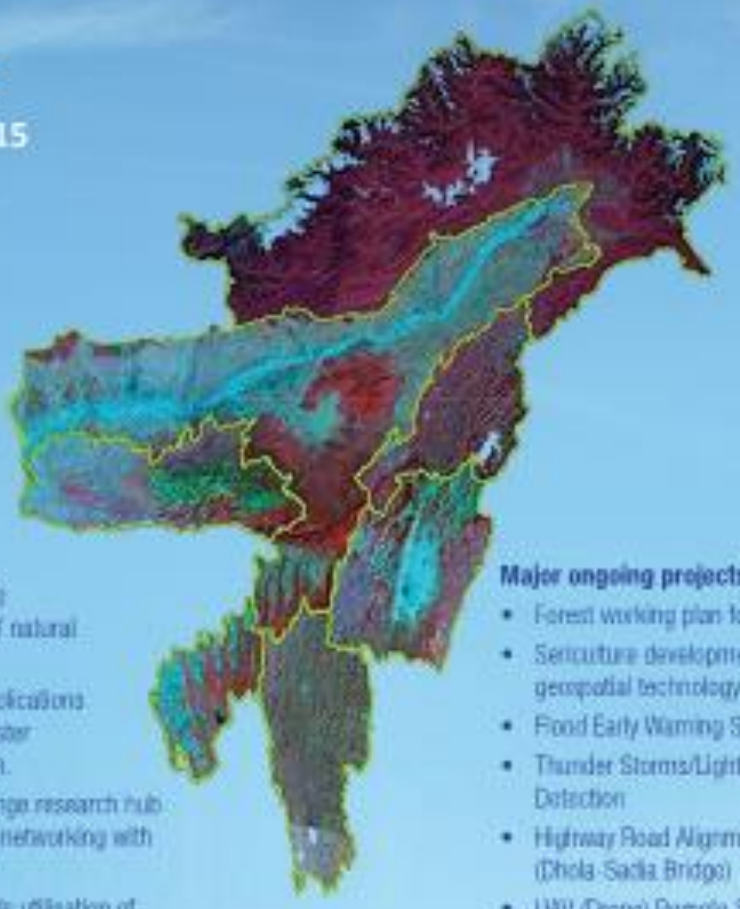

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NESAC role in development support

- Provides Remote sensing based natural resource information base to facilitate the management of natural resources and infrastructure planning.
- Provides operational satellite communication applications services supporting education, health care, disaster management and developmental communication.
- Development of space science and climatic change research hub by installation of necessary instrumentation and networking with various academic institutions of NER.
- Academic interface and capacity building towards utilisation of space science & technology in research and applications.

Major ongoing projects at NESAC

- Forest working plan for NER States
- Sericulture development using geospatial technology
- Flood Early Warning System
- Thunder Storms/Lightning Detection
- Highway Road Alignment (Dhola-Sadia Bridge)
- UAV (Drone) Remote Sensing
- Geospatial web-portals and Dashboard applications
- Doppler Weather Radar
- Tele Education/Tele Medicine

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Soil Laboratory

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Ka band precipitation experiment

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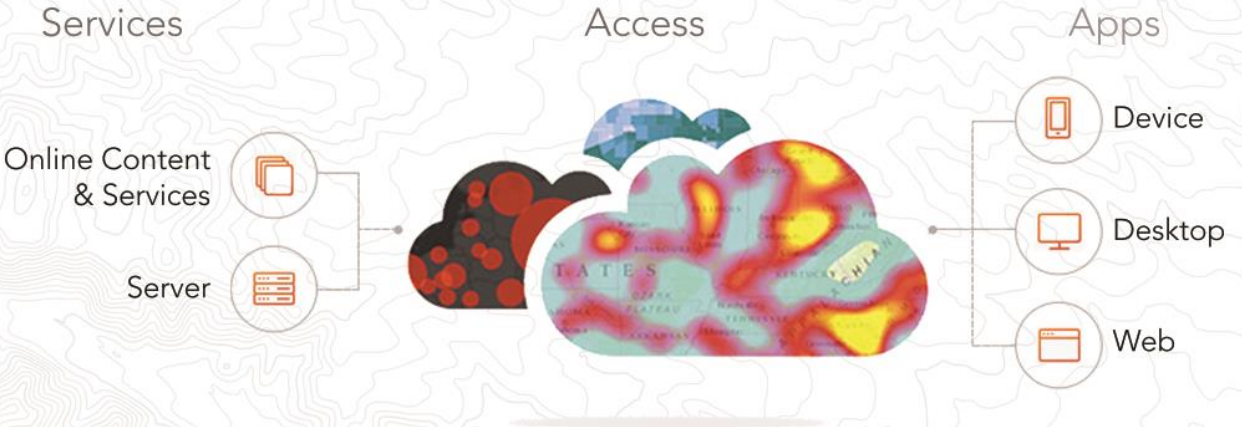

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