NNRMS e-Bulletin

NNRMS (B) - 40

MAY 2016

DEPARTMENT OF SPACE, GOVERNMENT OF INDIA, BENGALURU

BULLETIN OF THE

NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM

NNRMS (B) - 40

May 2016

NNRMS
Department of Space
Antariksh Bhavan, New BEL Road
Bengaluru - 560 231
INDIA

Editorial Advisors

Dadhwal VK, Director, NRSC
Tapan Misra, Director, SAC
Annadurai M, Director, ISAC

Editorial Board

Arunan S, Director, EOS
Diwakar PG, Deputy Director (RSA), NRSC
Sarnam Singh, Dean (Academics), IIRS

Technical Guidance

Shantanu Bhatawdekar, Associate Director (A), EOS

Technical Support and Compilation

Paul MA, Scientist/Engineer SF, EOS
Bandyopadhyay S, Scientist/Engineer SG, EOS

For details and inputs, please write to

Director
Earth Observations System
ISRO Headquarters
Antariksh Bhavan
New BEL Road
Bengaluru 560 231

Email: dir.eos@isro.gov.in

Fax: 91-80-2341 3806

Published by

P&PR Unit, ISRO Headquarters on behalf of
National Natural Resources Management System (NNRMS)
Antariksh Bhavan, New BEL Road
Bengaluru 560 231

Designed by

Imagic Creatives Pvt. Ltd., Bengaluru 560 071

MESSAGE

Over the years, Indian Earth Observation satellites have been playing a significant role in enabling inventory & management of natural resources, infrastructure planning and disaster management. These satellites provide finest opportunities to map the earth's resources at different spatial, spectral and temporal resolutions and generation of variety of products and services to support host of thematic applications in the areas of land & water, ocean & atmosphere, ecology & environment etc., including implementation of developmental plans and decision making processes.

While Indian Earth Observation programme ensures availability of remote sensing data, the National Natural Resources Management System (NNRMS) strives to optimize utilization of remote sensing data and operationalisation of space applications with active involvement of stakeholders. NNRMS has been playing a key role in institutionalisation of space technology applications in many user ministries/departments.

NNRMS brings out periodic bulletins on different themes comprising of articles on water resources, agriculture, biodiversity, urban planning, remote sensing and GIS applications and information about satellites launched by ISRO and also reports on major events & activities of NNRMS/Earth Observation for wider circulation. These bulletins have been widely acclaimed for its information and content by EO fraternity, academia, researchers and others interested in remote sensing and GIS applications in the area of natural resources management and monitoring.

I am happy to note that, now onwards NNRMS bulletins are brought out in e-format for faster, wider and easier outreach. I sincerely hope that this effort would immensely benefit the students, researchers in the areas of earth observation and natural resources management.

A. S. Kiran Kumar
Chairman
ISRO/ Secretary, DOS

PREFACE

Today, in the area of Earth Observation, our country has a constellation of 13 Indian Remote Sensing (IRS) satellites comprising of thematic series viz. Resourcesat, Cartosat, Oceansat and Weather & Atmosphere. These satellites, with a variety of instruments onboard, are providing data to cater to various applications ranging from agriculture, water resources, bio-resources, urban planning, environment monitoring, earth sciences and study of ocean and atmosphere. National Natural Resources Management System (NNRMS), which was set in the year 1985, plays a major role in facilitating optimal utilization of the country's natural resources through a proper and systematic inventory of the resource availability through effective planning.

NNRMS Bulletin, which is regularly published from NNRMS Secretariat acts as a conduit for information dissemination pertaining to various remote sensing and GIS applications in the country. So far, 39 volumes of NNRMS Bulletins have been published and have been well received and appreciated by many including, teachers, students and researchers of the various academic Institutions and Organizations.

From the current issue onwards, the NNRMS Bulletins will be published in e-format for its fast and much wider circulation. The current Bulletin is covering select articles from Remote Sensing and GIS applications, information about new satellites launched by ISRO and also reports on major events and current activities of NNRMS/Earth Observation area.

S. Arunan
Director, EOS

CONTENTS

General Information

CHAMAN: A NATIONAL LEVEL PROGRAMME FOR HORTICULTURAL ASSESSMENT & DEVELOPMENT

Ray SS[1], Mamatha S[1], Manjunath KR[2], Uday Raj[3], Seshasai MVR[3], Singh KK[4], Kimothi MM[1], Parihar JS[2] and Mamta Saxena[5]

[1]Mahalanobis National Crop Forecast Centre, DACFW, Pusa Campus, New Delhi
[2]Space Applications Centre, ISRO, Ahmedabad
[3]National Remote Sensing Centre, ISRO, Hyderabad
[4]India Meteorological Department, New Delhi
[4]Horticulture Division, DACFW, Pusa Campus, New Delhi-110012
Email: shibendu.ncfc@nic.in

Introduction

Over the years, horticulture has emerged as one of the potential agricultural enterprises in accelerating the growth of economy. Its role in the country's nutritional security, poverty alleviation and employment generation programmes is becoming increasingly important. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of agro industries which generate huge employment opportunities.

Ministry of Agriculture has been implementing various programmes and schemes towards the development of horticulture, under the scheme of Mission for Integrated Development of Horticulture (MIDH). However, there is still a lot of scope in harnessing the potential of the horticulture sector. One of the key areas to be looked into is developing a very accurate and standard inventory system for horticulture crops and practices. As the majority of horticultural crops are grown as part of the homestead, it is difficult to collect timely and proper statistics. Considering the fact that India is endowed a great diversity of agro climatic zones, allowing for production of a variety of horticultural crops such as fruits, vegetables, flowers, spices, plantation crops, root and tuber crops, medicinal and aromatic crops. These crops being capital as well as labour intensive, there is great popential to use modern technologies for development of horticulture.

Horticulture sector has also seen extensive use of remote sensing data. In fact, the birth of remote sensing applications in the country was in the field of horticulture, i.e. the conduct of an experiment aimed at early detection of coconut plantation wilt disease (Dakshinamurty et al., 1971). There has been quite a large number of studies/application of remote sensing data in horticulture sector, which include inventory of crop, site suitability, post-harvest infrastructure, precision farming, disease assessment etc. Apple plantations in Arunachal Pradesh and cultivation of grapes in large areas in Mizoram are the example of successful use of geomatics in horticulture development and planning, (Panigrahy and Manjunath, 2009).

In this context, Ministry of Agriculture & Farmers Welfare launched a programme, called CHAMAN (Coordinated Horticulture Assessment & Management using geoinformatics) during September, 2014, with an aim to use space technology for better horticultural inventory and development. The two and half year duration programme has following objectives.

Objectives of CHAMAN Project

i. Area assessment and production forecasting of 7 major horticultural crops in selected districts of major states

ii. Geospatial applications for Horticultural Development and Management Planning

iii. Detailed scientific field level studies for developing technology for crop identification, yield modelling and disease assessment

Area and Production Assessment

This first objective has two components: a) Remote Sensing technique and b) Sample survey techniques. While Mahalanobis National Crop Forecast Centre (MNCFC) is the National Level Agency (NLA) for the remote sensing component, Indian Agricultural Statistics Research Institute (IASRI) is the NLA for the sample survey component. This article deals with the remote sensing component of the project.

Area and production assessment is being carried out for selected crops in the selected districts of major states. The crops were selected based on the production share, as mentioned. All those major States are being covered for a particular crop, which account for about 70% share of the country's production and at least 55% of the area of that crop in the entire country (Table 1). The districts predominantly growing the selected fruit/vegetable crops in the State are selected for the purpose of area assessment (Figure 1). In total 180 districts of 12 states are covered for Horticulture crop inventory under CHAMAN project. In the fruit crops only managed orchards are considered. Amongst, vegetables and spices the major concentrated pockets are being covered. Satellite data such as Resourcesat-2 LISS III (23.5 m resolution), LISS IV (5.8 m) and LISS IV + Cartosat (2.5 m) merged product are being used depending upon the spatial extent and heterogeneity of the crop cover (Figure 2). Currently, District/State/National level area and production estimation of potato are being operationally carried out by MNCFC, while district level Onion area estimates, for selected states, is being generated by NHRDF (National Horticultural Research & Development Foundation).

Table 1. Horticultural Crops Covered under CHAMAN project and their major growing states, where the assessment will be carried out

Crop type	Crop	State
Fruit	Banana	Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu
	Mango	Andhra Pradesh, Bihar, Gujarat, Karnataka, Uttar Pradesh
	Citrus	Andhra Pradesh, Gujarat, Madhya Pradesh, Maharashtra, Punjab
Vegetables	Potato	Bihar, Gujarat, Punjab, Uttar Pradesh, West Bengal
	Onion	Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra,
	Tomato	Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Odisha, West Bengal
Spices	Chili	Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha, West Bengal

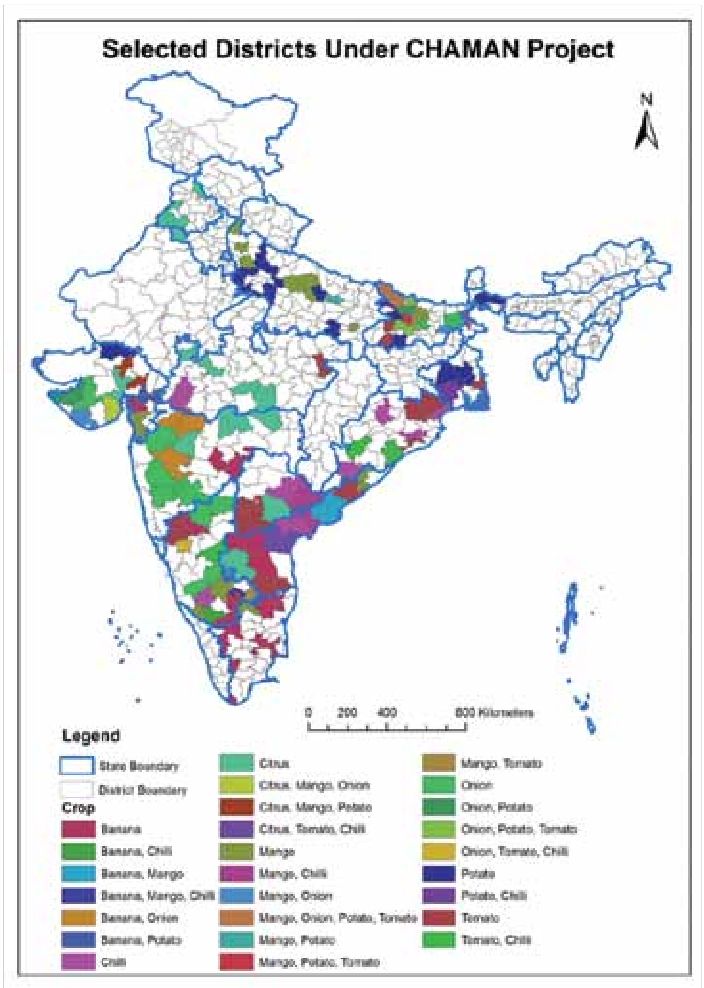


Fig. 1: Districts covered under CHAMAN project for crop inventory

Onion Crop in Nashik, Maharashtra as seen in LISS III data

LISS III data showing Banana crop in Bharuch, Gujarat

LISS IV Data showing Chili Crop in Dharwad, Karnataka

Mango Orchards in LISS IV+ Cartosat Merged Data in Saharanpur District, UP

Fig. 2: Various types of satellite data used for horticultural crop inventory

Geospatial Technology for Horticultural Development

Under this project, satellite data and various other thematic information, viz. land use/land cover map, weather and soil data, existing infrastructure information, socio-economic data will be analysed in GIS (Geographical Information System) tools for generating developmental plans.

The Horticultural development studies can be grouped into following categories.

i) **Site-suitability:** for introduction/ expansion of important horticulture crops in wastelands, e.g. horticultural development of Jhum (shifting cultivation) lands in North Eastern states. It is also proposed to carry out the site-suitability for expansion of grape orchards in different parts of the country.

ii) **Post-harvest Infrastructure:** GIS and remote sensing will be used to assess the need and to find the optimum locations for infrastructures such as cold chains, markets, etc. (Figure 3)

iii) **Crop Intensification:** In areas where cropping intensity is low and regions of unutilized/under-utilized, short duration horticultural crops can be incorporated into the crop rotation.

iv) **GIS Database Creation:** Under this aspect the orchard maps are being generated, along with different characteristics (age, species, variety etc.), which are being uploaded on Bhuvan platform for better management of the Orchards (Figure 4).

v) **Orchard Rejuvenation:** This would aid in identifying the plantations/ orchards that need rejuvenation and assess the shifting of orchard areas especially of Apples in Himachal Pradesh, Mango (West Bengal & UP) (Figure 5), Orange (Darjeeling) and Citrus in Arunachal Pradesh.

vi) **Aqua-horticulture:** Wetland maps created earlier at 1:50000 scale for the entire country using satellite data have been used for this study. Various horticultural crops (e.g. Makhana/Fox nut) are grown in wetlands (Figure 6). A GIS database will be created for selected sites to understand the ecology and economics of these crops so that these can be replicated.

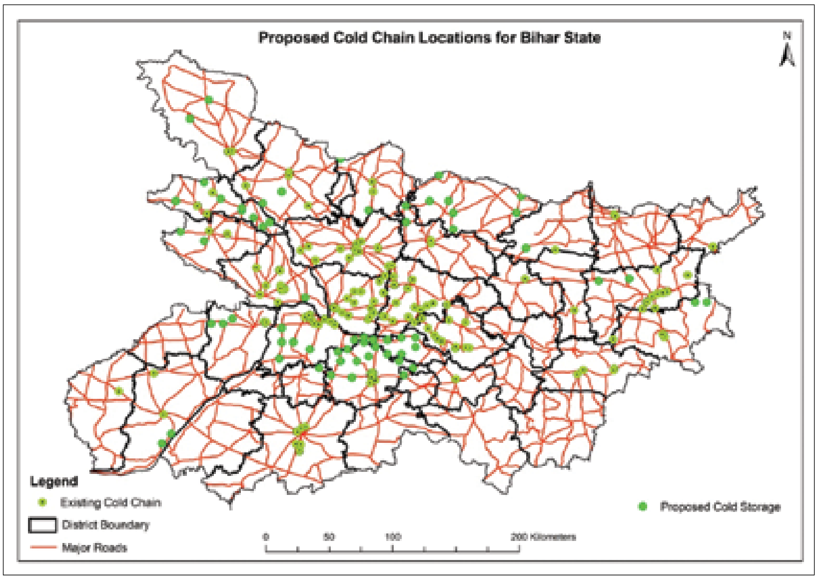


Fig. 3: Identification of sites for proposed cold storages in Bihar state

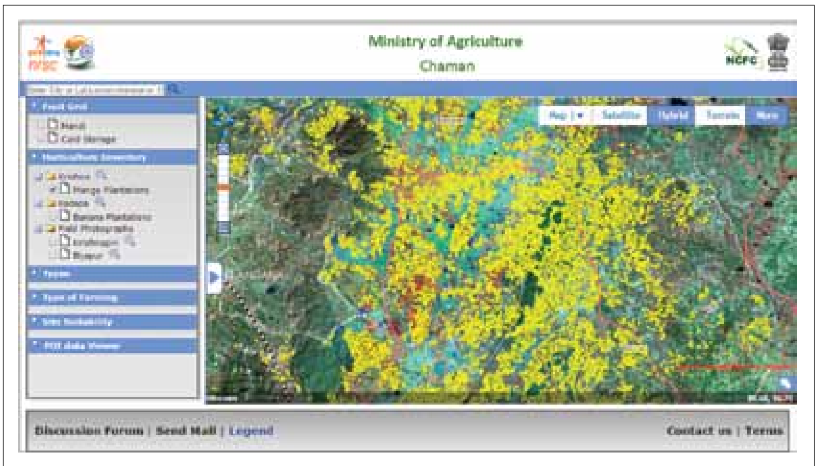


Fig. 4: CHAMAN portal on Bhuvan showing Mango Plantations

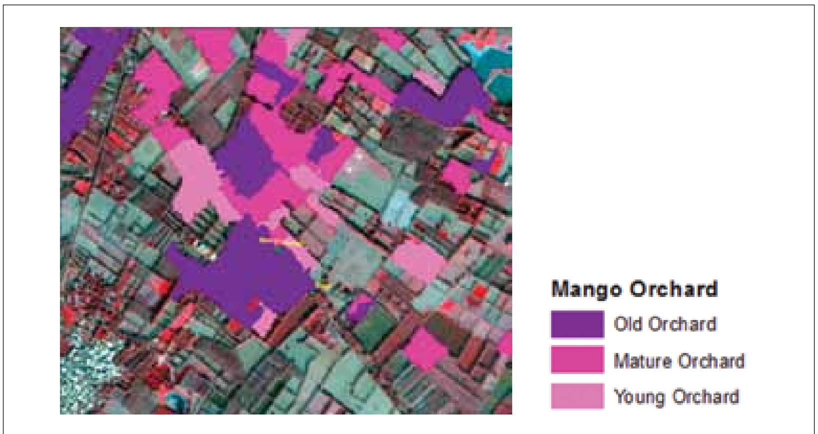


Fig. 5: Mango Orchard classified into three classes of age based on tonal and textural properties

Research Studies

Differentiation of crops within vegetable crops, yield modelling, stress detection (disease & nutrient) are the upcoming research issues in use of remote sensing in horticulture. It is proposed that 2 to 3 sites of major vegetable growing areas (e.g. Malerkotla in Punjab, Sonepat, Panipat and Karnal in Haryana, Dhapa Area in Kolkata, etc.) shall be chosen on pilot basis for collecting multi-level (ground, airborne, satellite based) data. This would facilitate in developing spectral signatures for major vegetables by covering a small area (Figure 7) and also develop the respective methodology for estimation of area and production for them. This would provide the framework in preparing estimates of area and production of vegetables in near future with use of remote sensing applications for horticulture. An attempt would be made to estimate production (acreage and yield) of Kharif onion using microwave remote sensing technology.

Precision farming tries to characterize within-field variability in crop and soil conditions and then adjust the management practices accordingly. High resolution remote sensing data has been shown to be useful in estimating plant parameters and characterizing plant variability. This study is being carried out, along with the ICAR institute, National Research Centre for Grapes (NRC-Grapes), in selected grape orchards of Nashik using ground observations and high resolution airborne/satellite data.

Fig. 6: Water Chestnut (PaniSingada) and Fox nut (Makhana) cultivation in Wetlands of Darbhnga district of Bihar

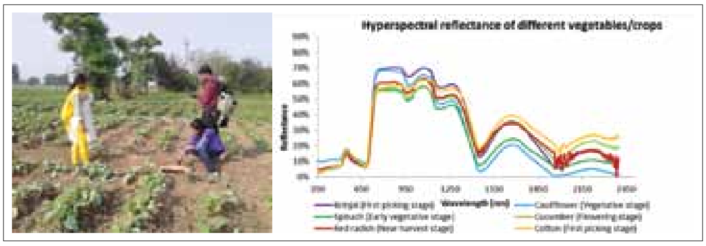


Fig. 7: Spectral profile of different vegetable crops collected form vegetable fields in Malerkotla, Punjab

Implementation Partners

Large numbers of organizations are partners in this activity. The major responsibility of project coordination and implementation is with MNCFC and its incubation, development and technology transfer are with Space Applications Centre, ISRO. State Horticulture Departments have a strong role in the project, not only for providing the crucial field information, but also providing inputs for horticultural developmental plans. Institution wise major responsibilities are summarized in Table 2.

Table 2. Organizations involved in CHAMAN project and their role

Name of the Agency	Responsibility
Horticulture Division, DACFW	Programme Lead
Mahalanobis National Crop Forecast Centre (MNCFC), DACFW	Coordination, Implementation
Space Applications Centre (SAC), ISRO	Technology Development & Technology Transfer
National Remote Sensing Centre (NRSC), ISRO	Geospatial Support and Orchard Mapping in Peninsular India
National Horticultural Research and Development Foundation(NHRDF)	Implementation Partner, especially for vegetable crops
India Meteorological Department (IMD)	Yield Model Development
ICAR Centre(s) (e.g. NRC – Grapes)	Knowledge sharing, Field Experimentation, Precision Farming
State Horticulture Departments	Ground truth collection and development of implementation plan
State Remote Sensing Centre(s)	Field data collection,Image and GIS analysis

Capacity Building

Capacity building, in the field of geospatial technology for horticulture, is also one of the major goals of the CHAMAN project. Since State Horticulture Department officials are the end users of the CHAMAN project, 10 two-day training programmes were carried out for 191 officials of 12 state horticulture departments (Table 3). The training programmes included lectures on Basics of Remote Sensing & GIS & their Applications in Horticulture and field demonstrations of field data collection using smartphones. The trainings were jointly imparted by MNCFC, SAC, NRSC and State Remote Sensing Centres.

Acknowledgement

Initiation and implementation of such a national level project would not have been possible without the strong support of various organizations and persons. Authors would like to thank Sh. Ashish Bahuguna, former Secretary, DAC; Sh. Siraj Hussain, former Secretary, DACFW; Sh. A. S. Kiran Kumar, Secretary, DOS; Sh. D. K. Jain, former Additional Secretary, DAC; Sh. Raghavendra Singh, Additional Secretary, DACFW; Sh Tapan Misra, Director, SAC; Dr. Vinay K Dadhwal, Director, NRSC; Dr. L. S. Rathore, Director General, IMD; Sh. Sanjeev Gupta & Sh Sanjeev Chopra, former Joint Secretaries of DAC; Sh. Narendra Bhooshan & Sh. Shkail Ahmed, Joint Secretaries of DACFW; Smt. Arundhati Singh, former Director (Hort), DAC; Scientists of SAC, NRSC, MNCFC & other partner organizations, Analysts and Consultants under CHAMAN project for their strong support.

Table 3. Capacity building activity carried out under CHAMAN project

S.N.	State	Training imparted by	Venue	Participants
1	Bihar	MNCFC	BIRSAC, Patna	23
2	Odisha		ORSAC, Bhubaneswar	12
3	West Bengal		RRSC-E, ISRO, Kolkata	19
4	Punjab		PRSC, Ludhiana	15
5	Gujarat	SAC	SAC, Ahmedabad	13
6	Madhya Pradesh		MPCST, Bhopal	21
7	Uttar Pradesh		RSAC-UP, Lucknow	12
8	Andhra Pradesh	NRSC	NRSC, Hyderabad	10
9	Telangana		NRSC, Hyderabad	16
10	Maharashtra	RRSC-C, NRSC	RRSC-C, ISRO, Nagpur	16
11	Karnataka	RRSC-S , NRSC	RRSC-S, Bengaluru	20
12	Tamil Nadu		RRSC-S, Bengaluru	14
Total				**191**

References

Coordinated Horticulture Assessment & Management using geoinformatics (CHAMAN): A Proposal submitted to the Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India,May, 2014

Dakshinamurty, C., Krishnamurthy, B., Summanwar, A.S., Shanta, P., and Pisharoty, P.R. (1971), Remote Sensing for coconut wilt, Proc. 6th Int. Symp. Rem. Sens. Environ., Ann Arbor, 25-29.

Panigrahy, S. and Manjunath, K. R. (2009), Horticulture Studies (2000-2008): Highlights of the results and achievements of the project. Project Report.EOAM/SAC/AMD/HORT/PR/01/2009. Space Applications Centre, Ahmedabad.

National Meet on 'Promoting space technology tools and applications in Governance and development'

- National meet on "Promoting Space Technology based Tools and Applications in Governance and Development" was held on September 7, 2015 at New Delhi. Action plans, prepared jointly by Ministries/Departments and ISRO/ Department of Space for 58 Ministries were presented during the National meet.
- About 160 projects across various Ministries/Departments have emerged in the areas of Natural Resources Management, Energy & Infrastructure, Disaster & Early Warning, Communication & Navigation, e-Governance & Geo-spatial Governance, Societal Services, and Support to Flagship programmes.

MoU Signing

MoU Signing with DoLR

MoU Signing with IBM

- About 1200 delegates across 60 Central Ministries/ Departments, 28 States and 5 Union Territories participated in this national meet including Secretaries, Additional Secretaries, Joint Secretaries to Government of India, Chief Secretaries and Principal Secretaries of the States and senior functionaries of Central and State Governments, officials from Prime Minister Office & Cabinet Secretariat, young administrators as well as experts from academia and institutions.

- The Prime Minister of India addressed during the concluding session of the National meet and emphasized the need for new initiatives for governance and development, using space technology applications
- Subsequent to the National Meet, ISRO/ Department of Space has constituted 22 dedicated Working Groups (WGs) to facilitate frequent interactions with the Ministries/ Departments, constant follow-up of the project activities, enabling formation of Space Technology cells, exploring newer space based applications, and for capturing the Capacity Building requirements.
- Actions have been taken up for 125 projects emerged out of 160 projects and significant progress has been made in 56 projects. ISRO has already signed MoUs with 28 Central Ministries and 10 State Departments. Post National meet, about 2600 officials have been trained across various Ministries / Departments.
- As advised by the Prime Minister to conduct State Meet, ISRO has constituted 28 Task Teams to coordinate with State Remote Sensing Applications Centre (SRSACs) to steer the conduct of the State meet. So far, State Meet has been completed for 6 States - Haryana, Bihar, Uttarakhand, Meghalaya, Nagaland & Mizoram.

Capacity Building

National Workshop on " Inventory and Site management plan for Heritage sites & Monuments of National Importance"

Workshop on "Application of Space Technology in Water Resources", Guwahati.

Capacity Building Under IWMP on Bhuvan Srishti & Drishti

Demonstration cum training to NDRF

PARAMETER RETRIEVAL OF AUTUMN PADDY IN PART OF TAMIL NADU, INDIA USING RISAT-1 SYNTHETIC APERTURE RADAR DATA

Dipanwita Haldar, Patnaik C, Manjunath KR and Manab Chakraborty
Earth, Ocean, Atmosphere, Planetary Sciences and Applications Area (EPSA)
Space Applications Centre, Indian Space Research Organisation, Ahmedabad-380 015
Email: dipanwita@sac.isro.gov.in

Introduction

Rice, a major staple food crop in India, is grown mostly during the kharif season in most parts of the country, but Tamil Nadu follows a continuous rice calendar throughout the year namely Kuruwai, Samba and Navarai. The paddy transplanted during October-November time frame viz. Samba rice accounts for majority of Tamil Nadu's rice acreage and production. Extensive cloud coverage hinders optical sensors to sense the crop growth, particularly during monsoon season and retreating monsoon season, thus SAR data remain the only viable option. The signature of rice is unique and dynamic when monitored using SAR data due to the presence of water background in most parts of the country throughout majority of its growth phase (Chakraborty et al., 1997). Choudhury and Chakraborty (2006) used multitemporal RADARSAT ScanSAR (SCNB) data and a knowledge-based decision rule classifier to achieve 98% accuracy in mapping rice. Chen and McNairn (2006) used multitemporal RADARSAT-1 fine mode images, with an integrated change detection and neural network approach, to delineate rice production areas. A minimum mapping accuracy of 96% was achieved.

Tamil Nadu has recently switched over to System of Rice Intensification (SRI) technique of paddy cultivation, which does not maintain standing water/ ponded fields. SRI is a method of raising rice that produces substantially higher yields with the planting of far fewer seedlings and the use of fewer inputs than either traditional methods (i.e., water) or more "modern" methods (chemical fertilizer or agrochemicals). This system of Rice intensification has been successfully used in a number of countries, (Hatta, 1967 and Puard et al., 1989). A positive correlation between number of panicles and grains per panicle with "SRI" method of rice cultivation and showed that an average increase in yield was associated with large number of weedings was reported by Bonlieu (1999). Kumar and Shivay (2004) reported the benefits associated with the SRI (Sivanagaraju, 2006).

Results using multi-temporal ERS/Radarsat imagery have confirmed that C-band HH backscatter can detect differences in crop type, crop growth stage and crop indicators. (Panigrahy et al., 1999). National rice acreage is being operationally carried out for the major 13 rice growing states in kharif (since 1998) and 4 states in Rabi season since 2007. Cross-polarized radar returns (HV or VH) result from multiple reflections within the vegetation volume and thus can add an extra dimension to the existing single polarization mode (McNairn et al., 2002). RISAT-1, the country's first indigenously developed SAR satellite, potential to monitor rice acreage (Chakraborty et al., 2013). In the present study rice crop identification and classification was attempted using RISAT-1 C-band two and three-date HH and HV- polarization data with central incidence angle 37°.

The decision rule based model is suitably used to study the rice crop with the RISAT-1 data. Also the signatures for SRI technique implemented in Tamil Nadu were suitably developed to refine the models.

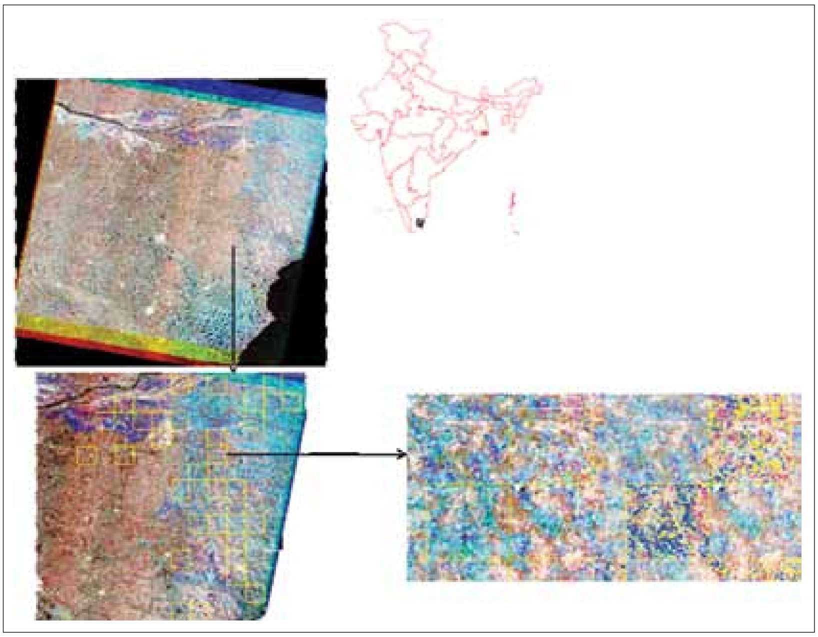


Fig. 1: RISAT -1 MRS 3-date-HH composite (25/10, 19/11 and 14/12/2012) of Tamil- Nadu -Thanjavur, Pudukottai and Shivagangai Districts Zoomed view for Thanjavur dist. showing first date (blue), second (yellow) and third (magenta) date transplanted rice

Datasets and study area

RISAT-1 C-band (5.35 GHz) dual-polarization (HH, HV) MRS L2 (level 2) data (18 m pixel spacing and 37° incidence angle) of 25th October, 19th November and 14th December, 2012 were used (Figure 1). Data have been collected for three different dates viz at transplanting, tillering and peak vegetative stage, these dates are sufficiently spaced in phenology to identify rice fields. Three sets of MRS scenes covering 8 main rice growing districts of Tamil Nadu have been used in the study. The districts are Thanjavur, Pudukottai, Sivagangai, Villupuram, Tiruchirapalli, Cuddalore, Aryalur and Perambalur encompassing the central coastal part of Tamil Nadu. Ground survey data of 40 sites distributed over 8 districts of Tamil Nadu, transplantation dates from farmers interview, wet above ground green biomass by destructive sampling at 50% of the above points, biophysical parameters like row to row distance, tillers per hill, grains per panicle, chaffiness were collected through ground survey. The present study is an attempt to monitor the rice growing areas with the initial datasets (MRS, Medium Resolution SAR) from this satellite, which is becoming the SAR workhorse for crop monitoring.

Methodology

Processing of the RISAT-1 data

RISAT-1 data analysis was carried out using PCI Geomatica (ver. 9.0) software and HH & HV images were imported to native raster format of PCI Geomatica (.pix) and transferred to a single file as two separate channels. The image was filtered by enhanced Lee adaptive filter with kernel size 5 × 5, as established by standard procedures. Calibration for HH and HV polarization amplitude image were carried out using the calibration constant. The step wise detailed methodology is presented in flowchart Figure 2.

The three-date images were co-registered by fitting manual GCPs with about 20-25 well-distributed points throughout the image scene. Classification of the rice area is performed inside the sample segments to derive the crop

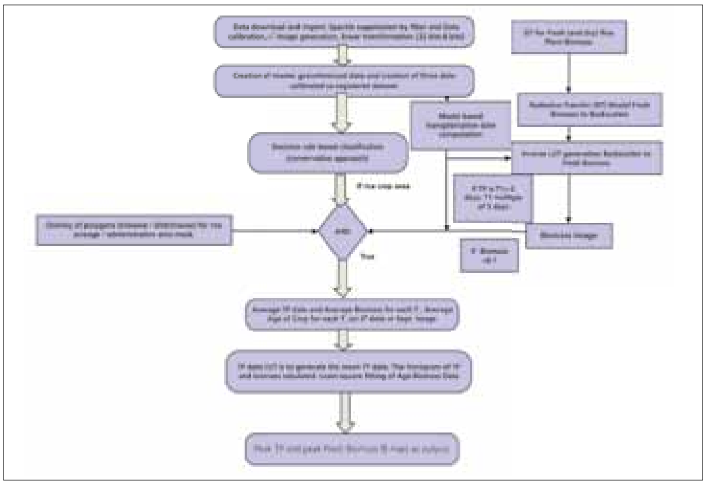


Fig. 2: Methodology for acreage estmiation and biomas retrieval

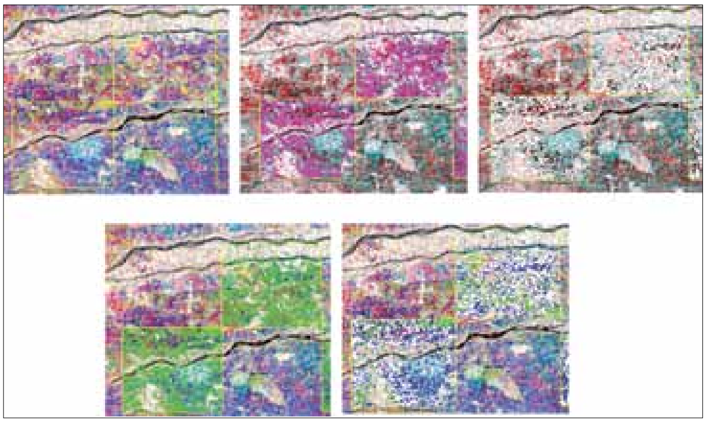


Fig. 3: a-c left to right first line, d-e second line a) 3 date(25th Oct, 19th Nov and 14th Dec, 2012) SAR FCC of a part of Tanjore district, Tamil Nadu, b)2 date HH based overlay (pink) c) 2 date HH& HV based overlay(white) on 2- date HH FCC d) 3 date HH overlay (green) e) 2 date HH&HV based overlay (white) on 3- date HH FCC. Green region in e) denotes the area omitted in 2-date

proportion and finally aggregated to obtain district rice acreage.

Use of cross-polarised channel

Addition of HV channel takes care of the fallow and river border region otherwise classified as rice using two-date HH data. These effects are more dominant in SRI technique of cultivation where we do not find ponded fields. Here the chances of committing exposed moist soils as paddy are high when using only HH data especially in the two-date case. These effects are very prominent in boundaries/border areas of water bodies and can be eliminated by adding the HV polarization for classification. A hierarchical decision rule based model was built to classify the rice areas using multidate SAR data. Tables 1 & 2 show the improvement in classification over single polarization.

The procedure can be summarized as follows:

Crop proportion = Pixel classified as rice in sample segments/ Total number of pixels within sample segments.

Acreage = Crop proportion × N × Segment area in suitable units.

where N is the total population of agricultural segments.

Table 1: Contingency table for 3-date HH classification for all major features in the study area

Class	Rice	Other crops	Fallow	Urban	Waterbody	Total
Rice	95.73	0.00	4.27	0.00	0.00	100.00
Other crops	0.00	85.99	14.01	0.00	0.00	100.00
Fallow	0.00	0.00	89.90	10.10	0.00	100.00
Urban	0.00	0.00	3.69	96.31	0.00	100.00
Waterbody	0.00	0.00	1.06	0.00	98.94	100.00

Table 2: Contingency table for 2-date HH and HV classification for all major features in the study area

Class	Rice	Other crops	Fallow	Urban	Waterbody	Total
Rice	88.14	0.00	11.86	0.00	0.00	100.00
Other crops	0.00	88.28	11.72	0.00	0.00	100.00
Fallow	0.00	0.00	91.85	8.15	0.00	100.00
Urban	0.00	0.00	2.89	97.11	0.00	100.00
Waterbody	0.00	0.00	0.72	0.00	99.28	100.00

Retrieval of Transplantation (TP) date and biomass

Tranplantation date

Multi-date SAR image is used for derivation of the TP date. Model based TP date computation is done from the multidate calibrated SAR data. The feasilibity with Radarsat data has been demonstrated by Haldar et al., 2014. The progress of emergence of the plant above the surface of water in subsequent date helps to generate the TP map. The emergence separates the transplanted surface from permanent water body. The TP date and biomass fresh weight are recorded from predetermined field campaigns. At unsampled locations these parameters are computed from the backscatter dB image with the help of a look up table. These look up tables have been generated over a dynamic range of data in the image validated with a large ground truth points. For generating the TP date, appropriate date image is to be used, nearest date in the 25 days interval is to be given. The areas transplanted much before the first date of pass has limitation to get the starting value. If the first date of data is chosen such that the transplantation has just begun, we would be able to estimate the TP dates with ±2 day's accuracy. Care is also taken by imposing a restriction in terms of appropriate choice of date mask. TP at 5 days interval under a particular date mask is computed sequentially from date 1 to date 3 or 4 as the case may be. The only source of error could be if the transplantation date precedes the first image date by 20 days or more. TP date generated is adjusted to get calendar date and 25 days nursery age. The peak TP date can be computed by plotting the series of histogram and the corresponding pixel frequency distribution. The peak/s of the curve gives primary peak and secondary peak.

Biomass:

Ground truth campaign for paddy wet biomass was carried out to encompass all ranges of biomass values. Radiative transfer fresh biomass to backscatter has been plotted for many sites to obtain an inversion transfer function. This inverse relation of biomass with dB is used to retrieve biomass. This is done by creating a rice mask. A proper model is used to take into account all the rice areas but optimization is done to minimize omission and commission error. More emphasis is laid to avoid commission error by using a conservative model. The sigmoid Badhwar growth curve is used to derive biomass for a specific backscatter. The inversion of biomass from backscatter is direct for the first rising portion of the curve. While inverting a cut-off is laid to take account of the other side of the curve. This is done to take care of the soil/ crop backscatter when the canopy starts drying up. The soil backscatter plays dominant role near the harvesting stage. A lot of ground data based validation for the second region of the curve was carried out. In this part of the curve, where soil exposure is allowed, a separate exercise is carried out. Biomass is estimated at flooded fields or smooth fields near field capacity soil moisture. Figure 2 demonstrates the entire methodology for acreage, transplantation and biomass retrieval.

Observations

Temporal signature: Rice, mostly a partially submerged crop for a substantial part of the growth period, generates unique temporal backscatter profile unlike other crops. During transplantation, backscatter is quite low due to puddled fields in standing water condition which reflects more energy in forward direction and minimal in the backscattering direction. As the crop growth progress, the backscatter rises and attains a peak coinciding with the peak biomass and falls after maturity till harvest. This dynamic range is captured with three date HH- data, but some misclassification results near water bodies or moist fallows.

Dual date-dual-polarized case: Only HH data-based assessment for rice field especially using 2-date data includes waterbodies and fallow lands as commission error. There is high probability of occurrence of such errors where standing water is not maintained throughout in System of Rice intensification (SRI technique). As this technique of rice cultivation is widely prevalent in Tamil Nadu, the over estimated area can be removed by introducing HV data with previous HH set.

In many cases, it has been noticed that signature generated from HH backscattered coefficient (in dB) of rice fields has overlaps with banks of waterbody or moist fallow land in the bordering fields whereas HV backscattering for these features differs. For the water bodies HH and HV backscatter occupies the lowest domain of the dynamic range. The linear cross-polarization is also of value for general land cover applications. Several researchers have indicated cross polarizations are useful for differentiating vegetative surfaces from bare surfaces (Baronti et al., 1995, Brisco, 1998) and for differentiating vegetation canopies such as agricultural crops and forested areas (Lemonie et al., 1991).

In two-date FCC (Figure 3), early transplanted rice fields appear as darkish cyan patches. During first-date data acquisition, as transplantation had taken place, rice fields had sufficiently low amount of backscattering which had subsequently increased on second-date acquisition. For late rice transplanted fields, high backscatter in observed on the first day due to field preparation and then there is a sudden dip in backscattered coefficient in the second date. So, energy available in green and blue channel (first date) is less and it appears as bright red patches in the images. Table 3 shows comparative results of RISAT versus Radarsat for rice acreage.

HV backscatter manifests the volume scattering component strongly and increases with growing crop. The rate of increase of HH backscatter is faster as compared to the HV backscatter as HV component measures the depolarized/repolarized part of the signal. Thus difference of σHH-σHV will decrease for a growing crop in a time series faster for a good vigour crop than poor vigour. For the first day transplanted case, the rise in HH backscatter was faster than HV. With time series analysis it was observed that the rate of HV increase is faster as crop growth progress and the HH-HV difference (cross polarization ratio) gets narrower. The polarization ratios in SAR domain like vegetation indices in optical data reflect the changes synergistically and are found to depict crop conditions like height, density, vigour and biomass. (McNairn et al., 2002). The co- and cross polarization ratios gives the measure of the change in VV polarization or HV polarization with respect to HH polarization. The depolarizing and repolarizing capability of the target is a measure of the volume scattering component of the target as manifested in HV backscatter.

There is increase in backscatter in both HH and HV with crop growth in phenological cycle (Zhang et al., 2011). HH backscatter may increase with crop growth or soil moisture and soil roughness fluctuation. Here comes the role of cross-polarization HV backscatter, which is solely due to volume scattering and depicts increase in vegetation biomass. As the surface roughness was below the C-band SAR sensitive zone, variation in HV backscatter is solely due to increased volume scattering in the vegetation, which is responsible for depolarization in H-polarization and repolarization in V-polarization. A decision rule based model was coded using the dual-polarization backscatter to classify the paddy area and it improved the classification by taking into account the commission error which occurred using 2-date HH data.

Transplantation date and Biomass retrieval: The biomass and transplantation map are shown in Figure 4a and 4b respectively. The black region in Figure 4a shows non- rice areas. The eastern and north central portion shows high biomass zones. The transplantation map depicts that majority of the transplantation had occurred during 2nd fortnight of October. Eastern region adjacent to the coast shows early transplantation during end September and early October. Most part of the image shows low-medium biomass zone. The peak biomass for this region is found to be 3.4kg/m^2. The age at inflection is observed to be 90 days (Figure 5a). This denotes the peak biomass stage i.e. maximum tillering phase. The progress of transplantation is shown in Figure 5b. The peak transplantation occurs during last week of October with spread in transplantation from end September to mid November mostly.

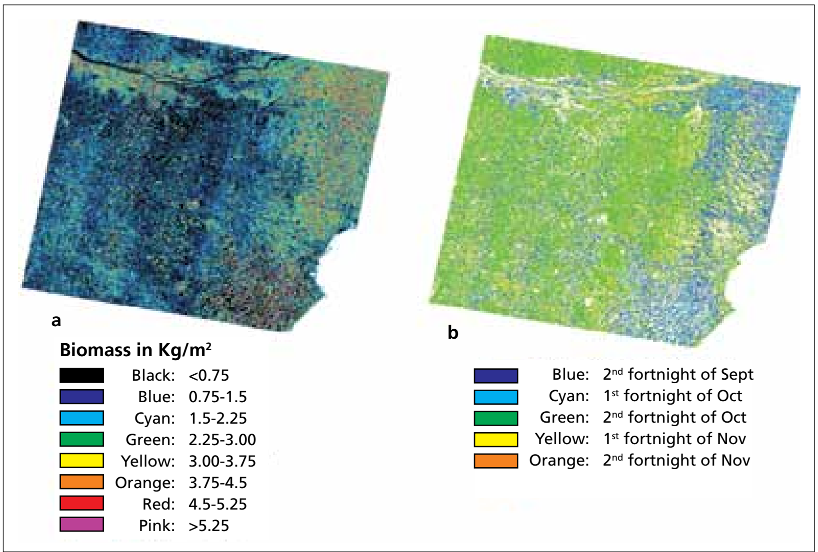


Fig. 4a: Biomass map and 4b)Transplantation date Map using three date RISAT data

Table 3: comparison of rice acreage using RISAT data vis a vis Radarsat data

Rice acreage estimation of some districts in Tamil Nadu		
District	**Acreage (ha) using RISAT 1 data, 2012-13**	**Acreage (ha) using Radarsat-2 data, 2011-12**
Thanjavur	1,23,568	1,28,918
Pudukottai	71,516	70,430
Shivagangai	84,610	85,480
Tiruchirapalli	78,719	76,587
Villupuram	1,30,036	1,29,106
Perambalur	16,662	13,463
Cuddalore	90,168	91,558
Aryalur	25,515	26,572

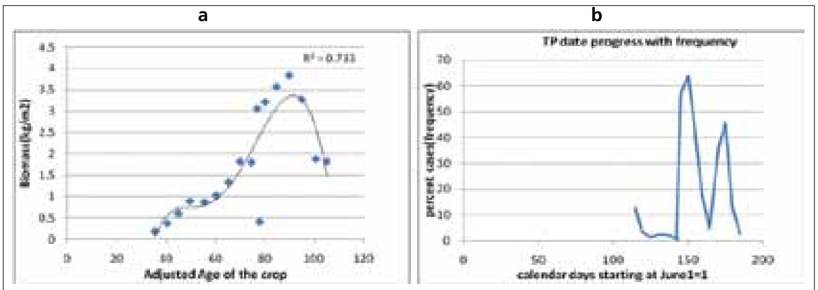


Fig. 5a: Biomass versus age of rice crop and 5 b) Frequency of transplantation using three date RISAT data

Ground validation for both transplantation date and green peak biomass was carried out and the results are illustrated in Table 4. The transplantation date could be retrieved within 7% in either side with t- stat of 2.3 which was found to be greater than the tabulated value. The Pearson's coefficient was found to be 0.92 for the modeled and field observed

Table 4. Validation table for transplantation date and above ground green biomass for 17 sites. The TP dates are expressed as numbers June1=1

Plot no.	Model_TP	Field_TP	Percentage Deviation in TP Date	Model_Biomass (kg/m2)	Field Biomass (kg/m2)
1	159	152	4.61%	3.4273	3.7300
2	171	166	3.01%	1.1133	1.6200
3	153	165	-7.27%	3.2382	3.8500
4	144	148	-2.70%	3.0370	4.1800
5	141	132	6.82%	3.6037	4.2600
6	133	129	3.10%	3.6470	3.8100
7	155	151	2.65%	2.7233	2.4700
8	165	155	6.45%	1.6478	1.9800
9	171	166	3.01%	1.2381	1.8690
10	134	130	3.08%	2.9319	3.5280
11	171	166	3.01%	1.7133	2.2740
12	142	140	1.43%	2.3949	3.5280
13	145	148	-2.03%	3.0570	4.7250
14	161	158	1.90%	1.3292	1.7250
15	155	151	2.65%	2.3037	2.9400
16	174	172	1.16%	0.8991	1.2758
17	160	156	2.56%	3.2282	3.8220

transplantation date. In most of the cases transplantation dates could be predicted in range of 2-4 days. The biomass retrieval was also validated and most of the samples show deviation within 25% with two outliers. The Pearson's coefficient was found to be 0.85 and t- stat of 5.4 which is much greater than the tabulated value.

Conclusion

The study shows a trial feasibility run of the methodology transfer for national rice acreage from Radarsat to RISAT-1 MRS systematic data. Also the advantages of cross polarization has been addressed which has potential of usage in the problem areas of fluctuating moisture status and in paddy growing environments where water use is limited or flooding conditions does not prevail through out the entire growth phase. HV polarization improves the classification in general and early forecast estimate in particular when only two temporal datasets are available. The transplantation date and biomass retrieval has also been validated with RISAT data. T- stat indicates the non-significant differences between the model derived transplantation dates and above ground biomass with the corresponding field observed values. The future thrust lies on validation in all rice growing environments across the major cultural types. This study demonstrated the operational utilization of the RISAT-1 data for both rice acreage and biomass.

Acknowledgement

The authors are grateful to Shri Tapan Misra, Director SAC, for his support and guidance. Part of the work was carried out as a part of FASAL project. Authors are thankful to the Tamil Nadu State Department of Agriculture for providing ground truth inputs. The encouragement and support provided by Smt. Arundhati Misra, Head, ATD/GSAG/EPSA, SAC is duly acknowledged.

References:

Baronti, S., del Frate, F.,Ferrazzoli, P.Paloscia, S.Pampaloni and Schiavon,G.(1995), SAR Polarimetric features of agricultural areas. International Journal of Remote Sensing. Vol.16, 2639-2656.

Bonlieu, F., (1999), Performances du systeme de riziculture intensive dans la region du Menabe a Madagascar : Evaluations des possibilites de development. Memoire de fin detude. Angers, France, Ecole Superieur d' Agriculture d' Angers.

Brisco B. and Brown, R.J. (1998), Agricultural applications with radar, Principles and Applications of Imaging Radars (3rd edition), Chapter-7, Manual of Remote Sensing vol. 2, John Wiley and Sons, Inc., New York (1998), 381–406.

Chakraborty, M., Panigrahy S., and Sharma S.A. (1997), Discrimination of rice crop grown under different cultural practices using temporal ERS-1 Synthetic aperture radar data. ISPRS Journal of Photogrammetry and Remote Sensing, 52, 183-191.

Chakraborty, M Panigrahy, S Rajawat, A.S. Raj Kumar, Murthy, T. V. R., Haldar, D., Chakraborty, A. Kumar, T., Rode, S., Kumar, H., Mahapatra M., and Kundu, S. (2013), Initial results using RISAT-1 C-band SAR data. Current Science Vol. 104, No.4

Chen, C., and McNairn, H. (2006), A neural network integrated approach for rice crop monitoring. International Journal of Remote Sensing, Vol. 27, No. 7, 1367-1393. doi: 10.1080/01431160500421507.

Choudhury, I., and Chakraborty, M. (2006), SAR signature investigation of rice crop using RADARSAT data. International Journal of Remote Sensing, Vol. 27, No. 3, 519-534. doi: 10.1080/01431160500239172.

Haldar, D., Manjunath, K. R., Panigrahy, S, Jain, V, Gopalan R. S., Khullar, M, Chakraborty, M. and Parihar J. S. (2014), Monsoon paddy monitoring and assessment using synthetic aperture radar data under BGREI. programme in Odisha, India. Paddy and Water Environment. http://link.springer.com/ article/10.1007 /s10333-014-0452-0.

Hatta, S., (1967), Water consumption in paddy field and water saving Rice culture in the tropical zone. Japanese Journal of Tropical Agriculture, 11 (3) : 106-112.

Kuenzer C., Knauer, K., (2013), Review Article. Remote sensing of rice crop areas. International Journal of Remote Senings 34(6):2101–2139.

Kumar D. and Shivay, Y. S., (2004), System of Rice Intensification. Indian Farming, 54(8) :18-22.

Lemonie, C.G., Hoekman, D.H. and van Leeuwen, H.J.C. (1991), Separability of Agricultural fields and forest stands using multifrequency polarimetric SAR dat of the Flevoland Site. In IGARSS 1991, Proceedings of the International Geoscience and Remote Sensing Symposium, 3-6 June 1991, Espoo Finland, IEEE, Piscataway,N.J. 681-684.

McNairn, H. Decker V., and Murnaghan K. (2002), The Sensitivity of C-Band Polarimetric SAR to Crop Condition. IEEE Transactions on Geoscience and Remote Sensing. 1471-1474.

McNairn H. and Brisco B., (2004), "The application of C-band polarimetric SAR for agriculture: a review", Canadian Journal of Remote Sensing, vol. 30, no. 3, 525–542.

Panigrahy, S. Manjunath, K.R. Chakraborty, M and Kundu, N. (1999,) Evaluation of RADARSAT standard beam data for identification of potato and rice crops in India, ISPRS J. Photogramm. Remote Sens. 54, 254–262.

Puard, M., Couchat P., and Lasceve, G., (1989), Etude des mecanismes d' adaptation du riz aux contraintes du milieu l: Modification de l' anatomie cellulaire. L 'Agronomie Tropicale, 44(2) : 156-173.

Sivanagaraju P. (2006), Traditional and SRI methods of paddy Cultivation – a comparative economic analysis. M.Sc thesis, Agricultural Economics. University of Agricultural Sciences, Dharwad.

Zhang, Y. Wang, C. and Zhang, Q. (2011), Identifying paddy fields with dual-polarization ALOS/PALSAR data. Can. J. Remote Sensing, Vol. 37, No. 1, 103-111.

UN/India Workshop on 'Use of Earth Observation Data for Disaster Management and Risk Reduction: Asian Experience' during March 8-10, 2016 at Hyderabad, India

NRSC / ISRO organised a three-day UN/India Workshop on 'Use of Earth Observation Data for Disaster Management and Risk Reduction: Asian Experience' during March 8-10, 2016 at Hyderabad, India. Shri A S Kiran Kumar, Chairman, ISRO inaugurated the workshop on March 8, 2016. He emphasized the need for sharing knowledge and experiences in disaster management and explained the importance of team work for disaster risk reduction.

A series of sessions were conducted on challenges in Disaster Management with respect to earth observation satellites, field experiences, disaster risk assessment, early warning system and emergency response, capacity building in disaster management and fostering international cooperation for promoting space technology.

About 120 officers from India and abroad (26 countries) participated in the workshop. International organisations like UNOOSA, UN-SPIDER, UNESCAP, UNDP, International Water Management Institute (IWMI), International Centre for Integrated Mountain Development (ICIMOD), Asean Coordinating Centre for Humanitarian Assistance (AHA Centre), Saint Xavier University (USA), International Charter 'Space and Major Disasters' and also representatives from remote sensing and disaster management departments of several countries from Asia and Africa actively participated.

National organisations like India Meteorological Department (IMD), Central Water Commission (CWC), Geological Survey of India (GSI), Indian National Centre for Ocean Information Services (INCOIS) and State Disaster Management Authorities (SDMA) of Assam, Bihar, Odisha, etc and IIRS, IIST, IITs and other academic institutes participated in this workshop.

GPS Radio Sonde Station Facility set up under SAARC STORM Project in Bhutan

STORM (Severe Thunderstorms: Observations and Regional Modelling) project was conceived as a cooperative scientific endeavour between SAARC countries, for improving prediction of severe storms frequenting India, Nepal, Bhutan and Bangladesh. India Meteorological Department (IMD) and Indian Space Research Organisation (ISRO) are participating in this programme. Under this programme ISRO is setting up meteorogical equipment in Bhutan, Nepal and Bangladesh.ISRO's commitment towards this projectin Bhutan include supply and installation of meteorological equipment comprising of 10 numbers of Automatic Weather Stations (AWS) and one GPS Sonde Station.

The AWS at the ground consists of meteorological sensors for temperature, pressure, wind velocity, humidity, radiation and rainfall. The data logger converts data to digital signal and this data is transmitted via satellite to the processing centre. In Bhutan, 10 AWS units have already been set up in association with Department of Hydro and Met Services (DHMS), Thimphu, Bhutan and the data is also being received by IMD, Pune.

Towards setting up of GPS Radio Sonde facility at Bhutan, a team from ISRO, led by Smt J Girija, Division Head, RFATD, VSSC, visited DHMS,Thimphu, Bhutan during 3-8th, January, 2016.

The GPS Sonde System is used to measure atmospheric parameters like pressure, temperature and humidity with the help of sensors and wind velocity using GPS module, as part of the balloon borne Sonde. As the balloon filled with hydrogen or helium gas ascents, these parameters are measured at different altitudes and transmitted. The compatible Ground Station retrieves the data which is used by scientists for atmospheric studies and modeling.

The team has set up the facility at the identified location (near to Paro airport), conducted trail runs and also imparted training on the GPS Sonde ascends to the concerned staff.

The upper air observation service, that will allow more accurate weather forecasts was officially launched by Director of Department of Hydro Met Services (DHMS) and Director of Department of Air Transport (DoAT), Thimphu, Bhutan, on 7th January 2016, at Paro International Airport by releasing the GPS Sonde Balloon in the air. The inauguration was attended by officials from the Bhutan Civil Aviation Authority (BCAA), Safety Officers, team from Indian Space Research Organisation (ISRO) and Media.

Members at site for releasing GPS Radio Sonde

ENERGY AND MASS EXCHANGE IN VEGETATIVE SYSTEMS

Bimal K Bhattacharya, Rahul Nigam, Gupta PK and Singh RP
Biological and Planetary Sciences and Applications Group (BPSG)
Space Applications Centre, ISRO, Ahmedabad-380015
Email: bkbhattacharya@sac.isro.gov.in

Introduction

The biosphere-atmosphere interactions and their role on regional climate are least understood over Indian monsoon region. Land (soil-canopy complex) surface plays a crucial role in climate systems through its 'response-feedback' mechanism to overlying 'Surface Layer" within Atmosphere Boundary Layer (ABL) with a large seasonal and spatial dynamics of different vegetative systems such as agriculture, forest, natural shrub, grasslands. The diurnal measurements of surface energy (radiation and convective) and mass (water, net CO_2, other green-house and trace gases) exchange components from micrometeorological towers and coupled simulation with Soil-Vegetation-Atmosphere-Transfer (SVAT) models provide thorough understanding of physical and physiological processes in different vegetation types at canopy-scale and in terrestrial ecosystems at landscape to regional scales through Soil-Plant-Atmosphere-Continuum (SPAC). The large-area implementation of detailed SVAT models suffers from obtaining reliable parameter fields. The remote sensing observations from satellite platform bridge the gap between canopy and regional scale fluxes. Global efforts could be seen through FLUXNET observations over different countries except India which remained void upto 2007 in the regular measurements of fluxes, database creation, sharing and further use for enriching scientific understanding.

To characterize radiation, convective fluxes and water exchanges over vegetated surfaces, and its linkages to surface hydrology and vegetation productivity using measurements, simulation and satellite observations, a project titled 'Energy and Mass Exchange in Vegetative Systems' (EMEVS) was initiated under ISRO geosphere-biosphere programme at Space Applications Centre. This has strong linkages to other ongoing and future national projects such as INSAT 3D, MEGHA-TROPHIQUE, "PRACRITi" (PRogrAmme on Climate change Research In Terrestrial environment), EO CAL-VAL activities for land, CTCZ (Continental Tropical Convergence Zone), NCP (National Carbon Cycle Project), RCM (Regional Climate Modelling), Value Added Agro-met advisories and international projects such as INCOMPASS. This would also support the cross-scale ecosystem comparison in AsiaFlux, the Asian arm of FLUXNET under the aegis of Global Earth Observation System of Systems (GEOSS) and Indian Meteorological Department initiative for unmanned evapo-transpiration flux monitoring over India.

The project aimed at addressing some science questions which are given below:

(i) How vegetation response differs due to changes in atmospheric radiation regime such as turbidity, cloud and fog over sub-tropical Indian landmass?

- What is the typical seasonal behaviour of E-M (E: Energy; M : Mass) fluxes over different Indian agro-ecosystems, grasslands, natural shrubs and forests?
- Can we quantify energy-water use over different vegetation types and their regional variability over terrestrial ecosystems in India?
- Can we identify anomaly in E-M fluxes and quantify these?

(ii) How short-term natural disturbances (drought, heat, cold wave, fire etc.) alter plant response?

- Can we quantify these in terms of resource (radiation + water) use efficiency?
- Can we quantity anomaly in phenological behavior?

(iii) Can we identify stomatal functions for different vegetation types through exchange processes?

(iv) How different soil hydro-thermal settings and vegetation types govern coupling of surface and sub-surface flow processes daily, seasonally and annually?

(v) How vegetation influences atmosphere under natural and anthropogenic (e.g. agriculture) forcings?

The activities during April 2007 to March 2015 were taken up with the following objectives:

- Understanding and characterizing vegetation-atmosphere energy (radiative, convective) and mass (water, net CO_2 assimilation) exchange processes at canopy-scale using measurements and simulation
- Bridging the gap between canopy and regional-scale E-M fluxes through modelling with space based observations
- Tracking long term trend of regional E-M fluxes to find link past and present scenarios:

The results from these are highlighted below.

Canopy-scale variability of E-M Exchange

INSAT-linked Agro-Met Station (AMS) network

The net radiation (Rn) energy available at the earth's surface is partitioned into sensible heat, H (temperature change with no phase change of water) and latent energy, LE (the phase change of water with little temperature change) and soil heat flux (G). This constitutes surface energy balance. The net radiation is the sum of net shortwave (reflective) and net longwave (emissive) constituting surface radiation balance. In vegetation systems, surface energy balance and land-atmosphere exchange are both "radiation" and "soil moisture" controlled. There is a need to understand, characterize and quantify exchange processes of energy and mass (water, CO_2, CH_4, N_2O and Volatile Organic Compound) at canopy-scale through soil-plant-atmosphere-continuum (SPAC) before their regional extrapolation for large-area mapping. The canopy-air exchange processes follow certain micro-meteorological principles based on which different measurement approaches have been developed. The surface fluxes can be estimated from micro-meteorological measurements over homogeneous flat and sloppy terrains over a range of vegetation systems. However, accuracy of canopy-scale fluxes depend on sensor response. Till 2008, in a developing country like India, the regular availability of canopy-scale flux data on diurnal, daily, monthly and seasonal scales were not available. The present article provides an account of INSAT-linked Agro-Meteorological Station (AMS) network over vegetation systems for canopy-scale characterization of radiation, heat and water fluxes using 'slow' response sensors as well as their inter-connection and link with vegetation spectral behavior.

The INSAT-linked micrometeorological stations known as Agro-Met Station (AMS) were installed at 23 locations over different vegetation systems such as agriculture, grasslands, shrublands, wetland and young forest spread over 15 major agro-climatic regions in India. These maintains a fetch ratio varying from 1:50 to 1:100 grossly representing the footprint of 500 m to 1000 m with varying degree of homogeneity for specific vegetation system. Technical specifications of AMS sensors (soil and above-canopy sensors) and their functioning are detailed by Bhattacharya et al., (2009a) and Bhattacharya et al., (2013). The automated half-hourly average (from samplings at five minutes interval) of measured radiation, multi-level weather parameters (air temperature, RH and wind speed), energy balance components are being stored in the datalogger and are also being transmitted through Yagi antenna to INSAT-3A communication transponder. The transmitted data are being received at common server at Bopal Earth Station (BES), Ahmedabad. The raw data are decoded and kept in user friendly format in MOSDAC (www.mosdac.gov.in) for dissemination to scientific users (Bhattacharya et al., 2009b). The overall network of AMS with their number and locations is shown in Figure 1. Out of 23 AMS, 13 sites represent agricultural systems including four prototype stations, different cropping sequences such as mixed agriculture in plain to plateau lands and mixed hill agriculture in North-Eastern Hill Region (NEHR). Remaining 10 AMS represent natural vegetation covering moist, Banni and desert grasslands, wetlands, shrublands and young pine forest.

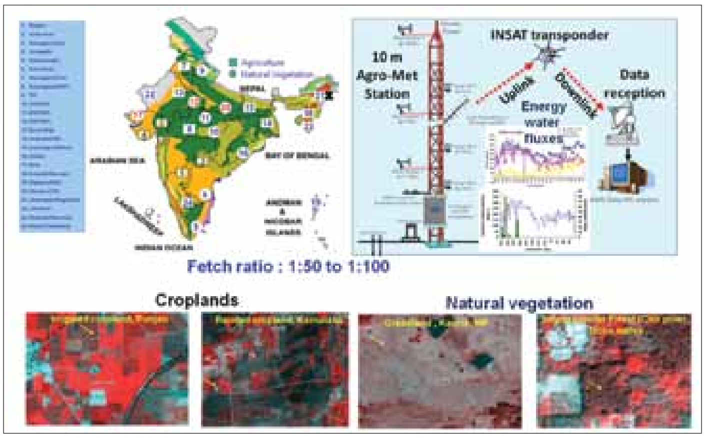


Fig. 1: Network of INSAT-linked Agro-Met Stations over different vegetation types as shown through FCC of Resourcesat-2 LISS-IV data

Reflective and emissive signatures from AMS

Surface albedo and net longwave radiation are considered here as reflective and emissive signatures of vegetated surfaces. The latter represents thermal regime of surface in a given climate and land use. In agro-ecosystems, decadal (ten-day average) surface albdeo largely varied between 0.1 and 0.3 which showed seasonal differences across different cropping systems. The albedo (Figure 2) decreased substantially during rainy season or with irrigation coupled with active vegetation growth period but showed higher magnitude during drier period. The persistence of more dry or bright background in the soil-canopy systems might lead to higher albedo (Singh et al., 2013).

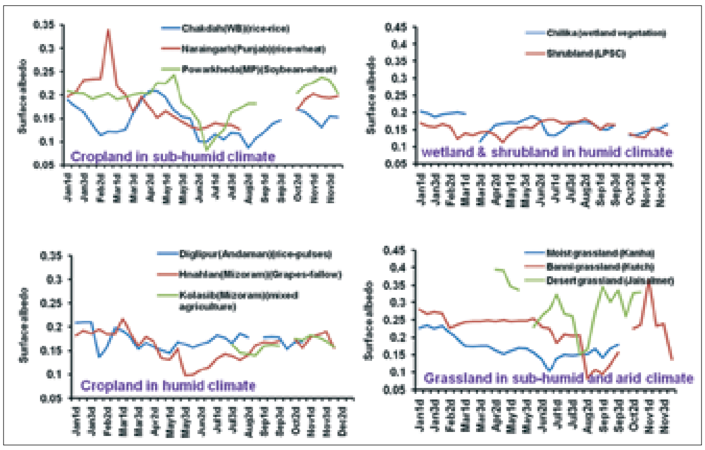


Fig. 2: Seasonal variation of surface albedo in different vegetation systems

In natural moist and desert grassland, surface albedo generally varied from 0.1 to 0.38. Moist grassland showed substantially lower range 0.12 to 0.22 as compared to higher range in Banni grassland (0.07 to 0.35) and desert grassland (0.15 to 0.38). Here also, wet and active grass growth period decreases the surface albedo substantially. The sharp fall in albedo to 0.07 from a higher magnitude of 0.2 in Banni grassland was noticed due to surface inundation by flood water due to heavy rainfall events. As the flood water receded albedo gradually increased. During dry period, high reflectivity from sandy soil of Jaisalmer as well as salt incrustation on soil surface substantially increased the surface albedo (Raja et al., 2013).

Differences in intra-seasonal variability of day time net longwave radiation were much larger than albedo. It showed higher magnitude during wet period coincident to rain spells or irrigation applications. However, inherent thermal and incident shortwave radiation regimes caused the differences in overall intra-seasonal variability. It is interesting to note that net longwave radiation hovered around -20 Wm^{-2} in the monsoon months in humid to sub-humid climate (Nanda et al., 2012) and around -40 Wm^{-2} in semi-arid to arid climate.

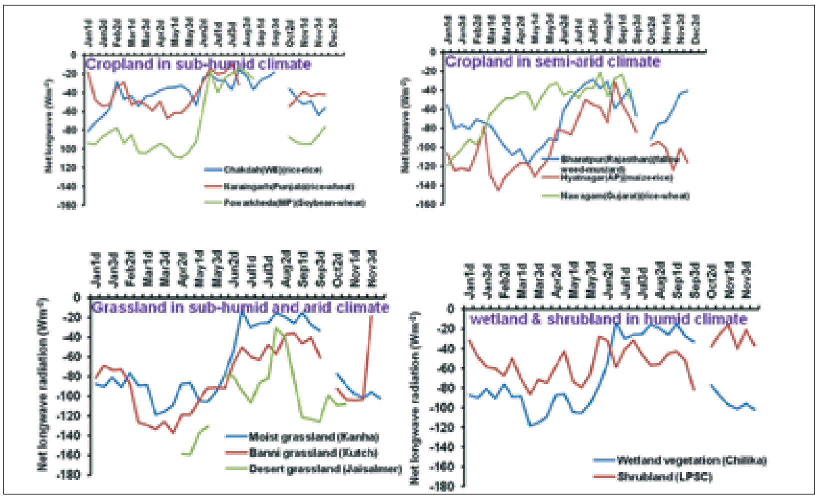


Fig. 3: Seasonal variation of surface net longwave radiation in different vegetation systems

The net longwave radiation showed relatively larger range (-20 to -160 Wm^{-2}) in grasslands than wetland and shrubland (-20 to -120 Wm^{-2}) as shown in Figure 3. The range was the highest in desert grassland followed by Banni grassland and moist grassland. Higher (towards positive direction) net longwave radiation was noticed during rainfall and cloudy situations than irrigated wet conditions or dry period. This could be due to low surface temperature due to cooling in cloudy as well as wet days coupled with increase in incoming longwave radiation from clouds as well as more humid air below clouds.

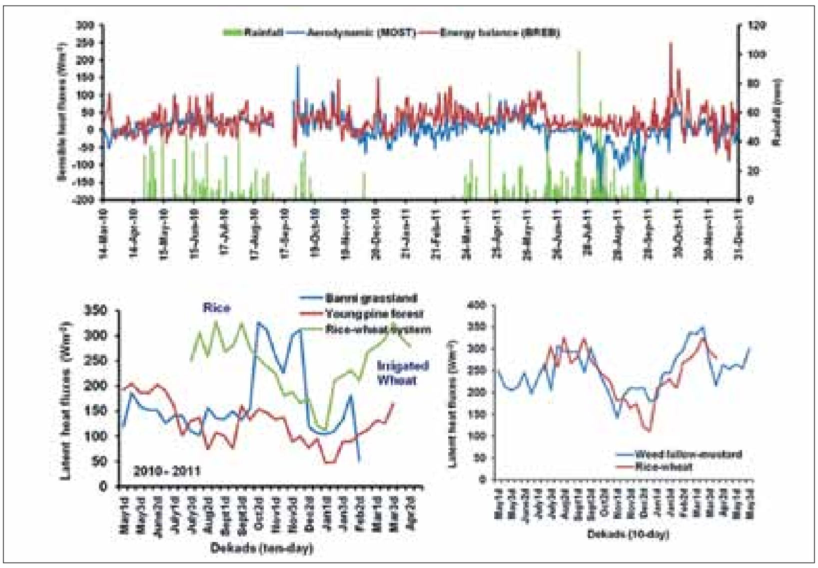


Fig. 4: Cross-canopy comparis on of seasonal variation of sensible and laten heat fluxes

Sensible and latent heat fluxes from AMS

The comparison of sensible heat fluxes from Bowen Ratio Energy Balance (BREB) and aerodynamic approaches was found to be matching well (Figure 4) except low wind and high rainfall spells. Energy balance is expressed here in terms of latent heat flux as a residual from net available energy and sensible heat flux with the assumption of energy balance closure using AMS data. A comparison was made regarding intra-seasonal variability of latent heat fluxes across different vegetation systems such as grassland, coniferous forest and rice-wheat crop rotation using datasets of May 2010 to April 2011. A clear distinction was found in water / latent heat flux exchange. The Kharif rice showed peak in latent heat flux (300 Wm^{-2}, 5.4 mmd^{-1}) during August (Figure 4) in Punjab followed by its decrease and increase towards February for irrigated wheat with another peak around 300 Wm^{-2} in March (Mukherjee et al., 2012). Grassland has generally low value throughout the year around 100 - 150 Wm^{-2} (1.8 to 2.7 mmd^{-1}) but a sharp peak of 300 Wm^{-2} around 3rd October. The conifer such as Chir pine maintained a substantially low evapotranspiration from 50 to 200 Wm^{-2} (0.9 to 3.6 mmd^{-1}) with two small peaks in May and October (Singh et al., 2014a & Singh et al., 2014b). Among agro-ecosystems also, mustard showed higher rate (200-350 Wm^{-2}, 3.6 to 6.3 mmd^{-1}) of latent heat flux (Figure 4) than wheat (100-300 Wm^{-2}, 1.8 to 5.4 mmd^{-1}) with peak earlier than wheat.

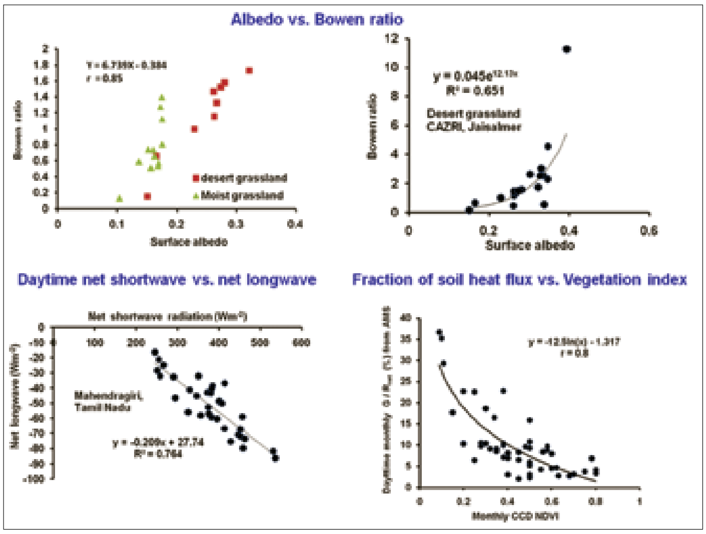


Fig. 5: Inter-linking of Bowen ratio and surface albedo

Development of Scaling Functions for Energy balance Components

The Bowen ratio (β) is the ratio of sensible and latent heat fluxes. It is approximated through the ratio of vertical gradients of air temperature and water vapour over surface under stable atmosphere. In desert grassland, β was found to have exponential relation with albedo for the whole range of it showing high correlation (r = 0.8). When data from both moist and dry grasslands were pooled together, significant linear correlation (Figure 5) occurred between these two for the Bowen ratio range of 0 to 2.0. Generally, surface albedo and Bowen ratio increase with the soil dryness. The above limit of Bowen ratio perhaps represents practical limit of soil moisture between field capacity to permanent wilting point. This makes both the variables linearly related within this limit.

Linear inverse functions were developed at monthly to seasonal scales for estimating daytime net longwave radiation from net shortwave radiation. These are useful to derive large-scale net radiation from satellite-based insolation and albedo without dependence on thermal remote sensing data. Non-linear function was developed at monthly scale between soil heat flux as a fraction of net radiation and satellite-based vegetation index (Figure 5). Some of these functions were used for large-scale extrapolation with satellite data.

Energy partitioning and spectral behaviour

Surface energy partitioning is represented through the ratio of latent heat fluxes (LE) and net radiation (Rn) fluxes. Land Surface Water Index (LSWI) for clear-sky days, derived from TOA reflectances of Resourcesat-2 AWiFS India mosaic (200m) data over AMS locations, were plotted with ten-day LE/Rn (Figure 6) ratio. The scattered points can be imagined as bounded within an inverted right-angle triangle where the hypotenuse denotes that LE/Rn increases linearly with minimum LSWI. The LE/Rn can be composed of LEc/Rn as canopy component and LEs/Rn as surface soil component.

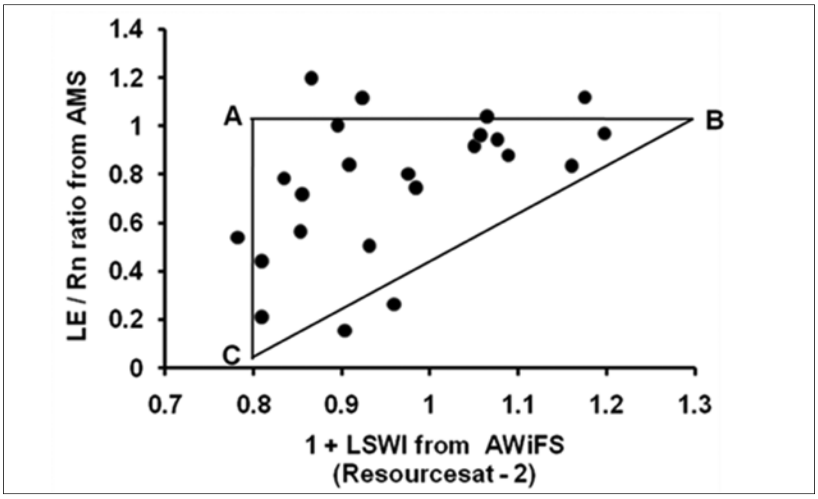


Fig. 6: Energy partitioning ratio and Land Surface Water Index (LSWI)

Fig. 7a: Forest phenology in relation to rainfall

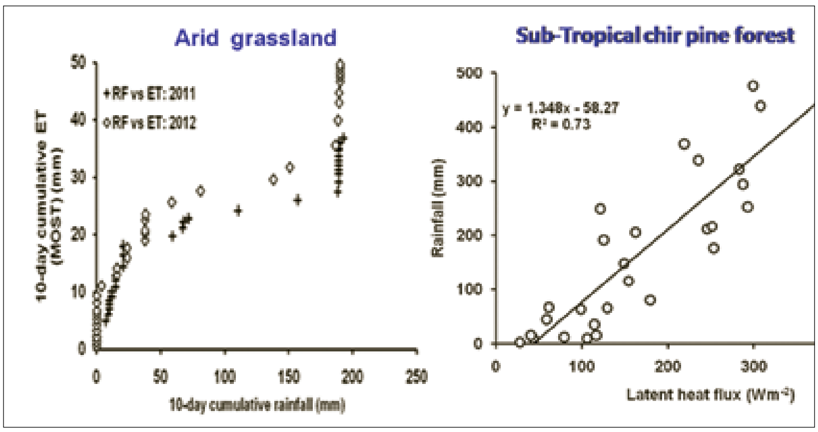


Fig. 7b: Latent heat fluxes in relation to rainfall based on AMS measurements in sub-tropical young conifer and arid grass land

The canopy component which mainly represents canopy transpiration fraction is linearly related to minimum LSWI represented by the hypotenuse. The minimum LSWI generally increases with increase in canopy moisture due to increase in root-zone soil moisture triggering vegetation growth. The soil surface component varies with the amount of soil evaporation from soil surface (0-10 cm) based on surface soil wetness, ponding (e.g. in transplanted rice), water logging and fractional vegetation cover. This triangular scatter can be explored in future to separate out canopy transpiration from soil evaporation.

Phenology and Latent heat fluxes in relation to rainfall in natural vegetation

Consistent records of tropical dry deciduous forest phenology through digital field photography (Parihar et al., 2013) showed that onset of rainfall during June in Madhya Pradesh region affects the greening of forest. It was observed that 2013 (Figure 7a) was associated with early and good rains in June which resulted in early greening of forest as compared to other years.

The latent heat fluxes were found to have correlation with rainfall (Figure 7b) in natural vegetation but within certain higher and lower thresholds of rainfall for arid grassland and sub-tropical young conifer forest.

Simulation of heat fluxes and hydrological discharge

Simulation experiments were conducted with Atmosphere Land EXchange (ALEX) Model in forest systems. It has found that simulated latent heat fluxes matched

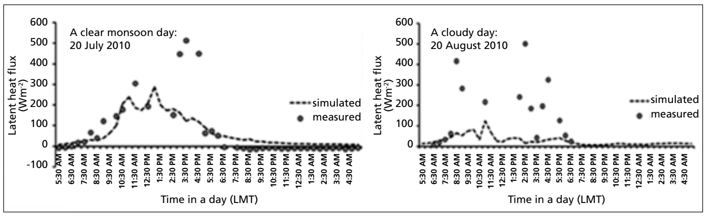
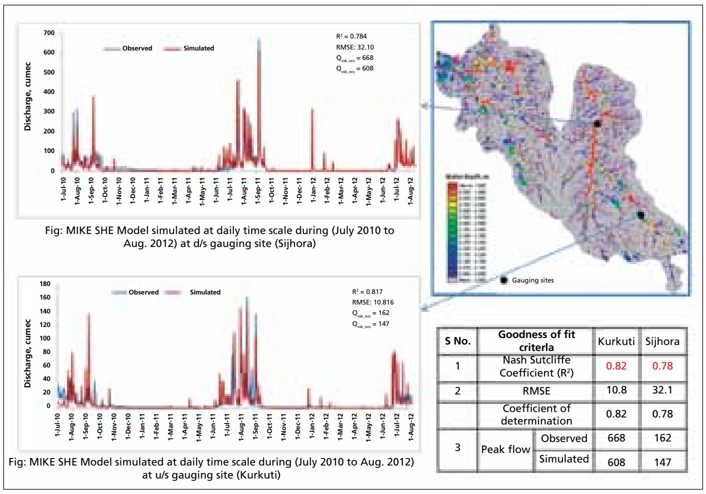


Fig. 8a: Simulation of latent heat fluxes using ALEX in clear and cloudy-sky days



S No.	Goodness of fit criteria		Kurkuti	Sijhora
1	Nash Sutcliffe Coefficient (R^2)		0.82	0.78
2	RMSE		10.8	32.1
	Coefficient of determination		0.82	0.78
3	Peak flow	Observed	668	162
		Simulated	608	147

Fig. 8b: Simulated vs. measured discharge rate through MIKE SHE simulation

well (Figure 8a) with AMS-based latent heat fluxes only in clear sky days for young conifer forest. State-of-the art hydrological system model, MIKE SHE, was parameterized using the remote sensing derived and in situ observations to study the surface and groundwater fluctuations. Model simulations (Figure 8b) have been done to estimate the various water balance components in the forest and neighboring regions in Kanha National Park, Madhya Pradesh. Drying and wetting patterns of springs were also studied. It was found that 26% of the surface water goes back to the streams as delayed interflow (base flow), which highlights the importance of forest for managing water by temporarily storing and then gradually releasing for various applications in the forest and neighboring regions during the lean flow phase. Seasonal and annual behavior of surface and groundwater were also studied.

Landscape-scale heat-water fluxes using Scintillometry and Thermal remote sensing

Line-averaged measurements were carried out using Large Aperture Scintillometer collocated with AMS at Nawagam, Gujarat (Figure 9a) to characterize intra and inter-seasonal variability of sensible (Figure 9b) and latent heat fluxes over a path length of 1.1 km in rice-wheat crop rotation. Thermal remote sensing data from MODIS-TERRA and AQUA satellites were used into single source surface energy balance models (e.g. METRIC) to estimate landscape-scale variability of sensible, latent heat fluxes and crop evapotranspiration. The MODIS based instantaneous estimates of sensible heat fluxes at 1km^2 using METRIC model from TERRA and AQUA were compared with LAS line-averaged (1.1 km^2) H for the period 1st November 2006 to 31st May 2007. The comparison of instantaneous sensible heat fluxes for a common period (October to March) resulted into RMSE of 21 Wm^{-2} (25% of measured mean) and correlation coefficient of 0.87. However, the comparison of ten-day average sensible heat fluxes for the same period led to produce reduced

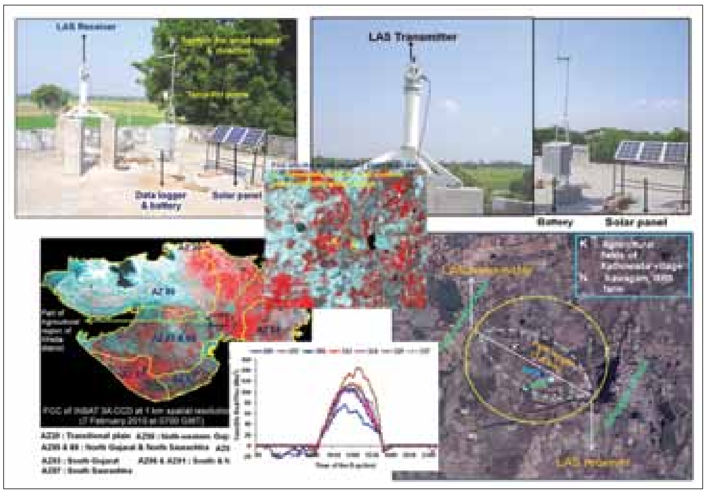


Fig. 9a: Set-up of Large Aperture Scintillometer (LAS) over semi-arid agriculture in Gujarat

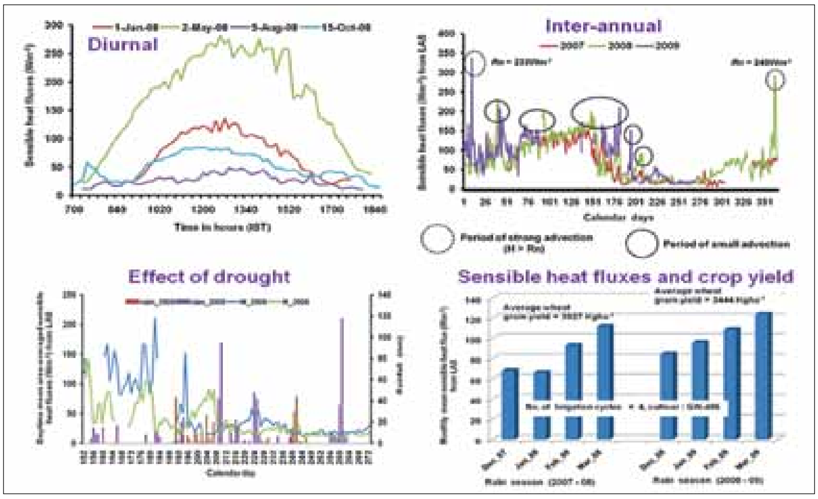


Fig. 9b: Intra and inter-seasonal variability of land-scape scale sensible heat fluxes from scintillometer

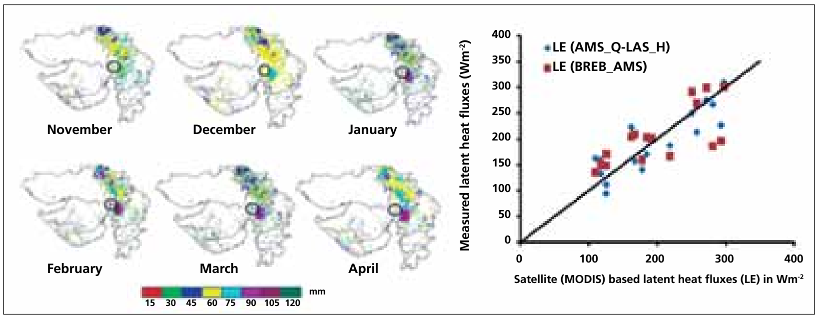


Fig. 9c: Dynamics of crop evapotranspiration over Gujarat and validation using scintillometer-AMS combination

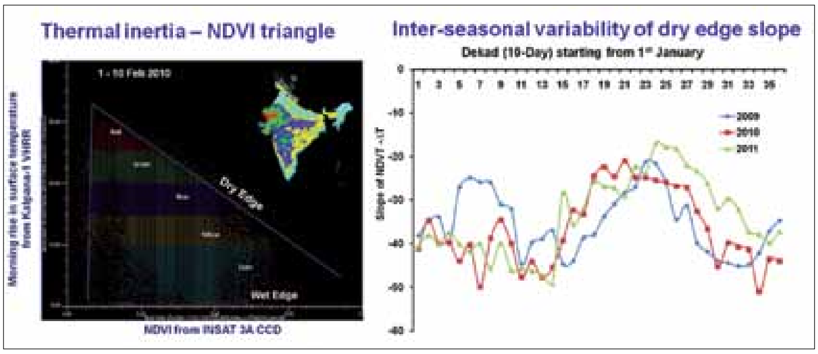


Fig. 10: Thermal inertia - NDVI 2D based approach for regional-scale evaporative fraction

RMSE of 13 Wm^{-2} (15% of measured mean) and increased correlation coefficient of 0.95. This proved that the use of line-averaged sampling of sensible heat fluxes from large Aperture Scintillometer (LAS) as validation reference produced less error of estimates from MODIS satellite (Nigam et al., 2008).

The monthly sums of evapotranspiration estimated over agricultural landscapes from MODIS AQUA daytime latent heat fluxes during rabi 2008 - 2009 (November 2008 to April 2009) are shown in Figure 9c. This varies from 45 to 120mm over Gujarat region and from 60 to 90mm over the study patch in Nawagam region. Evapotranspiration was the least in December and gradually increased upto peak in Nawagam and surroundings, then decreased towards March and April. This typically matches with crop growth cycle. The region opposite to Nawagam consistently showed higher evapotranspiration from January to April which could be due to continuous agricultural activity due to continuous source of irrigation water.

Regional-scale variability of evapotranspiration and gross primary productivity

Thermal inertia based approach was used to estimate evaporative fraction in cloudless skies using automated screening of 'dry edge' and 'wet edge' in the two-dimensional scatter of morning rise in surface temperature and vegetation index data from Kalpana-1 VHRR and INSAT 3A CCD, respectively. These are exemplified in Figure 10.

The other energy balance components such as net radiation, soil heat fluxes were estimated from satellite–based geophysical and biophysical products and AMS-based scaling functions. Regional-scale ten-day evapotranspiration at 8km spatial resolution was estimated for the period of 2009 to 2011 having both normal monsoon and drought years. Evaporative fraction was assumed unity in case of persistent cloudy days. The internal parameters of Vegetation Photosynthesis Model (VPM) for Gross Primary Productivity (GPP) were standardized for C3 crops using collocated AMS, PAR balance and photosynthesis measurements over C3 crops such as rice, wheat, mustard and soybean. Regional-

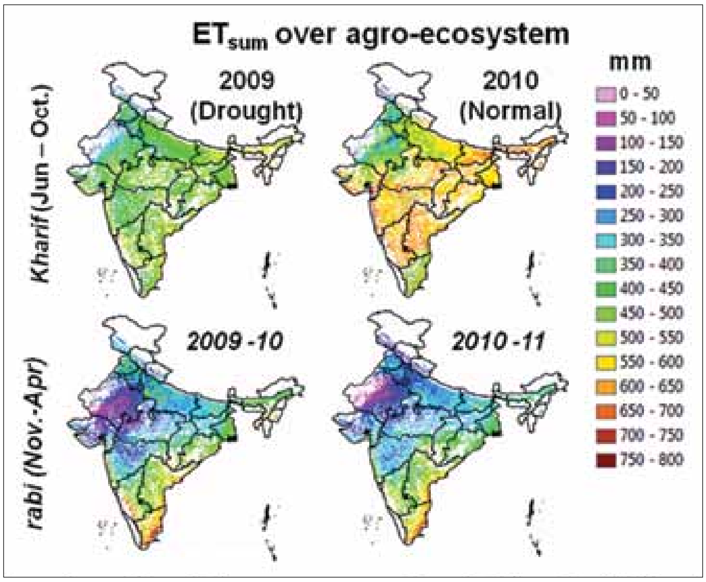


Fig. 11: Seasonal evapotranspiration over agro-ecosystems in India using INSAT products scaling functions and thermal-inertia-based single-source energy balance (SSEB) model

scale GPP was estimated for 2009 to 2011. Different INSAT-based products such as NDVI, LST, surface insolation and surface albedo were used into energy balance model and VPM to estimate regional-scale ET and GPP. Reduced ET and GPP were noticed in drought years as compared to normal years. The seasonal evapo-transpiration (ET) over agro-ecosystems was computed by summing daily ET flux over kharif (June to October) and rabi (November to April) seasons during June 2009 to April 2011 (Figure 11). Generally, the kharif ET was found to be higher in the range of 350 to 700 mm than in rabi season when it varied between 50 to 400 mm except some pockets of south-east and near south-west coasts. Higher ET during kharif season is associated with higher radiation regime and higher soil moisture regime driven by south-west rainfall as compared to lower ET due to lower radiation (except south) and less rainfall (north-east and western disturbances). The relatively higher ET in south-east coast is due to higher radiation regime and rainfall from north-east monsoon. Apart from that, a substantial reduction in kharif ET was noticed during a drought (2009) year (150 to 550 mm) as compared to a normal (2010) year (250 to 700 mm). The impact of drought is quite evident though with lower deviation that resulted into slightly lower ET during 2009-10 as compared to 2010-11 specially over north-western and Indo-Gangetic plains. The comparison of regional-scale (64 sq. km) ET with respect to AMS-based estimates (0.25 sq. km) leads to a range of root mean square deviation (RMSD) 5% to 40% of AMS estimates depending on heterogeneity within the INSAT foot-print.

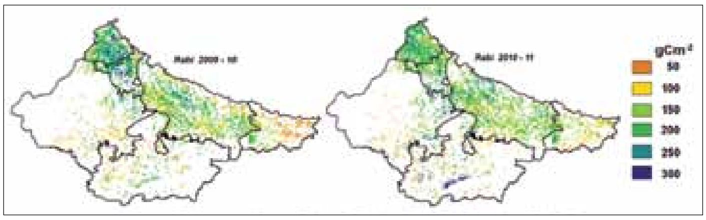


Fig. 12: Seasonal Gross primary productivity (GPP) in wheat in India

The gross primary productivity (GPP) was found to be at higher (Figure 12) range (200 – 800 gCm^{-2}) over agro-ecosystems in kharif season than in rabi season (75 to 225 gCm^{-2}) which could be due to relatively low PAR levels and relatively low moisture conditions in rabi season except in irrigated patches (Bairagi et al., 2012; Bera et al., 2012). The occurrence of drought in 2009 has substantially reduced the kharif GPP as compared to a normal year over north-west India, some parts of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu states. The partial drought during 2010 also showed little deficit as compared to 2011. Similar patterns in the distribution of seasonal GPP have emerged during rabi 2009-10 and 2010 – 11. But little deviation was noticed over Indo-Gangetic belt and north-west India. Inter-seasonal variability of wheat GPP at 8km spatial resolution is exemplified in Figure 12. Comparison with MODIS GPP yielded a correlation coefficient of 0.75.

Differences were noticed in wheat GPP between two rabi seasons of 2009 – 10 and 2010 – 11 having the former with higher patches noticed in Punjab and Haryana in 2009-10 than in 2010-11. But in 2010-11, patches of higher wheat GPP were noticed in parts of UP, Rajasthan, Madhya Pradesh and Bihar. However, the overall regional range of wheat GPP was 50 – 300 gCm^{-2}.

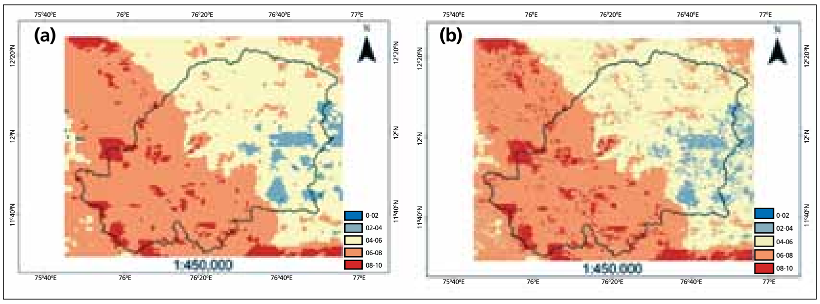


Fig. 13 (a-b): Average EF of the Kabini basin for the period 1st to 8th January 2014 at (a) 1000 m and (b) 250 m spatial resolution. The black line represents boundary of the Kabini basin

Spatial disaggregation of coarse-scale evaporative fraction

A model Disaggregation of Evaporative Fraction (DEFrac) was developed (Eshwar et al., 2013) for spatial disaggregation of evaporative fraction (EF). DEFrac is based on the observed triangular relationship between EF and NDVI. In the DEFrac model, it was assumed that for a given satellite scene, a unique relationship between EF and NDVI can be established and further such a relationship is assumed to be valid across different spatial resolutions. EF was estimated with the triangle method at 1000 m resolution for all the AMS sites using MODIS data. The EF estimated at 1000 m resolution was disaggregated to 250 m resolution using DEFrac disaggregation model. Moreover, the LST data was sharpened using the DisTrad and TsHARP thermal sharpening models and then used as an input to the triangle method for estimating disaggregated EF. The disaggregated EF was compared with the EF computed from the AMS data. The Root Mean Square Error (RMSE), bias and R^2 for the satellite estimated EF are 0.09, -0.02 and 0.63 respectively for all the five AMS sites put together (Eshwar et al., 2013). The developed model was utilized for generating a time series of EF images for the Kabini basin over Karnataka as shown in Figure 13. Even though the EF time series captured the seasonal variation in EF, there were huge temporal gaps due to non-availability of LST data due to cloud cover. Hence it is needed to develop a suitable gap-filling procedure to get time continuous EF.

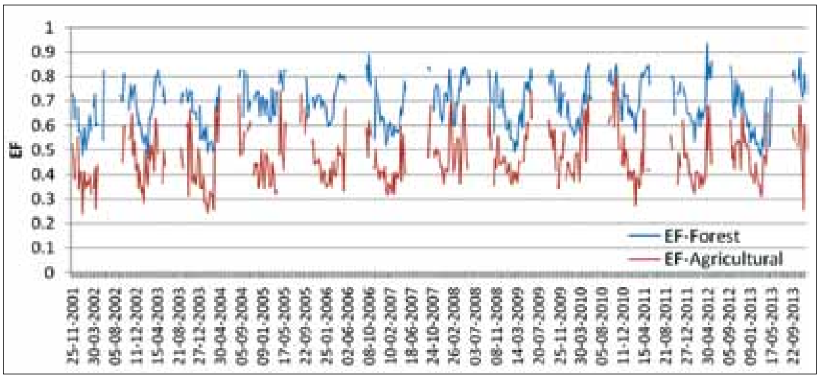


Fig. 13c: Inter-annual variability of disaggregated evaporactive fraction (EF) over agriculture and forest over Kabini river basin during 2001 to 2013

Long-term change in Energy-Mass Exchange

Evapotranspiration climatology and its regional trend

Thirty years (30) of satellite (NOAA+MODIS) observations in optical-thermal bands (Figure 14a) alongwith bias corrected reanalysis shortwave radiation and scaling functions were used to determine monthly and annual ET at 0.08° grid resolution using surface energy balance (Bhattacharya et al., 2010). Climatic mean annual ET loss (Figure 14b) from Indian agro-ecosystem was found to be almost double (1100 Cubic Km) than forest ecosystem (550 Cubic Km). Rainfed systems (forest, rainfed cropland, grassland) over India showed declining ET trend @ -4.8, -0.6 & -0.4 Cubic $Kmyr^{-1}$, respectively. Irrigated agriculture over Indian landmass initially showed ET decline upto 1995 @ -0.8 cubic $Kmyr^{-1}$, possibly due to solar dimming followed by increase in ET @ 0.9 cubic $Kmyr^{-1}$. A cross-over point is detected between forest ET decline

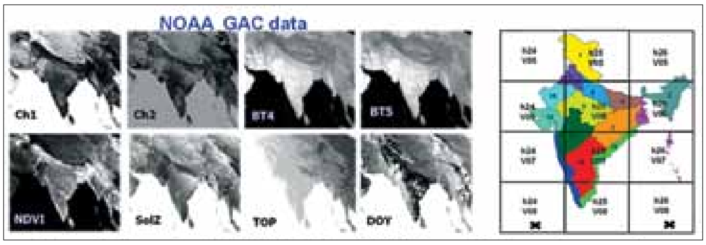


Fig. 14: Examples of NOAA AVHRR data and MODIS tiles used for time series processing

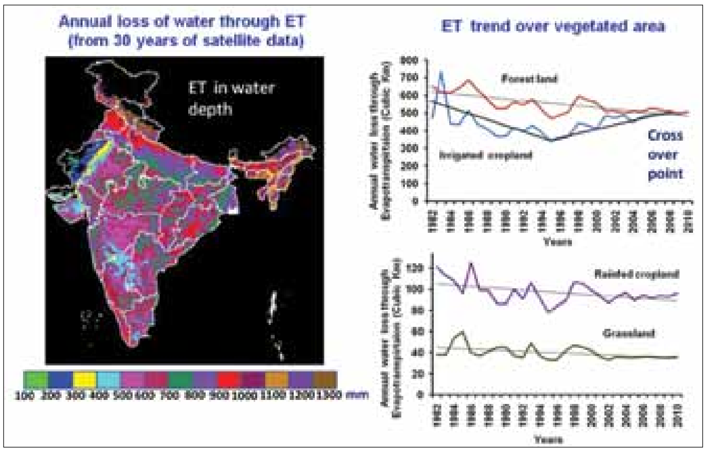


Fig. 15a: Evapotranspiration Climatology and its trend

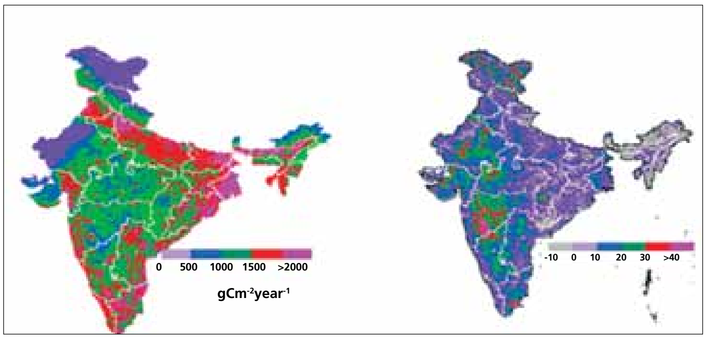


Fig. 15b: Average NPP of India (1991-2000) estimated using NOAA-AVHRR data. 15c: Decadal changes in NPP represented as relative deviations (%)=100*(NPPD1-NPPD2) / NPPD1) where d1 and d2 represent decadal period from 1981-1990 and 1991-2000 respectively

and ET increase in irrigated cropland during 2008. Regional analysis in the last decade (2000-2010) showed significant increase in ET without increase in rainfall in Bihar and M.P., possibly due to anthropogenic forcings. But increasing ET trends in Maharashtra and Tamil Nadu commensurate increasing rainfall and soil moisture trends.

Inter-annual variability of Net Primary Productivity (NPP) over India

NPP derived from GloPEM model over India showed maximum NPP about 3000 $gCm^{-2}year^{-1}$ in agriculture region of west Bengal and lowest up to 500 $gCm^{-2}year^{-1}$ in arid region of Rajasthan. The NPP mostly varied from 1000 $gCm^{-2}year^{-1}$ to 2000 $gCm^{-2}year^{-1}$ in agricultural areas of Indo -Gangetic basin due to variation in irrigation and cropping intensity. The inter-annual variations in average NPP in India ranged from 1084.7 $gCm^{-2}year^{-1}$ to 1390.8 $gCm^{-2}year^{-1}$ in the corresponding years of 1983 and 1998, respectively. The regression analysis of the 20 years NPP variability showed significant increase in temporal trend of NPP over India ($r=0.7$, $F=17.53$, $p < 0.001$). The mean rate of increase was observed as 10.43 $gCm^{-2}year^{-1}$. It can be seen from Figure 15a & b that carbon fixation ability of terrestrial ecosystem of India is increasing with rate of 34.3 TgC annually ($t= 4.18$, $p < 0.001$). The estimated net carbon fixation over Indian landmass ranged from 3.56 PgC (in 1983) to 4.57 PgC (in 1998). The Figure 15a shows the relative deviations in the NPP values in two decades. It can be seen from the Figure 15b that relative deviations in NPP ranged from –10% to 40% at different regions of India. The forested region of the north-east India was observed as region of decline in vegetation activity (-10%) (Parihar et al., 2014) whereas part of southern Maharastra and Karnataka showed highest increase in NPP (> 40%). Major agricultural belt of Indo-Gangetic plain showed moderate increase in NPP (< 20%) in two decades spanning over 1981 to 2000 (Singh et al., 2010). Overall, it can be inferred that regions with open shrubland and poor agricultural system showed significant improvement in NPP whereas regions which have already gone through technological improvements in agriculture (green revolution) showed relatively moderate increase in NPP in two decades of the study period.

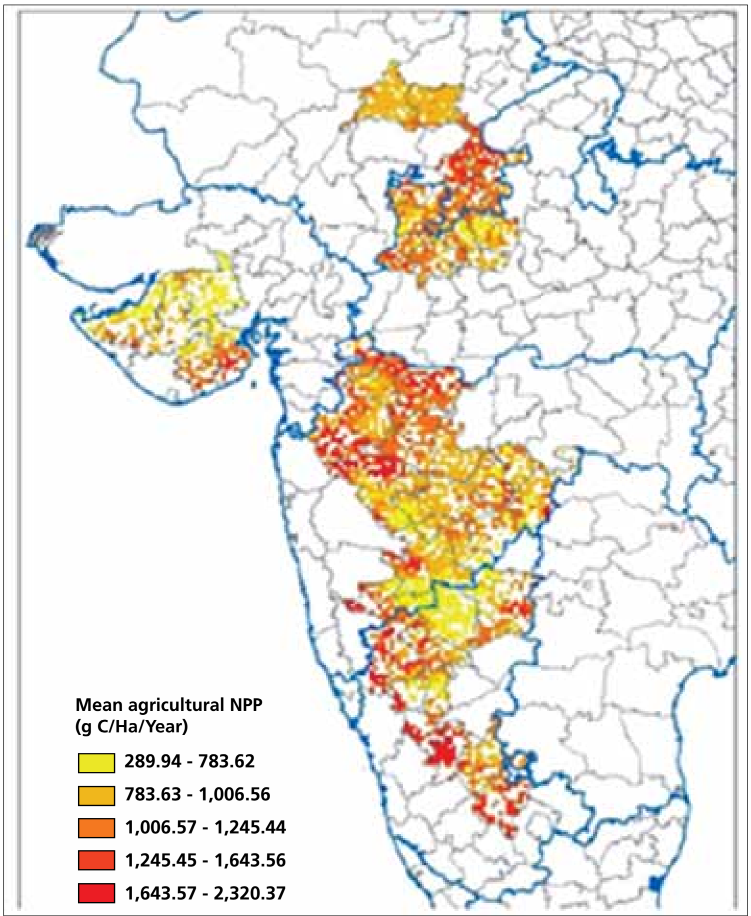


Fig. 16a: Mean agricultural Net Primary productivity (gm C/Year) of the selected districts of India for the period of 1981-2000

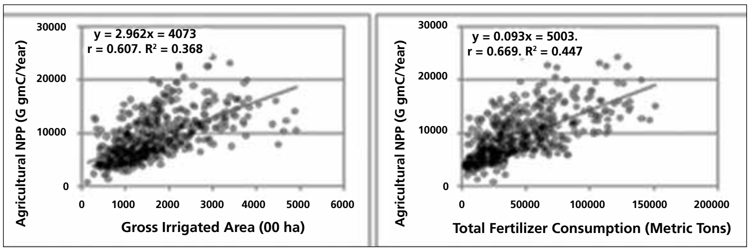


Fig. 16b: District wise agricultural NPP Vs total gross irrigated area and fertilizer consumption (n=620, Gms=109gm)

Over semi-arid region of India comprising Maharashtra, Rajasthan, Gujarat, Madhya Pradesh, the total agricultural NPP (Figure 16a) was increased by 33.40% during 1981-2000. This is mainly because the gross irrigated area has increased by 54.87% while the gross cultivated area increased slightly by 8.39% during the study period of 1981 to 2000. The fertilizer consumption of the study area has been tripled in the two decades. The Irrigated area and fertilizer consumption are the main anthropogenic factors (Figure 16b) which contributed to the increase in agricultural NPP.

Conclusion

The gap areas which need to be addressed in future are : (a) Evapotranspiration / Energy balance partitioning and Ecosystem Hysteresis (b) Resource (light, water, nutrient) Use Efficiency and natural disturbances (c) Waters availability, phenology and soil-plant processes under changing hydro-thermal regimes (d) Surface GHG emissions, energy balance and air quality coupling. The research activities have been planned to understand the link between eco-physical, ecophysiological, surface and sub-surface hydrological processes and their control mechanisms over different terrestrial ecosystems by developing improved modeling scheme for evaporation and transpiration, abiotic and biotic stresses, green-house-gas (GHG) emissions. The future studies would help in quantifying and modeling some of the scientific quests pertaining to vegetation-atmosphere interactions over sub-tropical region and help building important flux databases required by current and future satellites for assessing energy and mass interactions.

Acknowledgements

The authors are thankful to different research agencies and state departments such as Indian Institute of Science, Anand Agricultural University, Junagadh Agricultural University, Punjab Agricultural University, Bidhan Chandra Krishi Viswavidyalaya, ICAR centres (CRIDA, CAZRI, DRMR, CARI), Chilika Development Authority, Forest Research Institute, Tropical Forest Research Institute, State Forest Departments of Gujarat and Madhya Pradesh, MPCOST for providing necessary support at different phases of studies. The support extended by ISRO-GBP office and Director, Space Applications Centre is highly acknowledged.

References

Bairagi, G.D., Bhattacharya, B.K., Bhelana, B.K., Parihar, J.S. and Verma, P.K. (2012), Energy balance and CO_2 assimilation behaviour of soybean-wheat crop rotation in Narmada valley zone of central India. Journal of Agrometeorology, 14, 432-442

Bhattacharya B.K., Dutt C.B.S. and Parihar J.S. (2009a), INSAT uplinked Agromet Station – A scientific tool with a network of automated micrometeorological measurements for soil-canopy-atmosphere feedback studies. Paper no. TS9.13, In : ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, 72 – 77.

Bhattacharya B. K., Gunjal M., Nanda M. K. and Panigrahy S. (2009b), Protocol development for energy-water flux computation and model development. Chapter 3, Scientific report (SAC/RESA/EMEVS/SR/02/2009), 34 - 53.

Bhattacharya, B.K., Mallick, K., Patel, N.K. and Parihar, J.S. (2010), Regional clear-sky evapotranspiration over agricultural land using remote sensing data from Indian geostationary meteorological satellite. J. Hydrol., 387, 65-80.

Bhattacharya, B. K., Nigam, R., Mallick, K., Dakore, K. and Shekh, A.M. (2011), Efficiency based wheat yield prediction in a semi-arid climate using energy budgeting with satellite observations. Agricultural and Forest Meteorology, 151, 1394-1408.

Bhattacharya, B. K., Nigam, R., Dakore. K., Mehta, A., Pandey, V., Shekh, A.M. and Parihar, J.S. (2013), Landscape-scale surface heat fluxes from satellite thermal remote sensing data: Validation using measurements from Large Aperture Scintillometer. SAC/EPSA/ABHG/IGBP-EMEVS/SR/01/2013.

Bera, N, Nanda, M.K., Bhattacharya, B.K., Parihar, J.S., Banerjee, S., Saha, G., Das, L. and Khan, D.K. (2012), Estimation of canopy photosynthesis rate of rice from leaf chamber measurements and diurnal PAR balance. Journal of Agrometeorology, 14, 537-542.

Eswar, R., Sekhar, M. and Bhattacharya, B. K. (2013), A simple model for spatial disaggregation of evaporative fraction: Comparative study with thermal sharpened land surface temperature data over India. Journal of Geophysical Research : Atmospheres, 118, 1 – 16.

Mukherjee, J., Bal, S.K., Singh, J., Bhattacharya, B.K., Singh, H. and Kaur, P. (2012), Surface energy fluxes in wheat under irrigated ecosystem. Journal of Agrometeorology, 14(1), 16-20.

Nanda, M. K., Bera, N., Bhattacharya, B.K., Parihar, J.S., Banerjee, S., Pal, S. and Khan, D.K. (2012), Energy balance closure study over rice field. Journal of Agrometeorology, 14, 543-548.

Nigam, R., Mallick, K., Bhattacharya, B.K., Pandey, V. and Patel, N.K. (2008), Heat flux estimation from MODIS satellite and validation over a semi-arid agroecosystem using scintillometry and model simulation. Journal of Agrometeorology, 10(1), 75-81.

Parihar, J. S., Goroshi, S. K., Singh, R. P., Krishnayya, N. S. R., Sirsayya, M. B., Alok Kumar., Rawat, L. S and Sonakia, A. (2013), Observation of Forest Phenology using Digital Photography and Satellite data. Current Science, Vol. 105, No. 12, 25, Dec. 2013, 1740-1747.

Parihar, J. S., Goroshi. S. K., Singh, C. P., Lalramchuana. F and Lallianthanga, R. K. (2014), Decadal changes in Net Primary Productivity over Mizoram state in India, SAARC Forestry Journal, Vol.III, 63-75.

Raja, P., Bhattacharya, B. K., Singh, N., Sinha, N. K., Singh, J. P., Pandey, C. B., Parihar, J.S. and Roy, M.

M. (2013), Surface energy balance and its closure in arid grassland ecosystems : A case study over Thar desert. Journal of Agrometeorology. 15 (special issue – I), 94-99.

Singh, N., Patel, N.R., Bhattacharya, B.K., Soni, P., Parida, B.R., Parihar, J. S. (2014a), Analyzing the dynamics and inter-linkages of carbon and water fluxes in subtropical pine (Pinus roxburghii) ecosystem. Agricultural and Forest Meteorology, 197, 9, 206–218.

Singh, N., Bhattacharya, B.K., Nanda, M.K., Soni, P. and Parihar, J.S. (2014b), Radiation and energy balance dynamics over young chir pine (Pinus roxburghii) system in Doon of western Himalayas. Journal of Earth System Science, 1-15 : (11 nos.)

Singh, N., Bhattacharya, B. K., Soni, P., Raja, P., Singh, M.P. and Parihar, J.S. (2013), Energy and water dynamics over young pine forest as influenced by climatic variability and land management practices. Journal of Agrometeorology, 15 (special issue–I), 100 – 107.

Singh, R.P., Rovshan, S., Goroshi, S.K., Panigrahy, S and Parihar, J.S. (2010), Increasing Trend in Net Carbon Fixation by Indian Agro-Ecosystem Estimated Using NOAA-AVHRR based GloPEM MODEL, Journal of the Indian Society of Remote Sensing. DOI 10.1007/s12524-011-0123-1.

ISRO becomes member of CGMS

In view of its contribution to the Global Observing System of World Meteorological Organisation (WMO), ISRO has been included as a member of Coordination Group on Meteorological Satellites (CGMS) on May 21, 2015 in its 43rd Plenary session held in Boulder, USA. With this, ISRO becomes the 16th member of CGMS and the second member from India (India Meteorological Department – IMD serves as member of CGMS since 1979). CGMS pursues its coordination activities to support operational weather monitoring and forecasting as well as climate monitoring, in response to requirements formulated by WMO, its programmes and other programmes jointly supported by WMO and other international agencies. CGMS coordinates satellite systems of its members in an end-to-end perspective, including protection of in-orbit assets and support to users as required to facilitate and develop shared access to and use of satellite data and products in various applications.

ISRO has a long association with CGMS and has been participating in its meetings and working group activities as an Observer. ISRO's application to the CGMS membership was based on ISRO's existing and planned contributions in a number of areas relevant to the objectives of CGMS, that include: Indian Meteorological Satellite Missions; International Collaboration/ Joint Missions; Satellite Data Archival and Dissemination; Support to Operational Agencies; Contribution to calibration/ validations activities and to Committee on Earth Observation Systems (CEOS); Disaster Management Support; Training/Capacity building; Instrument Development and Support; and Climate Research.

Following are some of the expected benefits to ISRO on becoming CGMS Member:

- Participation in the global meteorologist's platform as an official member for preparation of global observation strategy
- Provide information on the Indian missions to the global community in the conception stage itself
- Plan ISRO's satellite missions complementing and supplementing the global data requirements
- Use this platform in developing collaborative missions with other space-faring agencies.
- Work out joint calibration strategy

Details of CGMS and its activities are in www.cgms-info.org

Revised satellite data price list

User Interaction Meet was organised at National Remote Sensing Centre during 3-4 February 2016. On this occasion, NRSC announced the revised satellite data price list and satellite data products new releases in public domain:

- Earth observation (EO) products from Indian Missions: RISAT-1 Level-2A product, Oceansat Scatterometer 2-day time composite global sigma naught product (25 km), CartoDEM V3.0 (data with 10 m spacing, covering India, Pakistan, Nepal, Bhutan, Afghanistan, Bangladesh, Egypt and part of Saudi Arabia)
- Earth observation (EO) products from foreign missions: Suomi NPP and Metop-B AVHRR (NDVI product).
- New geospatial products like AWiFS (Rabi & Zaid - 767 tiles), LISS III (Rabi - 6500 tiles) datasets for 2013 and various land, ocean and atmosphere products under National Information system for Climate and Environment Studies (NICES). These are useful for climate and environmental studies, made available for free download through NRSC Open Data Archive under Bhuvan geospatial platform.

IRS SATELLITE DATA PRODUCTS PRICE LIST
(Figures in Rupees)

IRS SATELLITE DATA PRODUCTS PRICE LIST

(Price in Rupees)

High Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
1.0	PAN (1m) (Cartosat-2)		
1.1	Mono Geo-referenced/Ortho kit 9.6 km x 9.6 km	100	2,440
1.2	Ortho Corrected 9.6 km x 9.6 km	15	2,890
2.0	PAN - A/F (2.5m) (Cartosat-1)		
2.1	Mono Geo-referenced/Ortho kit 27.5 km x 27.5 km	50	4,440
2.2	Stereo Ortho kit 27.5 km x 27.5 km	220	5,110
2.3	Ortho Corrected 27.5km X 27.5km	15	6,450
2.4	CartoDEM 14km X 14km	15	6,290
3.0	LISS- 4 MX (5m) (Resourcesat-1,2)		
3.1	Geo-referenced/Ortho kit 23.5 km x 23.5 km	50	1,540
3.2	Geo-referenced/Ortho kit 70 km x 70 km	50	4,170
3.3	Ortho rectified 70 km x 70 km	20	10,470
4.0	MICROWAVE (1m - 50m) (RISAT-1)		
4.1	Georeferenced SAR (FRS-1/FRS-2/MRS/CRS)	200	4,890

Medium Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
5.0	LISS - III (24m) (Resourcesat-2)		
5.1	Geo-referenced/Ortho kit 141 km x 141 km	100	3,520
5.2	Ortho rectified 141 km x 141 km	50	6,870
6.0	AWiFS (56m) (Resourcesat-2)		
6.1	Full Scene Geo-referenced 740 km X 740 km	150	7,420
6.2	Full Scene Ortho Rectified 740 km X 740 km	100	15,770
6.3	Quadrant Geo-referenced/ Ortho kit 370 km X 370 km	150	4,030
6.4	Quadrant Ortho rectified 370 km X 370 km	100	6,420

Low Resolution

S No	Product Type	Accuracy (CE90) in km	Price
7.0	OCM (360m) (Oceansat-2)		
7.1	Georeferenced 1420 km X 1420 km	1.5	3,050
7.2	Geo physical 1420 kmX1420 km	1.5	1,070

Airborne Visible/ Infrared Imaging Spectrometer Next Generation (AVIRIS-NG)

ISRO and Jet Propulsion Laboratory (JPL) of NASA jointly conducted an airborne campaign over Indian territory for collecting invaluable scientific data of surface-reflected solar spectrum (380-2500nm) in high spatial and pectral resolution for earth science studies.

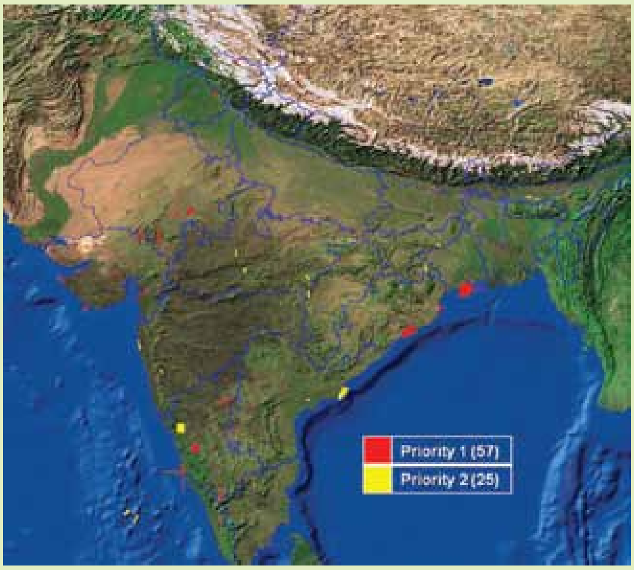
NRSC Beechcraft King Air B-200 aircraft flew a remote sensing mission campaign carrying the NASA's Airborne Visible/ Infrared Imaging Spectrometer Next Generation (AVIRIS-NG) instrument.

There are about 430 narrow continuous spectral bands in VNIR and SWIR regions at 5nm interval with ground sampling distance (GSD) vis-à-vis pixel resolution varies from 4-8m for flight altitude of 4-8 km.

Total 82 sites across India have been selected for the campaign. Acquisition of 57 sites as Priority-I spanning across diverse environments has been completed. Airbases of Hyderabad, Bhubaneswar, Mangalore, Coimbatore, Udaipur, Ahmedabad, Chandigarh, Patna and Kolkata has been used and about 200 officials participated in this campaign. Acquisition of 25 sites Priority-II will be planned in October 2016.

This joint airborne campaign will provide the first of their kind high fidelity imaging spectroscopy measurement of a diverse set of Asian environments for science and applications research. The collected data will be shared between scientific communities of ISRO and NASA for collaborative interpretation and application of results.

AVIRIS NG Instrument



82 diverse science sites approved for measurement

ISRO B-200 Aircraft at NRSC

MAPPING OF POTENTIAL AREAS FOR SERICULTURE DEVELOPMENT AND INFORMATION DISSEMINATION THROUGH SILKS WEBPORTAL

Handique BK, Das PT, Goswami J, Goswami C,
Singh PS, Chutia D, Rocky P and Raju PLN
North Eastern Space Applications Centre, Shillong-793103 Meghalaya
Email: bk.handique@nesac.gov.in

Introduction

Indian sericulture is an age old practice, producing all four types of natural silk namely Mulberry, Tasar, Eri and Muga. India is the second largest producer of mulberry silk accounting for about 15 percent of the of the global raw silk production. Sericulture plays an important role in programmes of poverty alleviation and employment generation. People employed under sericulture in the country is estimated to be 8.03 million during 2014-15. Sericulture production is still limited to a few pockets in our country and decline in silkworm foodplants is a matter of concern. The current production (about 28708 MT during 2014-15) is not adequate to meet the demand for silk in the country. There is tremendous scope for improving the production and quality of silk through expansion of sericulture to new potential areas, supporting the farmers with up-to-date scientific information through appropriate dissemination system. In this context, geospatial tools comprising of Remote Sensing (RS), Geographical Information System (GIS), Global Positioning System (GPS) and web technology have the potential of integrating, analysis and dissemination of satellite derived and other required information for further expansion of sericulture in the country.

Central Silk Board (CSB) and Indian Space Research Organisation (ISRO) in collaboration with the concerned State Sericulture/Textiles Departments used the technology of RS and GIS for mulberry acreage estimation, garden condition assessment and for finding suitable areas for introducing sericulture in the non-traditional states (Nageswara Rao et al., 1991; CSB, 1994). ISRO and CSB had carried out a project, called SPAARS (Survey of Potential and Actual Area under Sericulture with Remote Sensing), for mapping of potential and actual areas under Sericulture at 1: 250000 scale. Because of the coarse mapping scale the derived information could not meet the requirement for district and block/taluka level planning. Hence a project titled 'Applications of Remote Sensing and GIS in Sericulture Development' was taken up for implementation during 2008-09 to 2013-14 period with an objective to identify the additional potential areas for development of silkworm food plants for 108 priority districts in 24 states at 1: 50000 scale in three phases; Phase I: 41 districts covering all 8 states in North Eastern

Region (NER) including Sikkim. Phase II: 45 districts covering 11 other non-traditional states viz., Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Uttarakhand, and Uttar Pradesh. Phase III: 22 districts in 5 traditional states viz. Andhra Pradesh, Jammu and Kashmir, Karnataka, Tamil Nadu and West Bengal. It was also envisaged to develop a geoportal for integrating the potential area maps along with other required information for expansion of sericulture at district level.

Quick development of web technologies has transformed geoinformatics from a science for specialists into an application tool for wide range of users. Geoportals were developed to find and access geospatial information and associated geographic services (display, editing, analysis, etc.) via the internet. Geoportals are important for effective use of GIS and a key element of Spatial Data Infrastructure (SDI). The United States National Spatial Data Infrastructure (NSDI), started in 1994 is considered the earliest geoportal concept (Fu and Sun, 2010). In India the first initiative to establish a national level spatial data/information infrastructure was first mooted in 2000 by the Department of Space followed by initiative taken by Department of Science & Technology with the formation of task force on National Geospatial Data Infrastructure. A number of geoportals have been developed by various government departments and organization to meet the requirements of target users and also the common public. Bhuvan geoportal (http://bhuvan.nrsc.gov.in),launched by National Remote Sensing Centre, Department of Space on August 12, 2009 takes the lead among all the geoportals and offers detailed visualization of imageries along with a large volume of thematic information. Considering there is no other geoportal available in the country on sericulture, a geoportal titled Sericulture Information Linkages and Knowledge System (SILKS) was planned to develop integrating all the project outputs for 108 districts along with required district level information for expansion of sericulture and to host it under the domain name http://silks.csb.gov.in.

Identification of Potential Areas for Mulberry

The methodology for identification of potential areas for sericulture development involves evaluation of land, water resources and climatic requirements for growing silkworm food plants as well as rearing of silk worms (Sys, 1985, Sys et al., 1993). It needs interpretation and integration of soils, climatic parameters, vegetation and other aspects of land, like wastelands and slope using GIS. As there is limited scope of expansion of plantations area under silkworm food plants, emphasis was given in identifying cultivable wastelands using satellite data using standard classification approach (NRSC, 2006). Out of 23 wastelands categories at 1:50000 scale as per National Wasteland Classification System (NRSC, 2011), 7 categories were considered for further evaluation of suitability for silkworm food plants. IRS Resoursesat-1 and Resourcesat 2 LISS III satellite data during the period of 2008-2009 were acquired for delineating the cultivable wasteland areas.

Evaluation of Site Suitability Based on Landscape and Soil Characteristics

Six parameters of soil viz., drainage, ground water, texture, depth and pH and two topographic and landscape parameters viz., slope and erosion were considered for suitability evaluation. Soil characteristics were obtained from the soil map prepared under two projects at national level viz., National Natural Resources Data Base (NRDB) of Department of Space and project on soil mapping by National Bureau Soil Survey and Land Use Planning (NBS&SLUP) and Soil and Land Use Survey of India (SLUSI). Slope map was derived from SRTM DEM (Shuttle Radar Topographic Mission- Digital Elevation Model). Information on ground water availability was obtained from ground water prospect map prepared under Rajiv Gandhi National Drinking Water Mission. Soil erosion map of the study area was generated using Universal Soil Loss Equation (USLE) in GIS environment. Different thematic layers were generated in GIS environment for each of the land characteristics and compared with the requirements of silkworm food plants. Criteria of limitation ranging from 1 (suggesting no or slight limitation) to 4 (suggesting very severe limitation) were assigned to generate the suitability map as per the following FAO Sericulture Manual Standards (1990) (Table 1).

Table 1: Criteria of limitation rating for evaluation of soil site suitability for Mulberry

Soil-site characteristics		**Degree of limitation & Suitability class**			
	Unit	0-1 None to slight	2 Moderate	3 Severe	4 Very severe
		S1 (Highly suitable)	S2 (Moderately suitable)	S3 (Marginally suitable)	N (Not suitable)
Topography and landscape					
Slope	(%)	0-3 (level to very gentle)	3-5 (gentle)	5-10 (moderate)	>10 (steep)
Erosion		e1	e2	e3	e4
Soil characteristics					
Drainage	Class	Well	Well	Well	Excessive
Ground water	Availability	Good	Fair	Fair to moderate	Poor
	Quality (EC micromohs /cm)	Very good < 2000	Fair to good 2000 - 3000	Moderate 3000 - 4000	Poor > 4000
Texture	Class	Clay loam –gravelly clay	Fine loamy	Coarse loamy	Sandy fragmental
Depth	Cm	Deep	Mod. shallow–mod. deep	Shallow	Very shallow
pH		6.5-7.5	5.5-6.5 7.5-8.5	4.5-5.5 8.5-9.5	>4.5 >9.5

Evaluation of Site Suitability Based on Climatic Parameters for Silkworm Food Plants

Suitability of climate for the food plants were described in terms of: (i) temperature (ii) rainfall (water supply) and (iii) minimal length of growing period,. The weather data, collected from the class-I observatories of IMD and the Automatic Weather Stations (AWS) established by ISRO have been analysed for rainfall, maximum and minimum temperature, Potential Evapotranspiration (PET) and length of growing period (LGP) for the silkworm food plants.

Spatial Distribution of Temperature and Rainfall

The point observations on temperature and rainfall need to be translated into spatial domain and this was done by analyzing longterm monthly and annual average of mean temperatures of all the stations with corresponding elevation data (Patel, 2000).The empirical relation thus developed is used in GIS environment for depicting spatial variation of annual mean temperature or mean temperature for the growing season of silkworm food plants. For interpolation of rainfall data from point locations to represent the spatial coverage kriging method was adopted as kriging method assumed to yield more accurate predictions than linear regression (Goovaerts, 1999).

Spatial Distribution of Length of Growing Period (LGP)

Length of Growing Period (LGP) or moisture availability period for crop growth is the period (in days) when precipitation exceeds 50 percent of the PET(Potential Evapotranspiration). Shorter LGP (less than 120 days for mulberry and 90-120 days for castor, as examples) are not suitable for cultivation of silkworm food plants. Monthly potential evapotranspiration (mm) were computed by Thornthwaite method (1948). The calculated LGP is presented in spatial domain with interpolation using geostatistical analyst tools.

Based on climatic characteristics, limiting levels viz., highly suitable, moderately suitable, marginally suitable and unsuitable have been decided by matching the requirements of silkworms food plants (Table2) and assigned suitability class (limitation). The climatic limitation map was superimposed on the soil constraints map to finally derive site suitability map.

Table 2: Evaluation of climatic site suitability for Mulberry

Climatic characteristics	Suitability classes			
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Mean temperature in growing season(^{0}C)	20-30	31-37	31-37	<15, >37
Total rainfall (mm)	500-750	751-2000	2001-3400	<500, >3400
LGP(days)	>200	-	-	-

Evaluation of Suitability for Silkworm Rearing

Silkworms are delicate and very sensitive to environmental conditions. Among the various environmental factors, the most important are atmospheric temperature and humidity prevailing at the time of rearing. The combined effect of both temperature and humidity largely determines the satisfactory growth of the silkworms. The optimum temperature and humidity for normal growth in mulberry silkworm is between 23-28^{0}C and 70-85% respectively. Spatial layers on the temperature suitability for silkworm were generated as it was done in case of silkworm food plants.

Integrated Evaluation of Soil and Climatic Suitability for Silkworm Food Plants and Sericulture Development

The maps generated indicating limitations for climate, landscape and soil characteristics have been spatially overlaid in GIS environment to produce a resultant polygon layer. Each polygon has 8 values (soil characteristics) of degree of limitation. Based on the number and the intensity of limitations, suitability classes have been decided and graded as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) as given in Table 3. Figure 1.

Table 3: Criteria for determination of land suitability classes

Land classes	Criteria
S1: Highly suitable	Land units with no or only 4 slight limitations
S2: Moderately suitable	Land units with more than 4 slight limitations and/or no more than 3 moderate limitations
S3: Marginally suitable	Land units with more than 3 moderate limitations and/ or one or more severe limitation
N: Not suitable	Land units with very severe limitation

Development of SILKS Geoportal

A geoportal titled Sericulture Information Linkages and Knowledge System (SILKS) has been developed as a single window decision support system to provide all the sericulture related information for all the selected 108 districts. SILKS spatial modules has inbuilt webGIS tools for displaying and querying of spatial data. The portal has been developed using open source software packages. The UMN Map Server (developed by the University of Minnesota, and often referred as UMN Map Server) is used as a

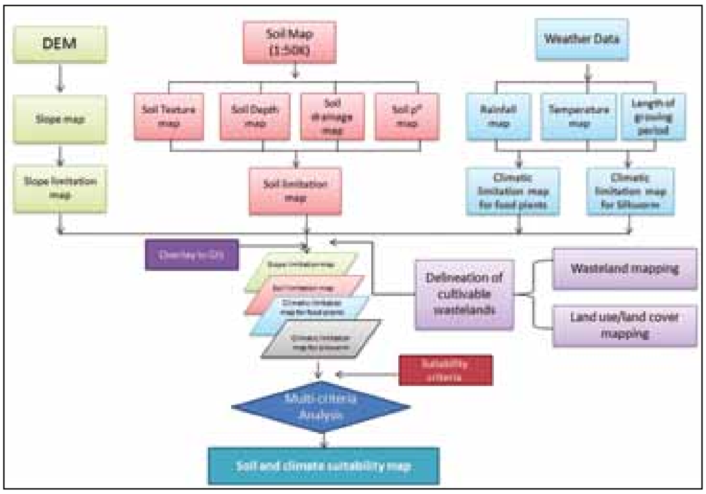


Fig.1: Flow chart of methodology for soil and climate suitability for sericulture development

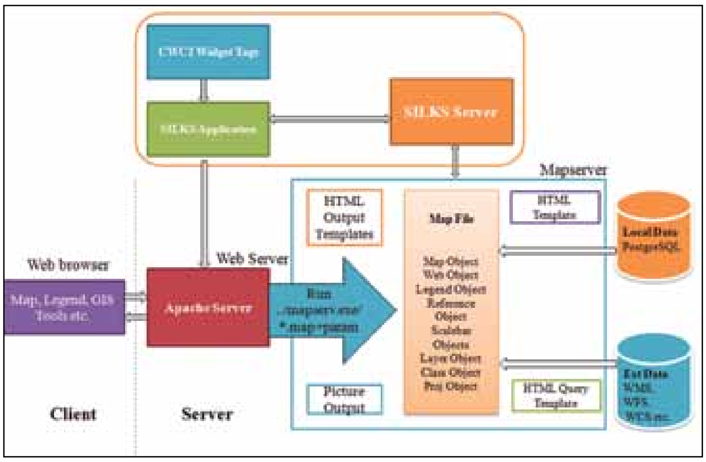


Fig. 2: SILKS Application architecture

GIS engine, PostgreSQL/PostGIS as an object oriented relational database management system (ORDBMS) and GeoServer for creating OGC(Open Geospatial Consortium) web services. An open source web application tool built on top of Map Script using the PHP programming language has been used for development of interactive user interface. SILKS allows effective dissemination, sharing and management of spatial information, which can be used as an effective decision making tool for sericulture planning and development. The non-spatial modules were created using web tools such as HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), JavaScripts etc. The basic architecture of SILKS is shown in Figure 2. First, the user makes a request having Mapserver parameters. The Apache HTTP web server upon receiving the parameters invokes the Mapserver engine. The Map file inside the Mapserver defines the basic and query template and tells how the maps will appear on the browsers. The Mapserver can connect to both local PostgreSQL data as well as external OGC data services from remote servers. The re-projection of the incoming data can be done on-the fly as per the projection defined in the "projection object". The Mapserver then processes the data as per the parameters and returns images in the desired map output format defined in the Mapfile.

Results and Discussion

Additional Area Suitable for Mulberry Host Plants in NE States

Out of total 108 districts, 41 districts were selected from 8 NE states including Sikkim covering a total geographical area of 9,35,195 sq km (Table 4). Among the NE states, Nagaland is found to have maximum suitable areas (21.9% of total geographical area) that can be brought under Mulberry Sericulture. This is followed by Meghalaya state (15.8%). Due to limitation of physiographic conditions and climate, Arunachal Pradesh is having very limited areas (17242 Ha in selected 7 districts) that can be brought under sericulture activities. A map with potential areas for sericulture development in RiBhoi district of Meghalaya is shown in Figure 3.

Additional Area Suitable for Mulberry Host Plants in Other Selected States

Among non-traditional sericulture states, Bihar has been found to have the highest percentage of areas suitable for mulberry sericulture, which is about 11% of total geographical areas in the selected 3 districts, followed by Madhya Pradesh (10.2%) and Himachal Pradesh (9.7%). Among traditional sericulture states, Karnataka is found to have as high as 11.6% of total geographical areas in the selected districts are suitable for mulberry sericulture. The state of Punjab has been found to be least suitable for Mulberry sericulture with only 521 ha of areas delineated as marginally suitable in the selected two districts. Other two states which have been found to be less suitable for Mulberry sericulture are Uttarakhand (0.05%) and Chhattisgarh (0.6%), but Uttarakhand has about 595 ha of area under highly suitable categories in the selected 5 districts. For non-mulberry sericulture, Bihar and West Bengal have significant proportion of suitable areas for Eri and West Bengal and Uttarakhand have significant suitable areas for Muga. For tropical Tasar, Orissa has the highest percent of suitable areas (25% of TGA) in the selected 4 districts followed by Jharkhand (21.2% of TGA) in the selected districts (Table 5).

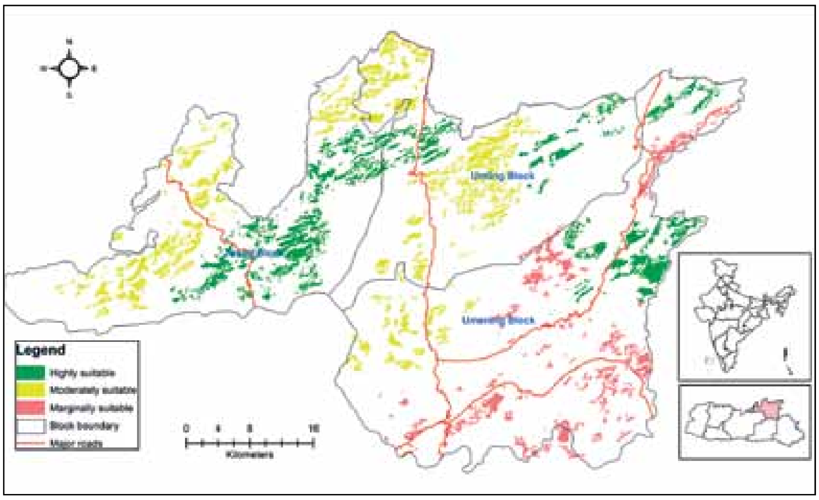


Fig. 3: Potential areas for sericulture development in RiBhoi district, Meghalaya

Table 4: Suitable for Mulberry host plants in NE states

STATES	No. of Selected districts	TGA (Ha)	Highly Suitable (Ha)	Moderately Suitable (Ha)	Marginally suitable (Ha)	Total (Ha)	% of TGA
Arunachal Pradesh	7	36981	13	1908	15321	17242	0.47
Assam	9	32713	1169	76893	232377	310439	9.49
Manipur	9	22327	-	-	67675	67675	3.03
Meghalaya	2	5051	13928	32381	33425	79733	15.79
Mizoram	6	18278	85598	73495	17567	176660	9.67
Nagaland	5	10910	-	-	239306	239306	21.93
Sikkim	1	750	-	827	5095	5922	7.90
Tripura	2	4423	219	17388	14745	32352	7.31

Information Dissemination through SILKS Geoportal

The SILKS geoportal developed as a part of the project has been put in the public domain under the domain name http://silks.csb.gov.in (Figure 4). SILKS is a single window, ICT-based information and advisory services system for the farmers, sericulture extension workers, administrators and planners working in the field of sericulture development. It provides computerized information storage, value addition, and supply sericulture knowledge to the users and planning and advisory services in formats and language appropriate for the local sericulturists. The portal is now made available in 12 languages viz., English, Hindi, Telugu, Kanada, Assamese, Bengali, Mizo, Manipuri, Khasi, Garo, Ao Naga and Sumi Naga. It has 13 major non-spatial modules and 4 spatial modules, which are grouped into three categories, namely Planning Services, Other Services and Natural Resources Management. The available modules under Planning Services are Silkworm

Table 5: Suitable for Mulberry host plants in other than NE states

STATES	No of selected districts	TGA (sq km)	Highly suitable (ha)	Moderately suitable (ha) Moderately suitable (ha)	Marginally suitable (ha)	Total (ha)	% of TGA
Andhra Pradesh	4	37518	2366	10339	6641	19346	0.52
Bihar	3	8934	-	59916	41458	101374	11.35
Chhattisgarh	2	22060	-	3162	9994	13156	0.60
Himachal Pradesh	4	15607	13755	96073	42254	152082	9.74
Jammu and Kashmir	2	2108	2551	6154	11299	20003	9.49
Jharkhand	3	8742	-	7651	11531	19182	2.19
Karnataka	4	33878	-	11877	379932	391809	11.56
Kerala	2	9411	9914	21970	14803	46686	4.96
Madhya Pradesh	6	35132	1136	77208	279563	357907	10.19
Maharashtra	7	72520	-	6441	76401	82843	1.14
Orissa	4	25986	238	7976	88217	96431	3.71
Punjab	2	4568	-	-	521	521	0.11
Tamil Nadu	4	24133	95325	59449	10446	165220	6.85
Uttar Pradesh	6	23886	584	8135	16382	25101	1.05
Uttarakhand	5	24990	595	300	263	1158	0.05
West Bengal	9	50438	38038	54272	24571	116882	2.32

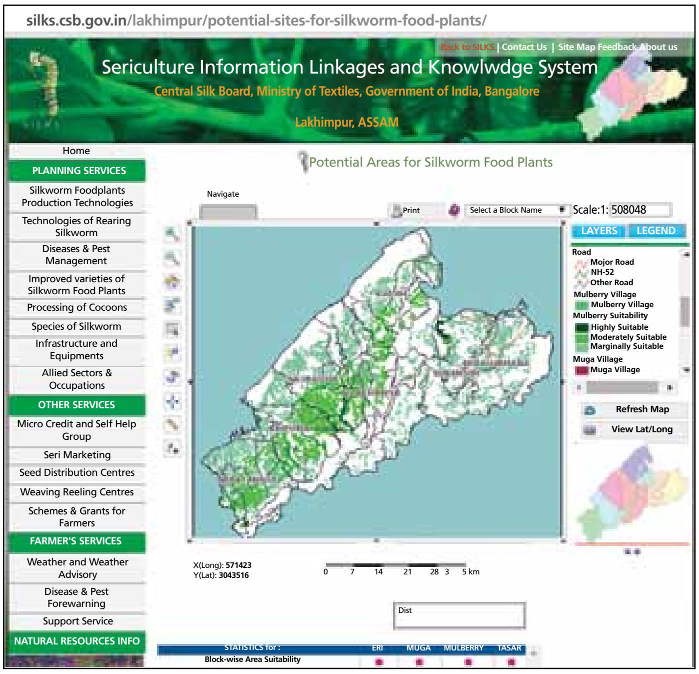


Fig. 4: SILKS webportal

Food Plants Production Technologies, Techniques of Rearing Silkworm, Diseases and Pest Management of Silkworm Food Plants, Improved Varieties of Silkworm Food Plants, Species of Silkworm, Processing of Cocoons, Infrastructure and Equipments and Allied Sectors and Occupations. Other Service has modules like Micro Credit and Self Help Group, Seri Marketing, Seed Distribution Centres, Weaving Reeling Centres and Schemes & Grants for Farmers. Farmers Services module consists of Weather and Weather Advisory, Disease and Pest Forewarning and Support Services. Within a short span of about one year, the portal has been able to make significant impact particularly in North Eastern region and a number of sericulture expansion activities have been initiated based on the outcome of the study. Regular updation of information content in the portal requires continuous support from all the stakeholders based on the feedback from the users particularly the sericulture farmers.

References

CSB (1994), Manual of satellite remote sensing applications for sericulture development, Central Silk Board, Bangalore. FAO (1976). A Framework for Land Evaluation. Soil Bulletin, 32. Food and Agriculture Organization. United Nations. Rome, Italy.

Fu, P., and J. Sun (2010), Web GIS: Principles and Applications.ESRI Press.Redlands, CA. ISBN 1-58948-245.

Goovaerts, P. (1999), Performance comparison of geostatistical algorithms for incorporating elevation into the mapping of precipitation,. Geocomputation 99, 1-17.

Nageswara Rao., Ranganath, B.K. and Chandrashekhar, M.G. (1991), Remote sensing applications in sericulture, Indian Silk, 30, 7-15.

Navalgund, R.R., Parihar, J.S., Ajai, and Nageswara Rao. (1991), Crop inventory usingremotely sensed data, Current Science, 61162-17.

NRSC (2006), Manual- National Land Use Land Cover mapping using multi-temporal satellite data, Land Use Division, National Remote Sensing Agency, Hyderabad.

NRSC (2011), Wasteland Atlas of India, National Remote Sensing Agency, Hyderabad.

Patel, N.R., Mandal, U.K. and Pande, L.M. (2000), Agro-ecological Zoning system. A Remote Sensing and GIS Perspective. Journal of Agrometeorology, 2(1), 1-13.

Rao, U.R. (1991), Remote Sensing for sustainable development, Journal of Indian Society of Remote sensing, 19, 217-236.

Sys, C. (1985), Land Evaluation Part I, II III. State Univ. Ghent Pub., Belgium.

Sys, C., Ranst, V., Debaveye, J. and Beernaert, F. (1993), Land Evaluation Part III, Crop requirements. Agricultural publication No. 7, ITC Ghent.

Thornthwaite (1948), An approach for a rational classification of climate. Geographical Review 38:55-94.

Mizoram and Uttarakhand State Meets on Promoting Space Technology based Tools and Applications in Governance and Development

Mizoram State Meet on Promoting Space Technology based Tools and Applications in Governance and Development was held on 8th March 20016 at Mizoram Secretariat Conference hall, Aizwal. Shri PLN Raju, Director, NESAC in his presentation has highlighted the Indian Space Programme and importance of the meeting and Shri Lal Masawma, Chief Secretary, Govt. of Mizoram, inaugurated the state meet. The State Meet was attended by around70 participants from 24 line departments of Government of Mizoram.

The technical programme consisted of four theme sessions namely (i) Environment and Energy, (ii) Agriculture and Allied departments, (iii) Infrastructure Planning and (iv) Health and Welfare.

The outcome of the above four sessions were presented in the concluding session, which was chaired by Shri Lal Thanhawla, Chief Minister of Mizoram. The Hon'ble Chief Minister, in his special address, stressed upon the importance of space technology for the remote states like Mizoram and urged the government. departments to utilize the technology to its fullest potential. The departments have projected many requirements. The line departments have been asked to submit the detailed project proposals for further scrutiny and finalization.

Concluding Session chaired by Hon'ble Chief Minister, Mizoram

Uttarakhand State Meet on Promoting Space Technology Based Tools and Applications in Governance and Development was organised on 27th February, 2016 by USAC in at IIRS campus of Dehradun. It was inaugurated by Chief Secretary, followed by presentation from 40 departments in 8 technical sessions, namely Agriculture, Environment and Energy, Infrastructure and Planning, Water Resources, Health and Education, Weather and Disaster Management, Developmental Planning, and Technology Diffusion, Communication and Navigation. It was attended by more than 250 participants from 52 departments and other govt. organizations. The Plenary session as addressed by Chief Minister of Uttarakhand and Chairman, ISRO. The Hon'ble CM highlighted the role of space technology in Uttarakhand particularly for disaster management and development of remote areas. In response to inputs from various state departments, USAC is working out the details of the joint projects to be carried out with their involvement.

P-5 P-6

AIZAWL THURSDAY 10 MARCH 2016 VOL 13 ISSUE 276 ₹ 5.00

The Mizoram Post

Window to Mizoram

8 pages

CM asks departments for more use of Space Technology

AIZAWL, MAR 9

Those nations that can make the most use of modern technology are developing, said Chief Minister Lal Thanhawla and asked the departments in the State to use space technology more and more.

He was speaking at the closing function of One Day State Meet on 'Promoting Space Technology Based Tools and Application in Governance and Development' here at New Secretariat Conference Hall yesterday evening.

Chief Minister thanked Indian Space Research Organisation (ISRO), North Eastern Space Application Centre (NESAC) and Mizoram Remote Sensing Application Centre (MIRSAC) for organizing the Meet, which, he added, would result into a fruitful progress for Mizoram.

It is necessary to make use of space technology in order to have good planning and good governance, Chief Minister said while appreciating the various departments in the Stare for their level best preparation to use space technology.

CM also lauded the initiative of MIRSAC while calling for making the most use of the fast growing and fast changing world technology.

During the theme session of the Meet, the Theme Chairman of each of the 4 Themes- Environment and Energy, Agriculture & Allied departments, Infrastructure Planning and Health and Welfare, summed up and explained the initiatives and plans of various departments.

Dr. M.A Paul, who came from ISRO Hqrs, Bangalore appreciated the action plans of various departments for using space technology and said that based on the report of the Meet, ISRO will find ways to help the departments.

The Meet, which was in pursuance of the initiative of Prime Minister Narendra Modi, was the first-ever in North East, C.Vanlaramsanga, Secretary, Planning Department, who conducted the closing function, said. And Mizoram is the only State to organize this kind of Meet twice in a year, he mentioned.

The Meet was attended by department representatives, ISRO Scientists, NESAC and MIRSAC Scientists.

CLIMATE CHANGE CONCERNS AND ADAPTIVE MANAGEMENT OF WATER RESOURCES IN INDIA

Bandyopadhyay S, Paul MA, Shantanu B and Arunan S
EOS Programme Office, ISRO HQ, Bengaluru-560231
Email: bandyo@isro.gov.in

Introduction

Climate change imposes uncertainties to the utilization and management of water resources. Based on distribution of rainfall, more than two third area of India falls under dryland and faces water scarcity. With the consequences of climate change looming across the horizon further accentuated a sizable pressure on this scare commodity. While the adverse impact of climate change on health, settlements and natural resources has been reported by many researchers, the severe stress on water resources and food-grain production are the major concerns in order to feed the growing population. Moreover, increased temperature and humidity due to climate change would enhance the incidence of pest and diseases, thereby severely affecting the agricultural crops (Mall et al., 2006a); Senapati et al., 2013). Studies on regional climate models and distributed hydrological models showed an increasing trend for maximum, minimum temperatures and rainfall. Global warming is being increasingly manifested through perturbing natural rainfall patterns and its uneven distribution. Many dry areas will suffer badly from reduced rainfall and increased evaporation affecting around millions of people in dry regions of Indian subcontinent. The other serious effects are sea level rise and degradation of coastal ecosystem, ground water salinization, melting of the Himalayan glaciers and shifting of growing height of Alpine vegetation. These changes will have profound effects on various economic sectors and the livelihoods of millions of people, especially the poorest section of the region.

World Bank (2013) and the Fifth Assessment Reports (2013) of the Intergovernmental Panel on Climate Change (IPCC) have brought out the evidences that the earth's climate system is changing on both global and regional scales since the pre-industrial era. The earth system is getting warmer with the intense anthropogenic activities specifically those that cause an increase in the atmospheric concentration of carbon dioxide. Researchers around the globe have found that climate change is likely to impact water resources depletion and land degradation considerably (Mall et al., 2006). There have been observed changes in surface temperature, rainfall, evaporation, and extreme events since the beginning of the twentieth century. Thus, changes in temperature and precipitation under climate variation have serious impacts on hydrology and water resources availability. Improved understanding of climatic effect on hydrological variability is of paramount importance for sustainable development and management of water resources (Arnell, 1999; Gosain et al., 2011; Devkota & Gyawali, 2015)

Livelihood and sustenance of development are highly climate driven. Floods, droughts and cyclones regularly batter economic sectors and infrastructure and cause deaths to human and livestock population (Kumar et al., 2003; Chhabra et al., 2004). In order to reduce vulnerability, there is an urgent need to design and implement adaptation measures. It is also warranted that adaptation be integrated into national development plans of the country, as a continuous process. The objectives of this article are to bring out the impacts of climate change on Indian water resources and the need for developing suitable strategies and adaptive framework to mitigate the effect of climate change on natural resources, especially on water resources. In this context, space and geo-spatial technologies are considered to be the important tools which enable systematic inventory of water resources and help in identifying the key measures towards sustainable management and conservation of resources.

Climate Change and Scenarios

The changes in the Earth's climate system are the integrated effect on atmosphere, biosphere, hydrosphere and the cryosphere. Extremes of climate are a key expression of climate variability, and this assessment includes new data that permit improved insights into the changes in many types of extreme events including heat waves, droughts, heavy precipitation and tropical cyclones (including hurricanes and typhoons). Therefore, multidisciplinary approaches are necessary in order to increase understanding of trends, variability and processes of climate change at global and regional scales.

The Intergovernmental Panel for Climate Change in its fifth report (2014) has projected climate change scenario based on direct measurements and from satellites and other platforms. According to the report the global climate system is warming up since the 1950s, with melting of snow and ice, rise in the sea level and increase in concentrations of greenhouse gases.

Key messages from IPCC report (2014)

- Coming years will see more extreme weather events (floods, cyclones, cloud bursts, unseasonal excessive rains and drought etc) in most parts of the globe Maldives, China, India, Pakistan, Bangladesh and Sri Lanka will be among the most affected countries in Asia
- Severe stress on fresh water resources in South Asia and China (Himalayan river basins) may become a reason for armed conflict in the region by middle of the 21st century
- Coastal flooding will not only kill people and cause destruction, it will also affect tourism in India (like in Goa and Kerala)
- Decline in food grain production (wheat in India/Pakistan and wheat and maize in China)
- Big coastal Cities like Mumbai and Kolkata will be affected by sea-level rise in 21st century
- Some fish and other marine animals will face extinction by 2050, affecting fishing community
- In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality
- Glaciers (including Himalayan) continue to shrink almost worldwide due to climate change, affecting run-off and water resources downstream
- Climate change will impact human health mainly by exacerbating health problems that already exist.

Some of the facts and figures related to climate change are: (i) averaged combined land and ocean surface temperature for the period 1880 - 2012 shows a warming of 0.85°C; (ii) it is projected that the contrast in precipitation between wet and dry regions/ season likely to increase; (iii) accelerated melting of glaciers with intensification of monsoon can lead to flood disasters in the Himalayan catchments; (iv) Since about 1950, many extreme weather and climate events are common and the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. (v) mean rate of global averaged sea level rise was 1.7 mm yr^{-1} between 1901 and 2010; (vi) deltas will be threatened by flooding, erosion and salt intrusion. (vii) loss of coastal mangroves will have impact on fisheries; and (viii) increased temperatures will impact the agricultural production.

Paris Climate Change Agreement -2015

- A long-term goal to limit global warming to 'well below' 2 ^{0}C or 1.5 ^{0}C if possible
- National pledges to cut greenhouse gas emissions in the 2020s
- A plan to make countries pledge deeper emissions cuts in future, improving their plans every five years
- Capacity-Building Initiative by developed countries – 'mobilising' $100 bn a year until 2025
- A plan to monitor progress and hold countries to account

Climate change and will see severe stress on water resources and food-grain production in the future. India, like other developing economies, may lose up to 1.7% of its Gross Domestic Product (GDP) if the annual mean temperature rises by 1 degree Celsius compared to pre-industrialization level, hitting the poor the most.

Water Resources of India

India receives annual precipitation of about 4000 km^3 including snowfall. Out of this, monsoon rainfall is of the order of 3000 km^3 (Kumar et al., 2005). Rainfall in India is dependent on the south-west and north-east monsoons, on shallow cyclonic depressions and disturbances and on local storms. Average water yield per unit area of the Himalayan Rivers is almost double that of the south peninsular rivers system, indicating the importance of snow and glacier melt contribution from the high mountains (Lal, 2001). The change in rainfall pattern, may adversely affect the future water resources availability in a basin (Nearing et al., 2005, Burns et al., 2007, Gonzalez et al., 2009). The hydrological cycle is being modified quantitatively and qualitatively in most of the river basins of our country as a result of the developmental activities such as construction of dams and reservoirs, land use change and irrigation. This has led to reduced availability of water from various surface and sub-surface sources. Prediction of climatic variables, under changing climatic conditions, at the basin level (fine resolutions) and their use in hydrological/hydraulic modeling is required for prediction of water availability for irrigation, domestic, industrial, power production; and flood and drought conditions at the basin levels.

India is an agrarian country and currently utilises around 85% of the total available water for food production. India has great variation of climate, with striking contrasts of meteorological conditions (Tyagi et al., 2012). Climate variability and climate change have substantially affected agricultural production in India. Under the climate warming scenario, severity of droughts and intensity of floods can get deteriorated in many parts of the region (Gosain et al., 2006). Most rainfall in India occurs during the southwest monsoon season, between June and September, and levels of precipitation vary from 100 mm a year in the western parts of Rajasthan to over 1,100 mm in the northeastern state of Meghalaya (Jain et al., 2007). Floods and droughts are both common throughout the country. But despite an estimated water availability of ~1800 cubic m. per person, per year, nearly 900 million people in the country suffer severe water shortages due to uneven distribution of water. The per capita availability of water in India is dwindling. The country currently uses only a small part of its water endowment; as such, there is still huge potential to meet the water needs through developing proper water distribution and harvesting systems.

Pressure on the water resources is increasing unabatedly with the growing demand in the various sectors. The water requirement for the irrigation purpose will increase in the coming decades for meeting the food requirement of the increasing population; although, its share in total water demand will reduce (Rakesh et al., 2005). In other words, the present demand of 85% for irrigation sector will reduce to 74% by 2050 indicating competition among the various sectors of water utilization, and the future challenges in water resources management (Gupta and Deshpande, 2004). The total utilizable water available works out to 1122 BCM, which is just sufficient to meet the estimated demand by 2025. There will be a gap between the water availability and the requirement by 2050, when the population of the country is expected to stabilize. Moreover, the projected full requirement cannot be possibly met through the conventional, intra-basin developments.

Geospatial Technology in Climate Change Studies

Geospatial technology includes three different technologies that are all related to mapping features on the surface of the Earth for environmental management. They are GIS, global-positioning systems, and remote sensing. This is also synonymous with spatial information technology. Together, the three components of geospatial technology can track, map, analyze, and disseminate environmental management information (Bandyopadhyay and Jha, 2008).

Research on global warming, GIS and remote sensing are widely used by climatologists as a way to catalogue the evidence for climate change in the past and to organize evidence for climate change now and into the future (Nemani et al., 2003; Weaver, 2007; Clark et al., 2016). The mathematical models to predict climate change scenario incorporate many independent variables related to temperature, precipitation, topography, atmospheric gases, population growth and industrial development to predict how the manifestations of climate change will vary by geographic scale and region. Some of the data needed to build these models, such as historic temperature records, vegetation indices, land cover changes, rates of deforestation can be obtained from time series satellite data.

Data from current and planned satellite missions can play an important role in providing synoptic atmospheric, terrestrial and oceanic environmental data from space to address these observational requirements. These data promotes multidisciplinary research in the circumpolar regions and can be instrumental in furthering our understanding of the Earth as a System, which includes few overarching themes viz, radiation, clouds, water vapor, precipitation, and atmospheric circulation; ocean circulation, productivity, and exchange with the atmosphere; tropospheric chemistry and greenhouse gases; land ecosystems and hydrology; snow, ice, and glacier extent; ozone and stratospheric chemistry; and volcanoes and climate effects of aerosol. In the area of precipitation, it was tracking the seasonal progression of rainfall and attempting to better understand development, movement and impact of severe storms, as well as improving the understanding of water cycles. It was also looking at land surface imaging to monitor changes to farmlands, coastlines, deserts and forests, and to track short-term threats to climate change, such as wildfires, floods and volcanic activity.

The observational need such as atmospheric compositions; ocean surface topography and physicochemical status; precipitation; and land-surface imaging are accomplished using space based platforms. In the area of atmospheric composition monitoring measurements encompasses CO_2, methane, water vapour, ozone aerosols etc (Baccini et al., 2012; Manjunath et al., 2007). Since the launch of Coastal Zone Color Scanner in 1978, chlorophyll has been derived from ocean color sensor to assess phytoplankton biomass, primary production, and the ocean's impact on the climate cycle (Longhurst et at., 1995; Behrenfeld et al., 2006). However, caution need to be adopted when using empirically derived chlorophyll to infer climate related changes in ocean biology (Dierssen, 2010). Ocean topography, monitoring sea level rise, as well as providing ocean temperature and chemistry trends hold considerable importance in global change modelling (Abraham et al., 2013; IPCC, 2013)

Satellite imagery is particularly useful for detecting changes in vegetation. The vegetation indices such as, NDVI has already been successfully applied on temporal and spatial scale to assess vegetation distribution, productivity, habitat degradation and fragmentation, and the ecological effects of climatic disasters such as drought or fire. The global coverage of the NDVI suggests that it could be used to predict the ecological effects of climate change on ecosystems functioning. Increase in the primary productivity was reported, particularly in the tropical ecosystem, owing mainly to decreased cloud cover and the resulting increase in solar radiation (Nemani et al., 2003).

Geospatial technology provides resource managers, as well as general public, with the insight and ability to react to climate change. One can monitor, map, and share the effects of: El Niño Ocean warming and La Nina ocean cooling; tropical forest depletion; the meltdown of sea glaciers in Antarctica or at the poles; vegetation monitoring through detailed knowledge of soils, erosions rates, nutrient cycles, and local agricultural practices; and water resources management through weather monitoring. With GIS, the global temperature pattern is mapped and shared among users. Researchers are using geospatial technology to quantify the carbon amount in biomass and using that information in carbon sequestration (Chhabra and Dadhwal, 2004).

Impact of Climate change: Stress on Water Resources

A number of researchers have reported the impact of climate-change scenarios on hydrology (Table 1) of various basins and regions; they projected that increasing temperature and decline in rainfall may reduce net recharge and affect freshwater resources (Fowler et al., 2007; Christensen and Lettenmaier, 2007). Human caused influences are expected to follow a steady growth trend in the future; climate modifications caused by anthropogenic radiative forcing are considered to be more permanent than those caused by natural variability factors. Increase in temperature perturbs the hydrologic cycle increasing evaporation from surface water and vegetation transpiration. As a result, these changes can influence distribution and intensity of precipitation and indirectly control the flux and storage of water in surface and subsurface systems. Climate change directly affects surface water resources while its effect on groundwater is rather complicated and matter of intense research. Variability in rainfall, low recharge and high withdrawals impact groundwater levels negatively and paves the way for saline water intrusion in coastal aquifers. As groundwater resources are vulnerable, quantifying the impact of climate change on groundwater resources are being studied using Global Climate Models (GCM) for assessing impact of climate change (Rosenberg et al., 1999; Payne and Dorothy, 2010; Chadha and Sharma, 2000).

Impacts of climate change on water resources will have a wide range of consequences for coastal ecosystems. The health of the Earth's ecosystems will be affected by changes in the quality and quantity of freshwater runoff into coastal wetlands, higher water temperatures, extreme runoff rates or altered timing, and the ability of watersheds to assimilate pollutants and wastes. Sea-level rise has the potential of causing increases in the intrusion of saltwater into coastal aquifers. sea-level rise include changes in salinity distribution in estuaries, altered coastal circulation patterns, destruction of transportation infrastructure in low-lying areas, and increased pressure on coastal levee systems.

Glaciers and ice sheets are good climatic indicators and influence the Earth's climate in two important ways. The first is their potential impact on sea-level rise and global water resources under declining ice regimes. Glaciers and ice sheets account for two-thirds of the Earth's freshwater and would contribute approximately 229 ft. (70 m.) to sea-level rise if they were to melt completely. The majority of this ice is located in the Earth's Polar Regions, largely in the Greenland and Antarctic ice sheets, which combined account for approximately 97.5 percent of potential sea-level rise. Second, decreases in global ice and snow cover are considered particularly important to the Earth's climate system because such changes are considered to be part of a positive feedback loop, commonly referred to as the snow-ice albedo feedback. Under this scenario, as temperatures increase, the extent of snow and ice decreases, and the highly reflective snow or ice surface is replaced with the darker (more absorptive) ocean or land surface underlying it. The increased absorption of energy completes the feedback loop, as more solar radiation is absorbed by the Earth's surface, leading to an overall increase in air and sea surface temperatures, and further decreases in ice and snow volume.

Climate extremes are expected to become more pronounced under the projected climate change (Easterling et al., 2000). Changes in hydrologic extremes have been noted at global scale with substantial variability in occurrences of droughts and floods (Dai et al., 1997). For instance, there is huge variability in drought occurrences, their durations, and areal extent in many regions (Sheffield and Wood, 2008). Among the natural disasters, the economic and environmental implications of droughts are highest due to wide area extent and persistence (Wilhite et al., 2005), which may further increase under the changing climate conditions. Floods are also likely to increase under the projected climate. Milly et al. (2002) reported that frequency of great floods has increased substantially in the 20th century and significant positive trends in great floods are consistent with the climate model projections.

Adaptive management provides a framework for managing uncertainty. This iterative approach, which recognizes the uncertainties inherent in climate change and response measures, assesses needs and options, develops and implements response measures, monitors and assesses these measures, and modifies them, as appropriate (Lawler, 2009). These different measures are illustrated by examples from managing water resources, the coastal zone, forests, and livelihoods, including agriculture. Measures to improve efficient water use, manage water demand, reuse water, and expand water resources can all improve resilience.

Satellite applications in Water Resource Inventory and Management

Earth Observation (EO) Satellites provides the data in different bands of electromagnetic spectrum which enables monitoring and developing management plans for country's water resources (Bandyopadhyay et al., 2006; Rao and Raju, 2010) . Some of the important application areas cover irrigation water management, flood mapping and damage assessment, snowmelt runoff forecasting, snow and glacier investigations, watershed planning and management, drought assessment and monitoring, reservoir capacity evaluation, ground water prospect zone mapping, water quality mapping and monitoring, environmental impact assessment of water resource project etc.

Table 1: Impact of Climate Change: Extremes of Water Scarcity and Excess		
Indicators	**Impacts**	**Mitigation**
Extreme Heat	Unusual and unprecedented spells of hot weather are expected to occur far more frequently and cover much larger areas.	Optimal urban planning, Improving the use of renewable energy
Changing Rainfall Patterns	An abrupt change in the monsoon could precipitate a major crisis, triggering more frequent droughts as well as greater flooding in large parts of India	Flood early warning and Improvements in hydro-meteorological systems for weather forecasting
Droughts	Droughts are expected to be more frequent in some areas, especially in north-western India affecting crop yield	Drought-resistant crop varieties, Efficient water management
Groundwater	Although it is difficult to predict future ground water levels, falling water tables can be expected to reduce further on account of increasing demand for water from a growing population, more affluent life styles, as well as from the services sector and industry	Judicious use of ground water resources and recharge
Glacier Melt	Melting glaciers and the loss of snow cover over the Himalayas are expected to threaten the stability and reliability of northern India's primarily glacier-fed rivers, particularly the Indus and the Brahmaputra. The Ganges will be less dependent on melt water due to high annual rainfall downstream during the monsoon season. The Indus and Brahmaputra are expected to see increased flows in spring when the snows melt, with flows reducing subsequently in late spring and summer.	Improvements in water storage capacity would be needed to benefit from increased river flows in spring and compensate for lower flows later on
Sea level rise	With India close to the equator, the sub-continent would see much higher rises in sea levels than higher latitudes. Sea-level rise and storm surges would lead to saltwater intrusion in the coastal areas, impacting agriculture, degrading groundwater quality, contaminating drinking water. Kolkata and Mumbai, both densely populated cities, are particularly vulnerable to the impacts of sea-level rise, tropical cyclones, and riverine flooding.	Enforcing coastal Regulation Zone codes and adhering to norms for the building codes in the urban areas.
Agriculture and food security	Extremely high temperatures in northern India - above 34°C - have had a substantial negative effect on wheat yields, and rising temperatures can only aggravate the situation.	Crop diversification, efficient water use, development of drought-resistant crops, improved soil management practices,
Water Security	An increase in variability of monsoon rainfall is expected to increase water shortages in some areas. Studies have found that the threat to water security is very high over central India, along the mountain ranges of the Western Ghats, and in India's northeastern states.	Improvements in irrigation systems, water harvesting techniques, watershed based approach

Analysis of time series of satellite data enables monitoring changes during and after implementation projects like commanding area development, flooding control, hydropower and multipurpose water resource projects. Inventory of land cover/land use in the reservoir submergence area, particularly the forest and agricultural cropped areas has been conducted using satellite data. Irrigability, mapping of command area, through integration of satellite derived and ground measured data, would help in appropriate allocation and application of water to minimize water logging and salinisation. In India, satellite data is used potentially in environmental monitoring of Idduki hydel project, Kerala, Western Ghat areas including Nilgiri Biosphere Reserve, large scale river valley projects of Narmada and the Tehri dam in Himalayas. The satellite remote sensing survey in these regions clearly brought the degradation of vegetation cover due to biotic interference as well as long spells of adverse climatic condition.

Conclusion

The availability of water is highly uneven in both space and time. As water is a prime natural resource, a basic human need and a precious national asset, planning and development of water resources need to be governed by national perspective. Floods and drought affect vast areas of the country. A third of the country is drought-prone. Floods affect an average area of around 9 million hectares per year. According to the National Commission on floods, the area susceptible to floods is around 40 million hectares. For better assessment of the climate change impact, a quantitative relationship should be established between 'damage due to flood' and 'damage due to drought' and need to be updated periodically.

Even the planning and implementation of individual irrigation or multi-purpose projects, though done at the state level, involve a number of aspects and issues such as environmental protection, rehabilitation of project-affected people and livestock, public health consequences of water impoundment, dam safety, etc. On these matters common approaches and guidelines are necessary. In some irrigation commands, problems of water-logging and soil salinity have emerged, leading to the degradation of good agricultural land. There are also complex problems of equity and social justice in regard to water distribution.

The drinking water needs of people and livestock have also to be met. Domestic and industrial water needs have largely been concentrated in or near the principal cities, but the demand from rural society is expected to increase sharply as the development programmes improve economic conditions in the rural areas. The demand for water for Hydro & Thermal power generation and for other industrial uses is also likely to increase substantially. This underscores the need for the utmost efficiency in water utilization and a public awareness of the importance of its conservation. The development and exploitation of the country’s groundwater resources also give rise to questions of judicious and scientific resource management and conservation. All these questions need to be tackled on the basis of common policies and strategies.

Another important aspect is water quality. Water pollution is a serious problem in India as almost 70% of its surface water resources and a growing number of its groundwater reserves are already contaminated by biological, organic and inorganic pollutants. In many cases, these sources have been rendered unsafe for human consumption as well as for other activities such as irrigation and industrial needs. Improvements in existing strategies and the innovation of new techniques resting on a strong science and technology base will be needed to eliminate the pollution of surface and ground water resources, to improve water quality and to step up the recycling and re-use of water.

The biggest problem occurs with the uncertainty surrounding the effects of climate change and the unknown time frames. It is still uncertain who will be most impacted by the changes and this fosters a lack of initiative for taking action now to mitigate the effects of climate change. Therefore, it is necessary to evolve comprehensive management plan for suitable conservation and utilization of water resources, especially in dryland areas. Systematic approaches involving judicious combination of conventional ground measurements and EO techniques pave way for achieving optimum planning and operation of water resources projects.

References

Abraham et al., (2013), A Review of Global Ocean Temperature Observations: Implications for Ocean Heat Content Estimates and Climate Change, Reviews of Geophysics, 51(3), 450–483.

Arnell, N. W. (1999), Climate change and global water resources. Global Environmental Change, 9, Supplement 1, S31–S49.

Baccini, A., Goetz S. J., Walker W. S., Laporte N. T., Sun M. , Sulla-Menashe D., Hackler J., Beck P. S. A., Dubayah R., Friedl M. A., Samanta S. and Houghton R. A. (2012), Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps, Nature Climate Change, 29 January 2012, nclimate1354, 1-4.

Bandyopadhyay S., Srivastava S.K., Jha M. K., Hegde V.S. and Jayaraman V., (2006), Harnessing Earth Observation Capabilities in Hydrogeology: An Indian Perspective. Hydrogeology Journal, 15: 155-158

Bandyopadhyay, S. and Jha, M.K. (2008), Land and Water Resources Management using Integrated Remote Sensing and GIS Techniques. In 'Disaster Management', Edited by KK Singh and MK Jha. APH Publishing Corporation, New Delhi.

Behrenfeld M.J., O'Malley R.T., Siegel D.A., McClain, C. R., Sarmiento, J.L., Feldman, G.C., Milligan A. J., Falkowski P.G., Letelier R.D. and Boss E.S. (2006), Climate-driven trends in contemporary ocean productivity, Nature, 444:752–755.

Burns, D.A., Klaus J., and McHale, M.R. (2007), Recent climate trends and implications for water resources in the Catskill Mountain region, New York, J. of Hydrology, 336, 155-170.

Chhabra, A. and Dadhwal, V. K. (2004), Assessment of Major Pools and Fluxes of Carbon in Indian Forests, Climatic Change, 64, 341-360.

Christensen, N. and Lettenmaier, D. P., (2007), A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin, Hydrology and Earth System Sciences, 11, 1417–1434.

Chadha, D. K. and Sharma, S. K. (2000), Groundwater management in India issues and options, Workshop on Past Achievements and Future Strategies, Central Groundwater Authority, New Delhi,

Clark et al., (2016), Consequences of twenty-first-century policy for multi-millennial climate and sea-level change, Nature Climate Change, www.nature.com/natureclimatechange.

Dai, A. Fung I.Y., and Del Genio A.D. (1997), Surface observed global land precipitation variations during 1900-1988. J. Climate, 10, 2943-2962

Devkota L.P. and Gyawali, D.R. (2015), Impacts of climate change on hydrological regime and waterresources management of the Koshi River Basin, Nepal. Journal of Hydrology: Regional Studies, 4, 502–515.

Dierssen HM et al., (2010), Perspectives on empirical approaches for ocean color remote sensing of chlorophyll in a changing climate. PNAS, vol. 107 (40): 17073–17078.

Easterling, D.R., Meehl G.A., Parmesan C., Changnon S.A., Karl T.R. and Mearns L.O. (2000), Climate extremes: Observations, modeling, and impacts, Science, 289: 2068-2074.

Fowler, H. J., S. Blenkinsop, and C. Tebaldi. (2007), Linking climate change modeling to impacts studies: Recent advances in downscaling techniques for hydrological modeling. International Journal of Climatology 27: 1547–1578.

Jain, S.K., Agarwal, P.K. and Singh, V.P. (2007), Hydrology and water resources of India. Springer publications.

Gonzalez, J.E., E.W. Harmsen, N.L. Miller, and N.J. Schlegel, (2009), Seasonal climate change impacts on evapotranspiration, precipitation deficit and crop yield in Puerto Rico. Agricultural Water Management, 96: 1085-1095.

Gosain, A. K., Rao S, and Basuray D. (2006), Climate change impact assessment on hydrology of Indian river basins, Current Science, 90(3), 346–353.

Gosain A. K., Rao S. and Arora A. (2011), Climate change impact assessment of water resources of India Current Science, Vol. 101, No. 3, 2011

Gupta, S. K. et al., and Deshpande, R. D., (2004), Water for India 2050: First order assessment of available options. Current Sci., 86(9), 1216-1224.

http;//www.ipcc.ch/pdf/assessment.report. (2014)

IPCC, Climate Change, (2013), Fifth Assessment Report (AR5), http://www.ipcc.ch/index.htm.

ISRO, www.isro.gov.in, (2014).

Kumar et al., (2003), Climate Change in India: Observations and Model Projections. In: Climate Change and India: Issues, Concerns and Opportunities (P. R. Shukla, Subodh K. Sharma and P. V. Ramana Eds.), Tata McGraw-Hill Publishing Company Limited, New Delhi, India, 2003.

Kumar, R., Singh, R.D. and Sharma, K.D. (2005), water resources of India. Current science, vol. 89, No.5, 794-811

Lal, M. et al., Climate change: Implications for India's water resources. J. India Water Res. Soc., (2001), 21, 101-119.

Lawler J. J. et al., (2009), Climate change adaptation strategies for resource management and conservation planning. The Year in Ecology and Conservation Biology, 2009: Ann. N.Y. Acad. Sci. 1162: 79-98.

Longhurst A, Sathyendranath S, Platt T, Caverhill C (1995), An estimate of global primary productivity in the ocean from satellite radiometer data. J Plankton Res 17:1245–1271.

Mall R. K., Gupta A, Singh R, Singh R. S. and Rathore L. S. (2006), Water resources and climate change: An Indian perspective. Current Science, Vol 90 (12): 1610-1626.

Mall R. K., Singh R, Gupta A, Srinivasan G. and L. S. Rathore. (2006a), Impact of Climate Change on Indian Agriculture: A Review. Climatic Change, Volume 78, Issue 2, 445-478

Manjunath K. R., Panigrahy S., Kundan Kumari, Adhya T. K. and Parihar J. S. (2007), Spatiotemporal modelling of methane flux from the rice fields of India using remote sensing and GIS, International Journal of Remote Sensing, Vol. 27, No. 20, 4701–4707.

Milly P. C. D.,Wetherald R. T., Dunne K. A. and. Delworth T. L. (2002), Increasing risk of great floods in a changing climate, 31 January 2002, Nature, Vol 415, pp. 514-517.

Nearing, M.A. and X.C. Zhang, (2005), Impact of climate change on soil erosion, runoff, and wheat productivity in central Oklahoma. Catena, 61: 185-195.

Nemani, R.R., Keeling, C.D., Hashimoto, H., Jolly W.M. Piper, S.C., Tucker, C.J, Myneni, R.B. and Running, S. W. (2003), Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999, Science, Vol. 300: 1560-1563.

Payne and Dorothy F. (2010), Effects of climate change on saltwater intrusion at Hilton Head Island, SC. U.S.A., SWIM21 - 21st Salt Water Intrusion Meeting, 21-26 June 2010, Azores, Portugal, pp. 293-296.

Rakesh Kumar, R. D., Singh and K. D. Sharma. 2005, Water resources of India Current Science, Vol. 89(5): 794-811.

Rao V.V. and Raju P. V. (2010), Water Resources Management, In Remote Sensing Applications, National Remote Sensing Centre. ISBN 978-81-909460-0-1.

Rosenberg, N. J., Epstein, D. J., Wang, D., Vail, L., Srinivasan, R. and Arnold, J. G. (1999), Possible impacts of global warming on the hydrology of the Ogallala Aquifer Region, Climatic Change Vol.42, 677–692.

Senapati, M. R., Behera, B. , & Mishra, S. R. (2013), Impact of Climate Change on Indian Agriculture & Its Mitigating Priorities. American Journal of Environmental Protection, 1(4), 109-111.

Sheffield J. and Wood E.F. (2008), Global Trends and Variability in Soil Moisture and Drought Characteristics, 1950–2000, from Observation-Driven Simulations of the Terrestrial Hydrologic Cycle. American Meteorological Society, Volume 21, pp. 432-458

Tyagi, S.K., Datta, P.S. and Ravinder Singh (2012), Need for proper water management for food security. Current science, Vol. 102, No. 5

Weaver, A. J., Zickfeld, K., Montenegro, A. & Eby, M. (2007), Long term climate implications of 2050 emission reduction targets. Geophys. Res. Lett. 34, L19703.

Wilhite D. A. et al., (2005), Drought and water crises: science, technology, and management issues. Taylor and Francis Press, Boca Raton

World Bank. (2013), Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience. A report for the World Bank, 1818 H Street NW, Washington DC 20433

Report of NCERT Training Programme

- As a follow-up to the National Meet outcome, set of Remote Sensing & GIS training course for the benefit of Post Graduate Teachers were taken up with financial support from ISRO. The training programme was successfully completed by the joint efforts of NNRMS/EOS, IIRS, and NCERT.

- The highlights of the training programme are as follows :

  - ❖ The course curriculum was designed by IIRS, Dehradun in consultation with NCERT mainly following the NCERT syllabus of class 11 and 12.
  - ❖ Apart from covering the basics of RS&GIS, concepts and applications of Global Navigation Satellite System, RS applications and School Bhuvan were also taught.
  - ❖ The 2 weeks duration training courses were conducted in 2 batches. The 1st batch was conducted simultaneously by 19 Centres across the country during July 22-August 7, 2015 and was attended by 292 teachers. The 2nd batch was conducted simultaneously by 9 Centres during Jan 4-15, 2016 and was attended by 150 teachers.
  - ❖ A total of 442 PG teachers of Geography representing 207 from Kendriya Vidyalaya Sangthan, 168 from Navodaya Vidyalaya Samiti and 67 from CBSE affiliated schools have got benefitted.
  - ❖ NNRMS/Earth Observations System took the responsibility of identifying the training centres which are already supporting the capacity building efforts under NNRMS SC-T, while NCERT took the responsibility of deputing the participants.
  - ❖ The centres which conducted the training courses include 6 SRSACs; 7 academic institutions apart from ISRO/DOS Centres.
  - ❖ The total expenditure towards conducting the training programme was met by the funds provided by ISRO including travel, boarding and lodging support of participants.

- Based on the feedback of the 1st phase of the training programme, NCERT has been requested to take care of additional requirements as well as strengthen the geography lab at schools with adequate RS&GIS infrastructure facilities

Heads of Space Agencies Decide to Join Efforts for the Monitoring of COP 21 Decisions

3 April 2016, New Delhi, India

A New Delhi Declaration has been adopted by the Heads of space agencies from around the world on April 3, 2016 on the sidelines of the Asia-Pacific Remote Sensing Symposium in New Delhi, India, organized by the Indian Space Research Organization (ISRO) and Ministry of Earth Sciences, Government of India. The declaration highlighted the importance of satellites to the global climate change agenda, particularly in relation to the Paris Climate Agreement that came from the overwhelmingly successful COP-21 in Paris in 2015.

1. Heads of space agencies recalled the Declaration of Mexico, recognizing the tremendous contribution of satellites to climate change studies and disaster management support, and expressing their determination to enhance their efforts to strengthen the role of space in these fields in support of political decisions taken at the UN Conferences Of the Parties (COP).

2. The Declaration of Mexico stated: "Satellite observations are the key element of a global measuring system aimed at verifying the reality of commitments taken in line with the United Nations Framework Convention on Climate Change (UNFCCC)." Following the agreement achieved at COP 21 in Paris during December 2015, there will be a growing need to implement an independent Measurement, Reporting and Verification system (MRV) that will become a tool for verifying national INDCs (Intended Nationally Determined Contributions). As stated in the CEOS Strategy for Carbon Observations from Space: "an ambitious long-term goal for CEOS is operational LEO and GEO constellations measuring greenhouse gases in the atmosphere. This new suite of observations has the potential to be an essential element for future MRV systems."

3. At present, several space agencies have invested in research satellites that pave the way for future operational satellites dedicated to Green House Gases monitoring: SCIAMACHY was a precursor by ESA; GOSAT of JAXA and OCO 2 of NASA are in orbit; TANSAT of China, GOSAT 2 of JAXA, OCO 3 of NASA, MERLIN of DLR and CNES, S5P and S5 in Copernicus program of EU and ESA, and MicroCarb of CNES are in development.

4. Together with more in-situ measurements, better assimilation and inversion systems, and increased computing resources, satellites face a number of challenges to become operational tools. Spatial resolution and revisit capability are among them. Space agencies from around the world are committed to tackling these challenges, either by developing new technologies to be flown in space or by encouraging their research community to contribute actively in related assimilation and inversion models.

5. Operational measuring capabilities based on satellites will also require coordination between space agencies and with the surface in-situ monitoring network, so that instruments in orbit can be cross-calibrated and their measurements cross-validated. An international independent way of estimating emission changes for all world countries based on internationally accepted data would create a level playing field and an independent basis for further reductions. Space agencies from around the world reaffirm their commitments to work together in the right international framework on these matters.

6. Cooperation between space agencies around the world for the monitoring of COP 21 decisions will be closely followed by the Heads of Agencies themselves.

Space Technology Applications for Groundwater Targeting

When Karnataka State was reeling under severe drought, as per the discussions had by the Hon'ble Minister for Rural Development and Panchayat Raj, Shri. H K Patil, and Chairman, ISRO; a quick attempt was made to utilize the space based inputs for Ground water development in the drought affected villages of Indi, Aland, Kundagol, Navalgund and Dharwar Taluks of Karnataka.

The groundwater prospects maps prepared by ISRO at1:50K scale have been used as the main source of information and were updated to 1:10K scale for identification of locations for field based observation, survey and subsequent drilling. The work was executed by Karnataka State Remote Sensing Application Center under the technical guidance of ISRO. A workshop and field demonstration was organized in Regional Remote Sensing Centre - South, Bengaluru on Quick assessment of Groundwater Potential at village level using Geoscientific database. About 80 Geologists from the Rural Drinking water and Sanitation Department and senior colleagues from CGWB and Geological Survey of India were trained for identifying sites for ground water development and its sustainability. Ground water prospects maps at village level were prepared for 390 villages on priority basis. As per the latest status 58 wells have been drilled with about 80% success rate. New recharge structures and augmentation of existing ones are also being planned.

8 | STATE — BENGALURU — THE HINDU • THURSDAY, MAY 5, 2016

TACKLING SCARCITY

Help from space to spot water underground

Most borewells sunk at spots pointed by satellite images have yielded water

FIROZ ROZINDAR
T.V. SIVANANDAN
N. DINESH NAYAK

VIJAYAPURA/KALABURAGI/DHARWAD: The State government's decision to use satellite imagery to find underground water sources in four chronically parched taluks in northern districts has turned out to be a mixed bag.

Tadavalaga in Vijayapura's Indi taluk and Aland in Kalaburagi district, which were reeling under shortage of potable water, have become tanker-free in the recent weeks. Borewells have been sunk here in the spots identified by satellite pictures.

In private properties

In Dharwad's Kundagol taluk, although eight underground water points were identified from satellite maps, zilla panchayat could not drill the wells as all eight points are in private properties. The points adjoin a canal at Rottigewad village. Kundagol tahsildar has been asked to either negotiate a compensation with the land-owners or acquire the lands, officials said.

The State government is using space-based imageries to locate borewells in Indi taluk, Kundagol taluk, and Afzalpur and Aland taluks of Kalaburagi.

In Indi, district officials said 11 borewells had been sunk, of which nine yielded a good average of 2 inches of water and two yielded 1 inch of water.

PINPOINTED LOCATION: A borewell being drilled at a spot identified by satellite pictures provided by ISRO in Indi taluk of Vijayapura district.

Drilling is under way at 18 more places.

Over the next two months, the engineering division of the Rural Development and Panchayat Raj Department plans to sink bore wells in 124 villages in Indi taluk alone based on satellite imageries.

The maps of locations provided by the Indian Space Research Organisation (ISRO) along with the survey number of the potential spot, they said, made drilling easy and speedy.

With some relief, officials said they would now concentrate on villages where water was supplied through tankers as the district administration wants to make these villages tanker-free. Supplying water by tankers, as they were doing in these villages, they said, had been a daunting task.

Although water was struck at nearly 1,000 feet, it was safe and free of arsenic and fluoride. "The success rate [of finding water based on satellite data] is around 90 per cent compared with the conventional method of using geologists on the field, where the success rate is around 60 per cent," the officials said.

In Aland, 12 of the 18 borewells sunk in the identified spots have yielded good supply of water of 1.5 to 2 inches. The problem of drinking water has been solved to an extent in these villages. Another 25 to 30 borewells are planned using imageries from ISRO.

Superimposed maps

Chief Executive Officer of the Kalaburagi Zilla Panchayat Anirudh Sravan told *The Hindu* that the maps provided in earlier years were on the 1:50,000 scale. The present maps on a 1:10,000 scale gave more precise locations. The maps came superimposed with the revenue survey numbers and officials could readily identify the areas.

In Dharwad, officials of the Department of Mines and Geology advised caution before sinking wells at the identified points. They said they, too, had earlier come up with the same underground water points as ISRO, but the wells sunk there failed.

TH POST YOUR VIEWS AT http://thne.ws/1Fhmfa