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Satellite agromet products and their adaptation for advisory services to Indian farming community

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ABSTRACT

Anomalous and erratic behaviour of weather pose various challenges for agricultural community from crop sowing to post harvest. The balance between turn-around-time for farm operations and resource optimization can limit the expected losses due to unfavourable weather. In the past, thrust was given to issue agromet advisories to farmers for a group of districts and blocks primarily using medium-range weather forecast with coarser grid resolution, crop records and point observation for crop condition. The current advisory framework under Gramin Krishi Mausam Seva (GKMS) of India Meteorological Department (IMD) lacks in, near real time assessment of crop and soil conditions to improve the quality and coverage of advisories. The spectral observations from polar and geostationary satellites provide agromet products for synoptic, real-time and continuous monitoring of crops. In order to strengthen the existing advisories under GKMS, the usage of satellite derived daily agromet products in six AFMUs (Agro-Met Field Units) (382 blocks of 60 districts) was initiated by Space Applications Centre, ISRO and IMD. Several agromet products such as Normalized Difference Vegetation Index (NDVI), Potential Evapotranspiration (PET), Surface Dryness Index (SDI), Minimum and Maximum Land Surface Temperature (LST) and Surface Soil Moisture (SSM) aggregated for block and district agricultural regions were provided to all six AFMUs in user friendly format since October 2019 through a dedicated web link from VEDAS (https://vedas.sac.gov.in) geoportal. Time series and near real-time agromet products during agricultural seasons are being used to interpret crop sowing prospect, crop condition, irrigation requirement, crop stress etc. at block and district scales. Regular evaluation of these products over respective AFMUs with measured ground data showed 9% and 10% difference for PET and SSM respectively, whereas, LST showed RMSE of 2.0 K. In future, crop specific agromet parameters and their short-term forecasting are primary focus to provide value-added quality advisories at Gram Panchayat level to all AFMUs.

***Keywords**:* Agromet Advisory, Satellite, Agromet Products, GKMS

Farming is the most weather-dependent economic activity in India among all the anthropogenic forcings to climate. The daily variation in weather and fluctuations in climatic normal remain the principal source of uncertainties for regional food security. In the present time, the increase in extreme weather condition such as high and erratic distribution of rainfall, flood, flash flood and drought, rise in minimum temperature, occurrence of high temperature events and other extreme weather conditions adversely affect the agricultural production. The sustainable agricultural growth and production are highly dependent on efficient farm operations under adverse weather conditions and optimization of input (fertilizer, water, agro-chemicals etc.) use during the crop growing season. Any deviation from the required optimum weather condition for a particular crop stage hampered the crop physiological and morphological growth even though there is continuous rise in crop production as a result of adaptation of new and modern technology by agricultural fraternity. The agrometeorological guidance for the timely farm operation and management can reduce the expected crop losses and provide insight to harness the favourable weather conditions. To initiate the agrometeorological services in India, Government of India (GOI) established National Centre of Medium Range Weather Forecasting (NCMRWF) under the Department of Science and Technology (DST) in 1988 in mission mode. The main objectives were to develop global and regional scale numerical weather prediction (NWP) models for forecasting weather in medium range (3-10 days) and generate information to guide farmers for various farm

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operations. This was first initiation by GOI to support the farm decision by providing Twice-a-week Agrometeorological Advisory Services (AAS) to farmers. To further strengthen AAS in India a network of 130 Agro-Met Field Units (AMFUs) was established by India Meteorological Department (IMD) under the umbrella of Gramin Krishi Mausam Seva (GKMS). The major objective of the AAS is the translation of medium range weather forecast for management strategies and required farm operations based on real ground situation of crop/livestock to increase crop production in order to reduce the losses due to unfavourable weather. The current advisory framework could reduce 5-10% cost of farming operations and increase in crop yield varying from 10-25% (Rathore and Maini, 2008). Improvement in the quality, confidence level and coverage of present advisory framework requires near real-time assessment of crop and soil conditions over a region comprising of few districts and blocks serviced by an AFMU. In the present scenario, historical crop record and point scale crop condition of close-by district/block along with medium range weather forecast are used for generation of advisory for a group of blocks and districts. The advances in the remote sensing from space-borne sensors onboard polar and geostationary satellites provide an opportunity to capture the near real-time synoptic and continuous coverage of crop condition throughout the crop season. The in-situ information over few scattered locations about the crop is unable to explain the regional variability of crop and soil condition in near real time within a block or district. Hence, the generated advisory remains generic for the numbers of blocks and districts under an AFMU. The regional variability can be addressed by capturing near-real time crop and soil status in space and time to provide specific advisories instead of generic advisory. In recent past, turn-around-time (TAT) between acquisitions to generate usable products from different satellites has been substantially reduced. This increases the possibility of value-added information to farming community using satellite agromet products. To utilize the space technology for farmers' advisory, Space Applications Centre, ISRO Ahmedabad and Department of Agrimet, IMD initiated pilot study for the usage of specific satellite-derived agromet products in enhancing the quality of agromet advisory issued twice a week from AFMUs \ since October 2019. The major objectives of this study are: (i) enabling availability, accessibility and adaptation of near real-time satellite-derived agromet products in GKMS, and (ii) evaluation of the satellite-derived agromet products with available ground data at AMFUs, (iii) generation of the block and district-specific advisory using satellite products.

MATERIALS AND METHODS

Framework of satellite agromet product generation to adaptation in GKMS

The timely execution of the farm-level operations on the basis of block and district specific advisory can prevent adverse effect of anomalous weather to maximize the gain from the favourable weather conditions. To channelize the comprehensive information system in spatio-temporal domain from the space platform, the delivery of the satellite-derived agrometeorological products in near real time is need of the present time. A comprehensive framework has been developed as shown in Fig. 1 covering data acquisition, satellite agromet product generation through specific algorithms and software implementation, dissemination of products through a portal in user-defined format with seamless flow of information and its accessibility to nodal officer at selected AMFUs under GKMS.

Selection of satellite products

To assess the crop status and variability a host of satellite-based geophysical/biophysical products from polar and geostationary satellites can be used to derive agrometeorological products at different spatio-temporal scales. The timely delivery of advisory and dynamicity of the crop both can be addressed by satellites having less revisit period. On this basis, the products from Indian geostationary and polar orbiting satellites having 30 minutes to 2 days temporal resolution were adopted to generate agrometeorological products for this service. Further, generation of agromet advisory on Tuesday and Friday of each week needs updated daily agrometeorological products on each Monday and Thursday evening. Each AFMU gets practically few hours to translate the crop and soil status into advisory bulletin for each block and district within the purview of AMFU. Having considered the limitation of time and their usability, only seven (7) satellite-derived agromet products were selected for advisory services which can provide conclusive inference about the crop and soil in short span of time for a number of blocks and districts for a given AFMU.

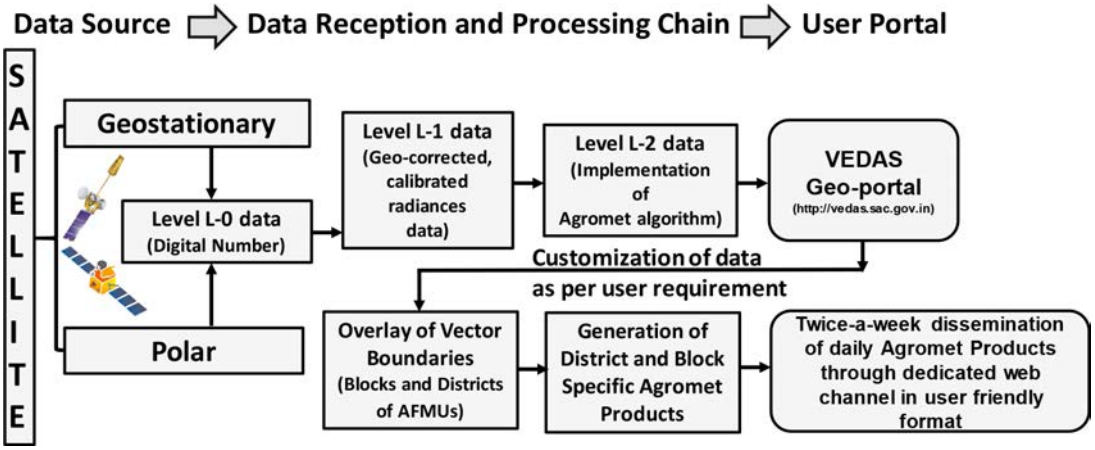


Fig. 1: Framework for satellite data to dissemination of agromet products in user friendly format for agromet advisory system

Table 1: Description of the agromet products

Sr. No.	Product	Satellite (Space Platform)	Electromagnetic Spectral Bands (µm)	Spatial resolution (m)	Temporal resolution	Source
1.	NDVI (Normalized Difference Vegetation Index)	OCM-2 (Polar)	Red (0.61-0.63) & NIR (0.84-0.88)	360	2-days	https://bhuvan.nrsc.gov.in
2.	Predicted NDVI	MODIS (Polar)	Red (0.62-0.97) & NIR (0.84-0.87)	1000	15-days	https://vedas.sac.gov.in
3.	LST (Maximum & Minimum of a day)	INSAT3D/3DR (Geostationary)	Thermal (10.2-11.3 & 11.5-12.5)	4000	30 minutes	https://doi.org/10.19038/SAC/10/3DIMG_L2B_LST
4.	Reference ET(ET_0)	INSAT3D/3DR (Geostationary)	Visible (0.55-0.75)	4000	Daily	https://doi.org/10.19038/SAC/10/3DIMG_L3C_PET_DLY
5.	SDI (Surface Dryness Index)	INSAT 3D (Geostationary)	Visible (0.55-0.75) & Water Vapor (6.7-7.1)	4000	Weekly	https://vedas.sac.gov.in
6.	Surface Soil Moisture (upto 0.1 m) (SSM)	SMAP (Polar)	Passive Microwave (L band 3.5 GHz))	12000	2-days	https://vedas.sac.gov.in

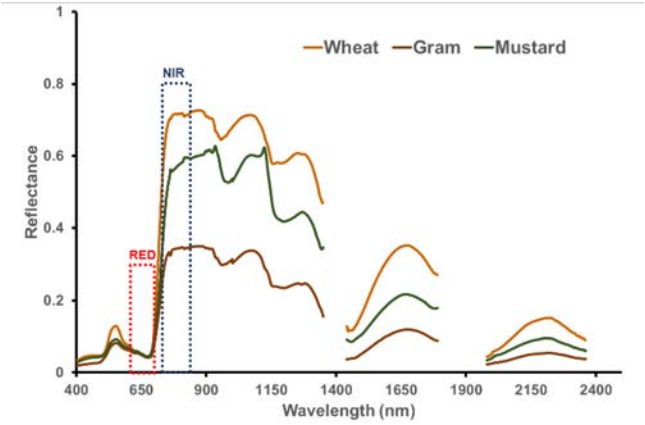


Fig. 2: Vegetation response over RED and NIR spectral regions for different crop types

The selected agromet products are given in Table 1.

Normalized Difference Vegetation Index (NDVI) Product: The mathematical representation (equation 1) of RED ($\rho_{(RED)}$) and NIR ($\rho_{(NIR)}$) spectral band reflectances provide vegetation index named as Normalized Difference Vegetation Index (NDVI) (Fig. 2). This index represents the spread and vigour of green vegetation and the temporal NDVI of a particular crop characterizes its growth and development. For agricultural crop, NDVI varies from 0.25 to 0.9 during emergence to peak vegetation (Nigam et al, 2009, Nigam et al, 2011). To obtain daily NDVI from Indian satellite Ocean Colour Monitor-2 (OCM-2), red (B6 = 0.61- 0.63 µm) and NIR (B8 = 0.84-0.88 µm) spectral bands were used. Alternate day NDVI product at 360m spatial resolution from OCM – 2 (Ocean Color Monitor – 2) is used for the advisory.

$$NDVI = \frac{\rho_{(RED)} - \rho_{NIR}}{\rho_{(RED)} + \rho_{NIR}} \quad (1)$$

Fortnightly predicted NDVI product: The twenty-years (2002-2022) 16-day MODerate Resolution Imaging Spectroradiometer (MODIS) NDVI composite data was used to predict fortnightly NDVI for the current season. The sequence-to-sequence Long Short-Term Memory (LSTM) machine learning (ML) algorithm was customized to predict the NDVI. LSTM network is a special kind of Recurrent Neural Network (RNN), capable of learning long-term dependencies. The mechanism was also developed to validate the predicted NDVI simultaneously with the actual data in hindcast mode (Fig. 3).

Land Surface Temperature (LST) product: Crop canopy-soil composite (or skin) temperature is directly linked to crop growth and canopy water status in the form of transpiration than to ambient air temperature. The satellite derived LST represents soil-canopy composite temperature. As the vegetation fraction becomes greater than 0.5 it tends to represent canopy temperature. Diurnal LST at 30 minutes is retrieved through split-widow algorithm and radiative transfer simulation model (e.g. MODTRAN) for varying atmospheric and surface conditions (Bhattacharya *et. al.* 2009, Pandya *et al*., 2014; Pandya, 2015) (Fig. 3).

Potential / Reference Evapotranspiration (PET or ET_0) product: The potential evapotranspiration (PET or ET_0) represents evaporative demand of the atmosphere for a given surface as per the meteorological factors such as solar radiation, wind speed, air temperature and vapour pressure deficit. Daily PET was generated from INSAT 3D/3DR satellite by adopting the FAO 56 protocol (Allen *et. al*., 1998) as per the Penman-Monteith model by ingesting the daily surface insolation from INSAT 3D/3DR and three-hourly Weather Research Forecast (WRF) (Nigam and Bhattacharya, 2015; Vyas *et al* 2016) model (Fig. 3).

Surface Soil Moisture (SSM) product: The regular operational surface Soil Wetness Index (SWI) and volumetric Soil Moisture (SM) products were developed using SMAP L-band time series

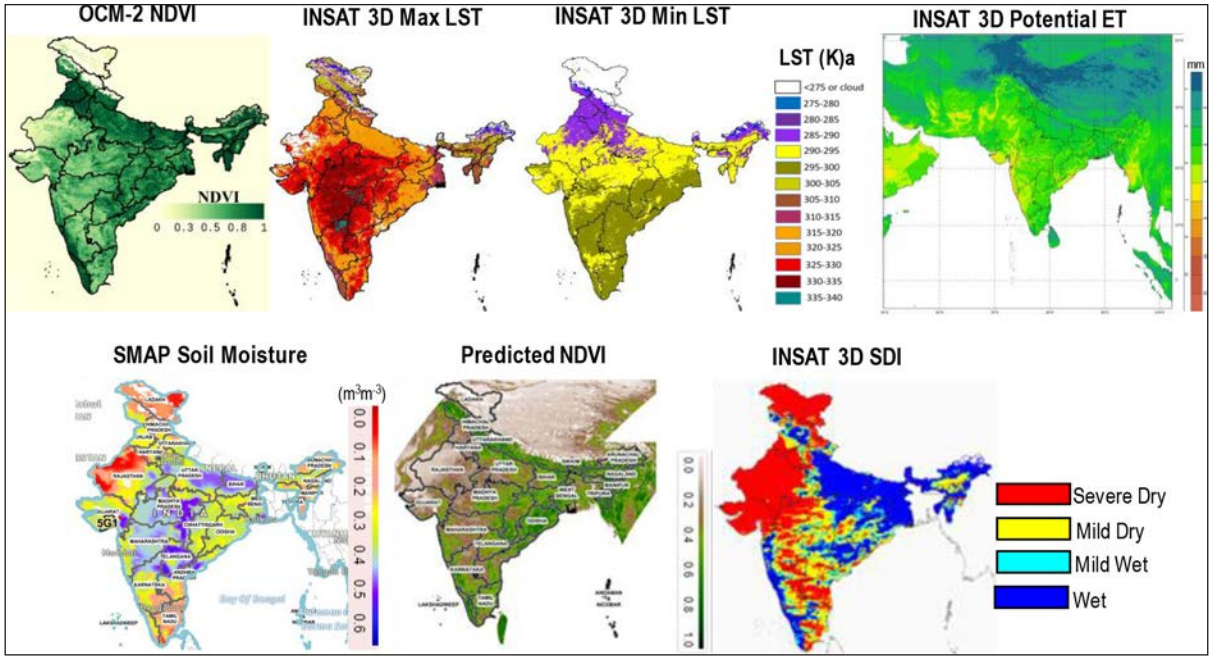


Fig. 3: Spatial distribution of satellite derived products for agromet advisories

radiometer data. An absolute soil moisture W(t) at particular time was derived from SMAP-L band brightness temperature (T_b), permanent wilting point (PWP) and field capacity (FC) of soil modelled using time series data (Pandey *et al*., 2021).

Surface Dryness Index (SDI): Surface Dryness Index (SDI) is used to quantify precipitation availability over atmospheric water demand. SDI represents adequacy of the precipitation to satisfy atmospheric water demand. A methodology as well as module has been developed to generate weekly (standard meteorological week) SDI using INSAT 3D derived daily potential evapotranspiration (PET) and Hydro Estimator (HEM) rainfall products (Fig. 3).

Mechanism for on-line near real time dissemination of satellite products for agromet advisories

In the present time, all satellite data and products are available as raster data in different file formats such as Tag Image File Format (TIFF), Netwrok Common Data Form (Netcdf), Hierarchical Data Format 5 (H5) and binary files etc which can be processed through image processing software only. To reduce the processing time and for quick display of different satellite data/ products, a geospatial (Web-GIS) portal named as Visualization of Earth Observation Data and Archival System (VEDAS) (https://vedas.sac.gov.in) has been developed by Space Applications Centre, ISRO, Ahmedabad for the scientific and academic user community to visualize the real-time data and on-the fly basic analysis at their own respective (desktop to mobile) systems. The specific geospatial tools have been provided to the user for the display and processing of the spatial and time series data for various satellite land products under different themes viz. (i) Vegetation and Crop Monitoring, (ii) Desertification and Land Degradation, (iii) New and Renewable Energy, (iv) Air Quality Monitoring, (v) Snow and Glacier, (vi) Urban Sprawl Information System, (vii) Hydrological Science and Applications, (viii) Wetlands, (ix) Coastal Environment, (x) Polar Science and (xi) Forest Biomass. To interpret the data through VEDAS for a cluster of districts and blocks is really a challenge specially for those users who are having limited exposure and expertise in the usage of raster data in their daily work. To overcome this challenge, a new mechanism was formulated in such a way that it will reduce the user time to gather the required data and provide time window for its interpretation. In this regard, the new software and dedicated secure web link were developed in java script under the umbrella of VEDAS to read all the required raster data as mentioned in section 2.2 and Table 1 and provide the district and block-specific values of the selected satellite products as user-friendly CSV format. The whole chain of generation to downloading the data as CSV at the user side (AFMU) is shown in Fig. 4.

In this mechanism, the user was given specific username and password to login into the developed dedicated FTP link. After login, user was provided the option to select their respective AFMU. For each AFMU, two options viz. (i) district and (ii) block were provided. Under each district and block, one dedicated CSV file was provided with different data fields. The developed software appends the daily data in each Comma-Separated Values (CSV) file for district and block on every Monday and Thursday evening for the generation of advisory bulletin on each Tuesday and Friday. The CSV file format provides an opportunity to use the data in tabular format not only for the present time and allows to keep all the past daily data for the user to compare each product in near real-time with the past record.

STUDY REGIONS: SELECTED AFMUs

At the initial phase, six (6) AMFUs (Fig. 5) were selected for satellite agromet product dissemination and adaptation for advisories in GKMS. The agro-climatic settings of these AMFUs

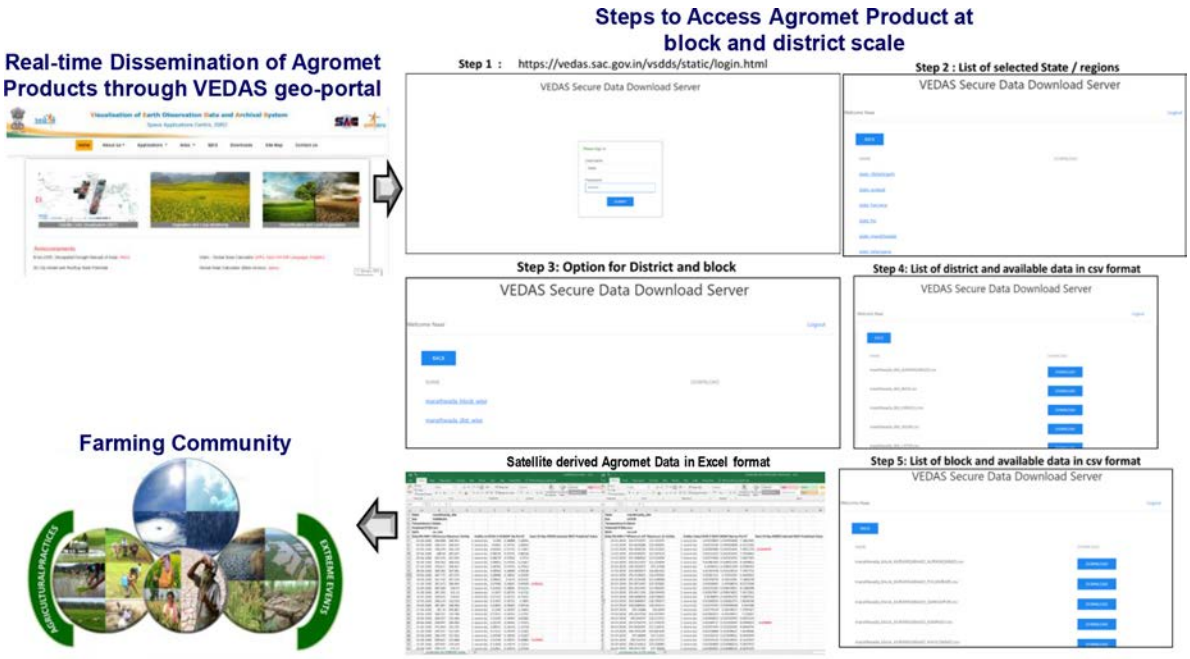


Fig. 4: Flow of real time dissemination chain and steps to download agromet products at AFMUs

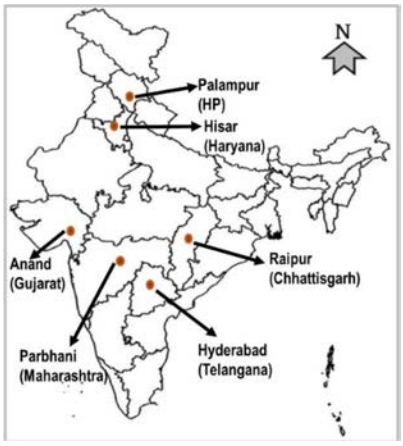


Fig. 5: Selected AMFUs for first phase of dissemination of satellite agromet products and adaptation for advisory system in GKMS

are briefly described below.

Palampur

The region lies in Shivalik Hill Region of Himanchal Pradesh at 350-650 meter above mean sea level (msl), has humid sub-tropical climate and geographically covers 40% of the state total area. The low hill soil is having greyish to yellowish brown and loamy sand to sandy loam texture. The average annual minimum and maximum temperatures lie in the range of 1.8–20 °C to 12.8-25 °C, respectively. The major crops of this region are wheat, maize, paddy, gram, sugarcane, potato, vegetables etc. The approximates 41.04% of the total crop area of the state and each farmer possesses land parcel varying from 1 ha to 3 ha. The major crop rotations are paddy-wheat, maize-peas and maize-toria-wheat. In irrigated system, dominant crop rotations are paddy-wheat, paddy-berseem and tomato-wheat. Other than major crop, this area is having intense vegetable farm lands both in rabi and kharif seasons. Even though this region receives more than 2000 mm rainfall annually but undulating topography lead to rainfed conditions. Moreover, soil erosion is a major limitation for agricultural growth in this region. The CSK Himanchal Pradesh Krishi Vishvavidyalaya, Palampur issues advisory for 4 districts and 28 blocks.

Anand

The whole region lies in middle Gujarat agroclimatic zone and annually receives 800 mm. The climate is typical sub-tropical, semi-arid and is having dry and dense hot summer. The April and May are the hottest months with mean maximum temperature around 40°C. The onset of south-west monsoon generally begins from the third week of June and retreats by middle of September. In general, July and August are the months of maximum rainfall. The moderate winter season sets in the months of middle November to prevailing up to the middle of February. The minimum temperatures are observed between last week of December and last week of January. Summer is hot and dry which commences from mid of February and ends by the month of June. The soil in this region is alluvial in origin and belongs to the order Alfisol. The texture of the soil is loamy sand. The soil is deep enough to respond well to manuring and numbers of short and long duration crops in this region. The major crops of this region are wheat, chickpea, mustard, millet, rice, cotton, banana, tobacco, potato and fodder crops during *rabi* and *kharif* seasons. The soil is low in organic carbon and nitrogen, medium in available phosphorus and available sulphur. Anand advisory is issued for 7 districts and 54 blocks through Anand Agricultural University.

Parbhani

The region lies in the central Vidarbha zone of

Maharashtra and is having semi-arid climate. The annual minimum and maximum temperature range within 13-22 °C and 30-38 °C, respectively. The annual rainfall of this region is 938 mm and 83% rainfall is received during south-west monsoon. The typical annual minimum and maximum relative humidity vary within 21-57% and 55-81%. In this region, black soil weathered from basalt rocks is having medium to heavy texture and alkali in nature. The low-lying region is more fertile than upland regions. This is the most drought prone region of India due to erratic rainfall pattern from south-west monsoon and high evaporation rate ranging from 4.8 to 9.4 mm. The crops such as cotton, sorghum, pigeon pea, soybean, maize, wheat, pulses, sugarcane and oilseed are generally grown in *rabi* and *kharif* seasons. The total 8 districts and 76 blocks are covered under Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani to issue advisory for the farmers.

Hyderabad

The majority of the geographical region lies in semi-arid tract with annual rainfall of 900 mm. The rainfall contribution from south-west monsoon (June to September) and north-east monsoon (October to December) contribute 67% and 24% of annual total, respectively and rest 9% is received during winter and summer seasons. The mean annual temperature is 33°C with humidity ranges within 60 to 85% having high annual evaporation (1945 mm). The coarse coastal sands to highly fertile deltaic alluvium soil dominate the whole area. The major crops include cereals such as paddy, maize, sorghum; oilseeds such as groundnut, sunflower, castor and legumes such as chick pea and Pigeon pea. The Cotton, sugarcane and chillies are grown as commercial crops. The advisories for total 16 districts and 61 blocks are issued by Professor Jayashankar Telangana State Agricultural University, Hyderabad.

Raipur

The region is having dry sub-humid climate which lies in Chhattisgarh plains of agroclimatic zone. The temperature ranges from 10 to 48 °C and humidity from 30 to 90%. The average annual rainfall is around 1150 mm and 90% is received during the south-west monsoon (June to September) and rest is received during winter and summer seasons. The annual potential evapotranspiration is very high upto 2250 mm and hence this region lies in the drought prone region of India. Across the region, the soil is very shallow, extremely well-drained and sandy-loamy in texture. The soil is red laterite with typical features of low water holding capacity and low soil fertility which are the major constraints leading to low crop productivity. A major area of these soils remains fallow or constitutes wasteland. The region is termed as *Rice Bowl* of central India. Other crops include wheat, maize, pigeon pea, sunflower, groundnut, millets and soybean. Indira Gandhi Agricultural University, Raipur provides advisory for a total 16 districts and 99 blocks.

Hisar

The climate of the region is semi-arid with hot-dry summer and cold winters. The maximum temperature reaches up to 48°C in summer while in winter, minimum temperature even goes below freezing point. The annual evaporation rate lies between 4 mm day^{-1} (rainy season) to 25 mm day^{-1} (summer season). The average annual rainfall of the region is 455 mm and 77% of annual rainfall is received from the south-west monsoon while rest of rainfall is received during the winter months from western disturbances. The sandy loam and loamy sand are dominant soils in the region. The major crops grown in the region are rice, wheat, bajra, mustard, sugarcane and cotton. Choudhary Charan Singh Haryana Agricultural University, Hisar owns the responsibility to provide the advisory for 9 districts and 64 blocks.

Presently satellite agromet data is being disseminated for a total 60 districts and 382 blocks under above-mentioned AMFUs.

RESULTS AND DISCUSSION

Evaluation of the satellite agromet products at the selected AFMUs

The validation of satellite derived agromet product was done at selected study area using point observations collected at different AFMUs. The block level product was selected to minimize the spatial scale effect for validation of the respective agromet products. For the validation of PET, the ground measured data was used to compute the PET using Modified Penman Monteith formulation commonly known as the FAO56 model (Allen *et al*. 1998) for the particular location as per the available instrumentation. The validation results showed RMSE of 1.0 mm day^{-1} and correlation coefficient (r) of 0.87 with the ground measured daily PET for Parbhani block during the month of July 2021 as shown in Fig. 6. The weekly measured PET over Ranga Reddy block of Hyderabad produced RMSE of 2.4 mm during July to December 2021 (Fig.7). The rise and fall of ground computed PET were well captured by INSAT 3D derived PET both on daily and weekly time scale.

The INSAT 3D derived LST was compared with the ground measured soil temperature at 5 cm depth. The daily data from July to October 2021 was taken at Ranga Reddy block of Hyderabad for measured at early morning and afternoon for the comparison of minimum and maximum LST, respectively. Only clear sky data of INSAT 3D was used for validation of LST. The RMSEs of 1.6 and 2.9°C were found in case of INSAT-based minimum and maximum LST, with r of 0.86 and 0.90 (Fig. 8), respectively. The minimum LST comparison was done with morning hours soil temperature data when land and atmosphere attain thermal equilibrium and this led to low RMSE. During noon to afternoon hours, large gradient in temperature exists among soil, canopy and overlying atmosphere. This leads to more RMSE in maximum LST when compared to soil temperature.

The SMAP derived soil moisture, plotted with measured rainfall at Ranga Reddy block of Hyderabad, is able to show concomitant variability in line with the dry and wet rainfall spells during September 2020 as presented in Fig. 9. The Figure also showed that there is a lag of 1-2 days between rainfall occurrence and resultant soil moisture variation as SMAP used to provide soil moisture estimates based on morning hour observations only. The rainfall event of <5 mm to >70mm were well captured by SMAP surface soil moisture estimates. The SMAP derived

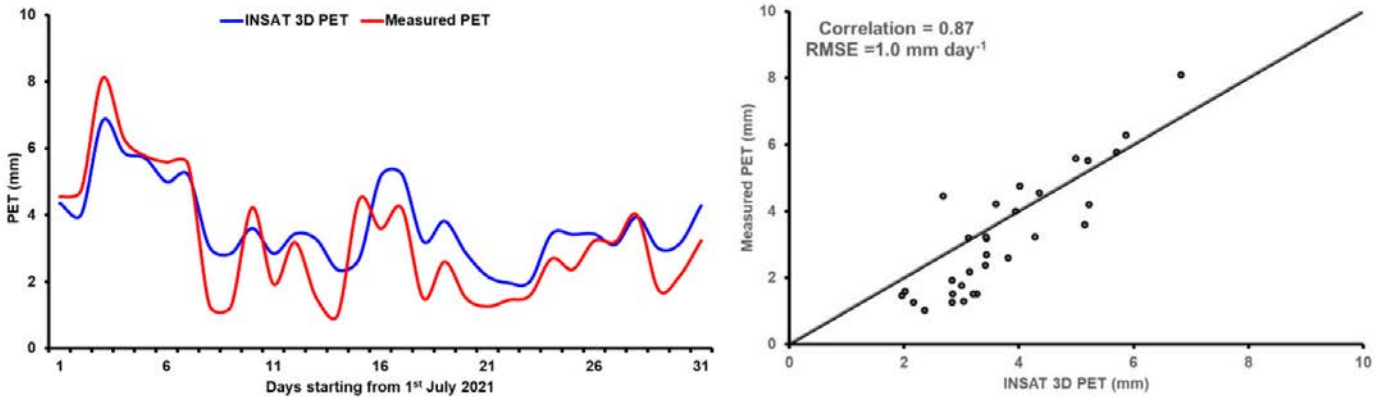


Fig. 6: Comparison of the INSAT daily PET with that from in situ measurements over Parbhani block

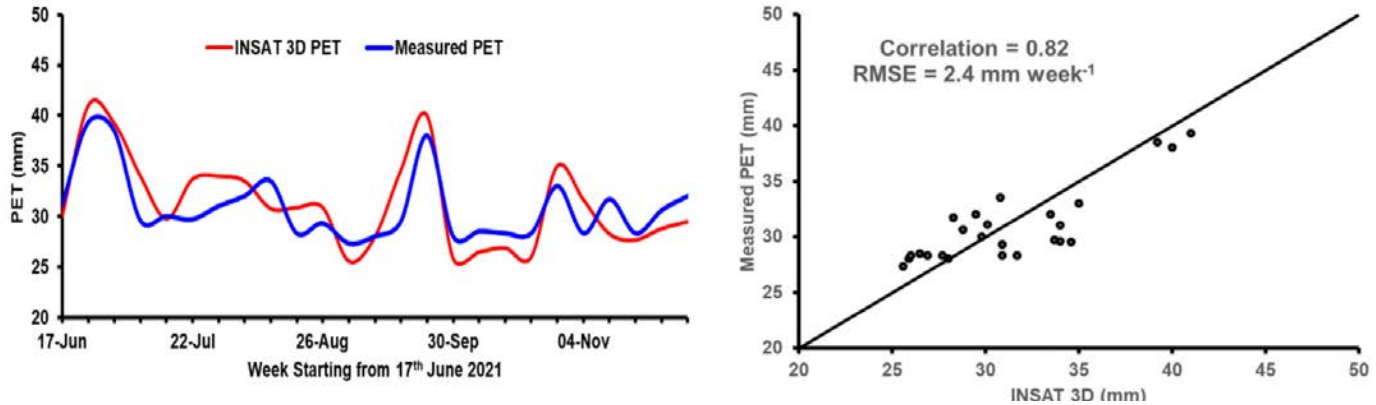


Fig. 7: Comparison of the INSAT daily PET with that from in situ measurements over Ranga Reddy block of Hyderabad

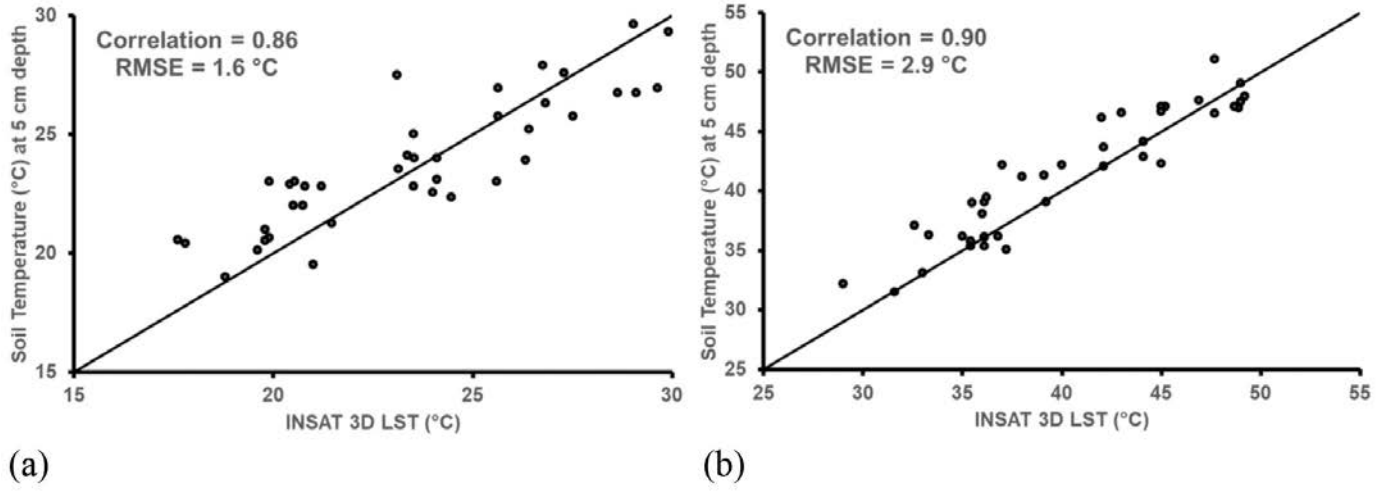
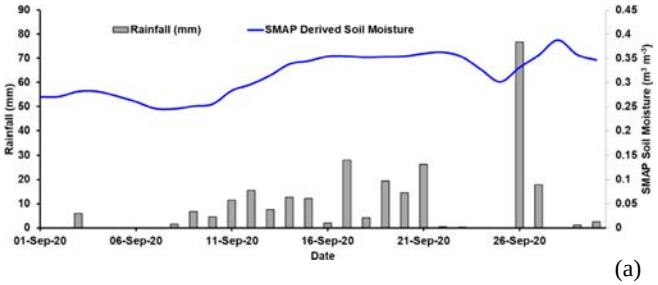


Fig. 8: Comparison of clear-sky (a) minimum and (b) maximum LST at Ranga Reddy block of Hyderabad

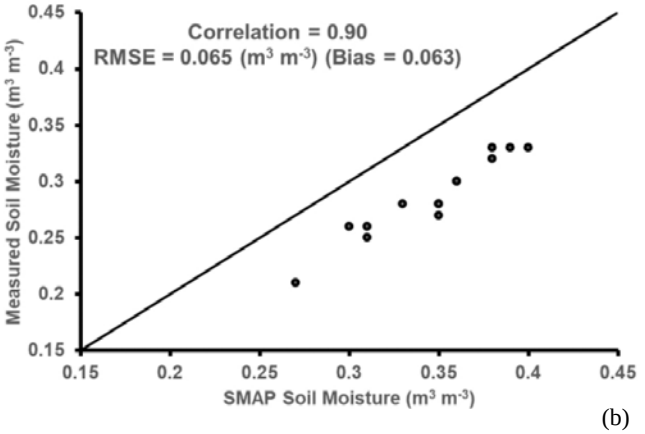
soil moisture showed RMSE of 0.065 m^3m^{-3} and 'r' of 0.90 with measured soil moisture during kharif season. The Fig. 9 showed a bias of 0.063 m^3m^{-3} for SMAP soil moisture which could be due to mismatch of spatial footprint. The measured in-situ data represents a smaller footprint area of 0.01 km^2 as compared to footprint of different satellite agromet products at block level.

Potential usage of satellite derived products in current Agromet Advisory Services

The synoptic daily coverage of vegetation vigour by satellite derived NDVI product provides rapid assessment of crop growth status and agricultural land use. NDVI and soil moisture products also provide crop sown area and its progress in different blocks and districts. The regular NDVI data are able to discriminate



(a)



(b)

Fig. 9: (a) Temporal variation in SMAP derived surface soil moisture with measured rainfall at Ranga Reddy block of Hyderabad (b) Comparison of SMAP derived and in-situ measured surface soil moisture at Parbhani block

timely and late sowing blocks and districts of that particular region. It also provides guidance regarding the response of dry and wet spells to different crop growth stages through deviation in NDVI from the normal. The anomaly in NDVI also helps in locating the damaged/ adversely effected cultivated regions due to extreme events (Fig. 10). As NDVI gets contaminated due to cloud and fog, the daily 10-day moving maximum composite was provided to users. Through the usage of NDVI product differential crop growth in various block and districts can easily be evaluated. Similarly, anomaly and large fluctuation in minimum and maximum LST provide information about the crop stress. The LST and air temperature provided by weather forecast also can be used to identify the block and districts having maximum and minimum difference between these two types of temperatures to mark the crop stressed locations. PET acts as critical input for optimizing irrigation scheduling for different blocks and districts as per their cropping pattern, sowing time and weather. The orientation of irrigation scheduling for each location can save guard local water resources and optimize the cost of cultivation in agricultural system. The consistent dry and wet regions are categorized using surface dryness index. Surface soil moisture determines sowing suitability both in *kharif* and *rabi* seasons and in combination with NDVI data it helps to compute sowing date for different blocks and districts. The surface soil moisture status also helps in issuing advisory for light irrigation as well as fertilizer applications in different crops. The persistent high soil moisture with low PET also provides guidance for assessment of probable disease and pest attack in different crops as high surface moisture and low vapour pressure deficit create conducive environment for biotic stress.

CONCLUSIONS

In order to boost the reliability and acceptance of agromet services across farming community there is a need to provide location-specific advisory by providing finer-resolution medium range weather forecast and satellite agromet products for timely evaluation of the real ground situation for a given AFMU. In the present time, dynamic agricultural practices by farmers' need continuous monitoring over large area to capture the spatial and temporal heterogeneity and to assess the impact of weather on crop growth with least turn-around time. Hence, one set of advisory on farm operations for a particular block and district cannot be viable for others. The spatial heterogeneity across different blocks and districts due to different crop growth stage, management practices and weather are well characterized by aforementioned satellite-derived agromet products. For a particular AFMU, the unique agromet products unfold the real crop growth state across the blocks and districts. The initiation of usage of satellite agromet products showed the preliminary pathway to assess the ground situation in quicker manner to incorporate into the agromet advisory bulletin. The awareness and acceptance of the satellite derived agromet products among agrometeorological community can be a new beginning for the generation of location-specific advisories for the farmers. The future ISRO and global collaborative space missions such as GISAT (Geostationary Imaging Satellite), INSAT 4th generation, NISAR (NASA ISRO Synthetic Aperture Radar), Indo-French TRISHNA (Thermal InfraRed Imaging Satellite for High-resolution Natural Resource Assessment) etc. will not only provide better spatial and temporal resolutions but will further enhance the accuracies of agromet products. Among aforementioned missions, NISAR will provide all sky monitoring of ecosystem through L and S-band SAR (Synthetic Aperture Radar) observations while TRISHNA mission will address irrigation management at farm scale through high-repeat advanced multi-band thermal infrared remote sensing observations. The future advancement in space technology will help in improving the quality of current agromet advisory services to provide better farm-scale solutions to farmers.

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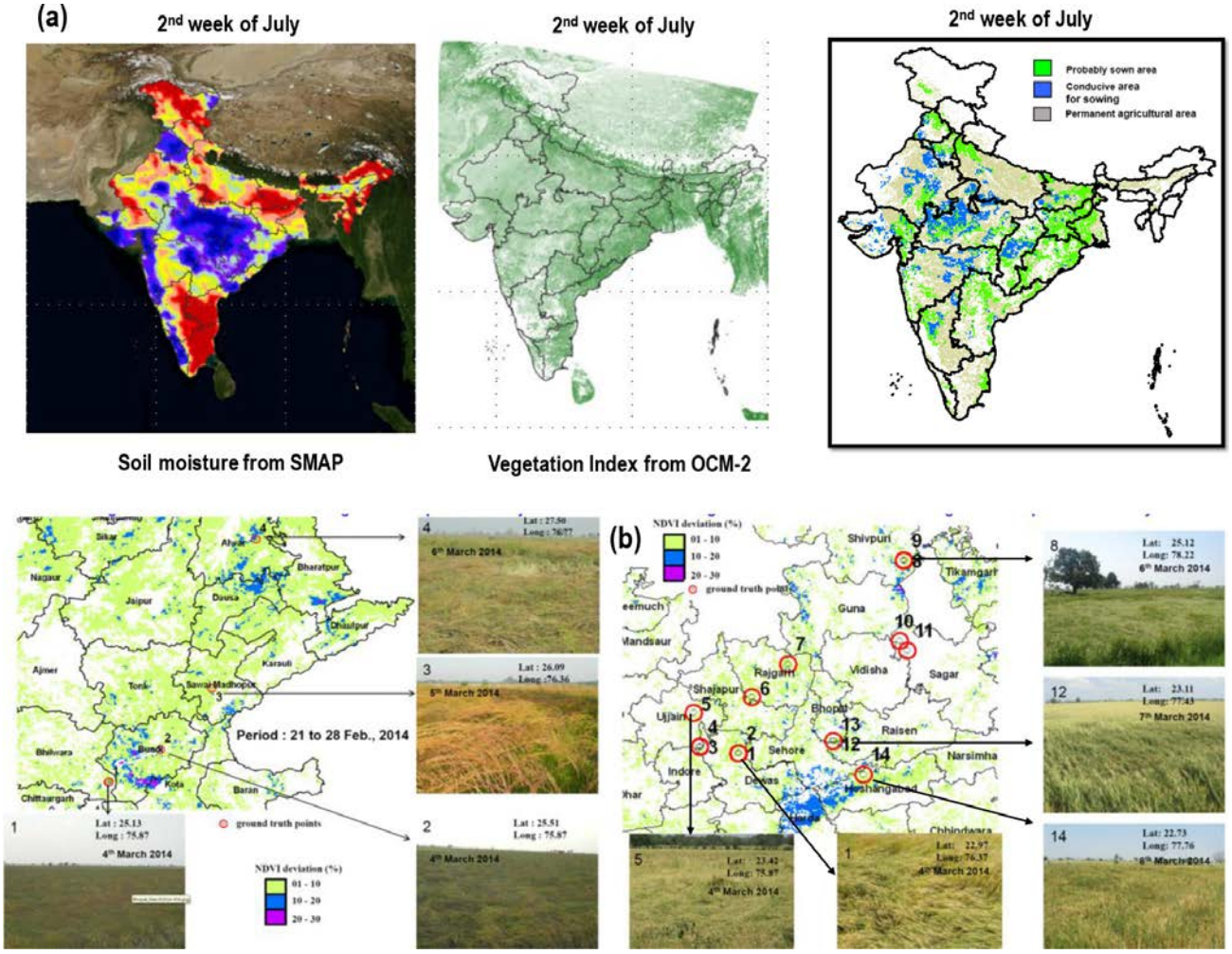

Fig. 10: Examples of potential usages of agromet products to assess (a) crop sowing prospect and (b) damage assessment due to extreme (hail-storm) event

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