

EOS-4 dual-polarised and Hybrid polarimetric data utilization for field crops and plantation monitoring

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Research Article

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Posted Date: October 15th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11170234/v1>

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Additional Declarations: No competing interests reported.

**EOS-4 dual-polarised and Hybrid polarimetric data utilization for field crops and plantation
monitoring**

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Singh

Abstract: The utility of multiparametric radar data for agricultural applications has been extensively demonstrated in the past, particularly using Radar Imaging Satellite (RISAT)-1 over the past decade. Recent advancements in radar remote sensing have enabled the Indian SAR research community to achieve hybrid/compact proficiencies and full-polarimetric capabilities in both high-resolution FRS (Fine Resolution Stripmap) and larger swath MRS (Medium Resolution ScanSAR) modes. Wide-swath data now supports a range of applications, from oceanography and glaciology to, notably, agriculture and field crops stands out. While previous satellites, including RISAT-1, offered limited agricultural applications, this study demonstrates their immense potential not only for crop discrimination and mapping but also for monitoring crop growth and estimating biophysical parameters. Crop growth stages, both standing and at harvest, were analyzed, and biophysical parameters were found to be highly sensitive to different modes of data acquisition—both amplitude and decomposed scattering—particularly for biomass 5- 6 kg m⁻² and LAI up to 6. The temporal progression of crop growth and harvest monitoring is demonstrated for 2022–2025. The recent NISAR-S band based analysis will add values to this by capturing wider range of sensitivity as indicated by the initial analysis. In addition to field crops, plantation crops, which have received limited attention in prior radar-based studies, were investigated, particularly deciphering the key economic stages for timely management.

Keywords: Crop monitoring, temporal data remote sensing, plantation crop, RADAR, EOS-4, MRS, hybrid polarimetric FRS

Introduction:

Optical sensors often face operational limitations in crop monitoring during the Kharif season due to extensive cloud cover in tropical regions, also during the winter growing season particularly in the northern and eastern parts of India due to thick fog or haze. In contrast, Synthetic Aperture Radar (SAR) is largely unaffected by weather conditions and cloud cover, exhibiting high sensitivity to both crop structure and dielectric properties. This makes SAR an ideal tool for reliable crop monitoring under foggy, hazy, or monsoon conditions. SAR has been efficiently used to monitor rice and other Kharif crops across India (Chakraborty and Panigrahy, 1997; Halder et al., 2014, 2019). Among non-rice Kharif crops, millets have also gained recognition over cereals due to their nutritional benefits and resilience under extreme climatic conditions. With the initiative of Government of India, the United Nations declared 2023 as “International Year of Millets.” Pearl millet, the fourth most consumed crop in India (Millet Network of India, Deccan Development Society, FIAN, India), presents unique monitoring challenges for optical datasets because its short 80–90-day life cycle coincides entirely with the monsoon period. Satellite based monitoring for pearl millet and maize has been carried out utilising dual-pol and quadpol data in the SUFALAM program at centres and units of ISRO.

The potential of RISAT-1 (the first sensor for civilian) for crop monitoring was demonstrated between 2012 and 2016 using Medium Resolution ScanSAR (MRS, dual-pol) and Fine Resolution Stripmap (FRS, compact- or full-pol) data. MRS served as a workhorse for monitoring Kharif crops across India and parts of the subcontinent (Chakraborty et al., 2013; Halder et al., 2014, 2018, 2020; Dave et al., 2017), and for Rabi crops (Halder et al., 2020). Hybrid/compact-pol data, which has been the first of its kind in which the transmit is circularly polarized and the receive is linearly polarized in both channels, has shown strong potential for multiple applications across varied domains. Pertaining to the

Agricultural applications, the major ones are: crop identification, condition assessment, crop damage assessment and biophysical parameter retrieval at various critical stages. The performance of compact/hybrid-pol data closely approaches that of fully polarimetric data for such applications (Charbonneau et al., 2009; Haldar et al., 2012). Furthermore, the benefits of RISAT-1 compact polarimetry—including system design advantages such as the lack of preferential transmit orientation—have been highlighted by Raney (2007, 2012, 2017) and Misra et al. (2013).

Tea, a high-value cash crop, has been recently studied in the recent past by our team (Mitra et al., 2024). It requires timely monitoring of multiple harvests from March end to October, the first ones being of higher value than later ones. While early growth phases (up to May–June) can be monitored using optical data, cloud-free observations become increasingly scarce with the onset of the monsoon. Important economic stages could be detected which could support harvest and post-harvest management.

From 2016 to 2022, most polarimetry-based research suffered in the developing nations because compact/hybrid polarized data was unavailable. Consequently, remote-sensing applications were primarily conducted using dual-pol Sentinel data (VV/VH) globally, with a few RADARSAT-2 (R2) scenes used where full polarimetry was essential. Sentinel-based studies yielded satisfactory results; however, performance saturation occurred, particularly for at advanced biomass ranges (Haldar et al., 2019, 2020; Srikant et al., 2021). The launch of EOS-4 (RISAT-1A) on 14 February 2022 represents a milestone in advancing India's SAR remote sensing program. Designed as a key operational platform, RISAT-1A has served in various operational program of ISRO particularly for kharif crop acreage and production estimates during these 3 years. It will be further augmented through the inclusion of RISAT-1B forming a constellation capable of continuous and high-temporal-resolution observations for precision Agriculture. Such a configuration will enable large-scale agricultural monitoring, including retrieval of vegetation optical depth, canopy water content, at high repeat observations that serve as key indicators of crop health, condition and yield predictors. The potential of temporal Medium Resolution ScanSAR (MRS) data for field-scale agricultural assessment has been demonstrated in our recent work (Bhattacharya et al., 2024), where multi-temporal datasets acquired over two to three cropping seasons were utilized for monitoring multiple crop systems for informed decision making.

Historically, plantation crop monitoring has received limited attention in RADAR-based studies, but needless to say that it will play major role in picking/ pruning and harvest monitoring particularly due to structure sensitive properties of SAR. Vegetation health, reflected in structural characteristics, can be effectively assessed using remote sensing, and SAR, in particular, offers unique insights into crop geometry and architecture (Haldar et al., 2014). Tea, the second most consumed beverage globally after water, is brewed from the tender leaves and buds of *Camellia sinensis* and is cultivated extensively across India, including in regions such as Assam, Darjeeling, Nilgiri, and Kangra. Remote sensing provides a rapid and accurate means to map the various stages and cultural operations of tea plantations, while also supplying geospatial data for geographic information systems (Sishodia et al., 2020, Mitra et al., 2024). The spectral reflectance of tea fields varies with phenology and crop health, and multispectral and multi-source sensors can effectively capture these variations. Unlike other perennial crops, only the two youngest leaves and the bud are harvested for commercial purposes, requiring precise monitoring of growth trends and environmental factors influencing crop development. Traditional ground-based methods, such as manual measurement of leaf area index (LAI), crop height, and plant density, are accurate and continuous but are influenced by subjective human factors and are feasible only for small areas (Y. Huang et al., 2022).

Building on this background, the present study evaluates the potential applications of RISAT-1A (EOS-4) data with two primary objectives:

1. To utilize EOS-4 (RISAT-1A) data for crop discrimination, and monitoring.
2. To assess the potential of EOS-4 data for Tea plantation monitoring.

2. Study area:

For addressing objective-1, Agra district, located in the south-western semi-arid zone of Uttar Pradesh, India (27.1767° N, 78.0081° E), was selected. The district experiences two primary cropping seasons: the monsoon or Kharif season (June–October) and the winter or Rabi season (November–March). Pearl millet is the dominant *Kharif* crop, cultivated alongside paddy, with minor crops including jowar and maize. The sowing window for pearl millet typically spans from the last week of June to mid-July, with harvesting occurring by the first week of October. Agra district falls under the ecological zone UP-3 (South-Western Semi-Arid Zone of NARP), the Western Plain Zone of ICAR, and the Upper Gangetic Plains as classified by the Planning Commission.

For addressing objective-2, Palampur, a hill town and municipal corporation in Kangra District, Himachal Pradesh, India ($32^{\circ} 6' 37.95''$ N, $76^{\circ} 32' 10.41''$ E), was selected. The sub-district covers an area of 429 km², of which 428.32 km² is rural and 0.67 km² is urban. It is bounded by Chamba District to the north, Dhira, Thural, and Jaisinghpur sub-districts to the south, Baijnath sub-district to the east, and Dharamsala and Bagwan sub-districts to the west. The area is surrounded by pine forests and flanked by the Dhauladhar ranges. Numerous streams, including Awa Khad, Bhiral Khad, Neugal Khad, and River Mol Khad, flow from the mountains to the plains, shaping the topography and supporting the extensive tea plantations in the region.

3. Data Sets

RISAT-1A data acquired in Medium Resolution ScanSAR (MRS) and Fine Resolution Stripmap-2 (FRS-2) modes were utilized. The MRS data, acquired in dual polarization (HH, HV), FRS-2 data, acquired in hybrid (RH, RV) and quad-polarization modes, spanned across multiple crop growth stages of paddy and pearl millet, enabling detailed crop identification and monitoring. From July to October, MRS data were acquired every 17 days, providing a wide swath coverage of 160 km that encompassed major rice- and pearl millet-growing districts across Uttar Pradesh, Rajasthan, and parts of Haryana. The satellite's flexible acquisition geometry, offering multiple look angles and beam configurations, supports diverse thematic applications spreading across soil moisture, vegetation monitoring, geology and oceanic applications. Furthermore, RISAT-1A also provides the capability for interferometric data acquisition, enhancing its potential for topographic/geological and biophysical studies. The high-resolution FRS-2 data, with a spatial resolution of 3.6 m, covered selected regions of Agra district.

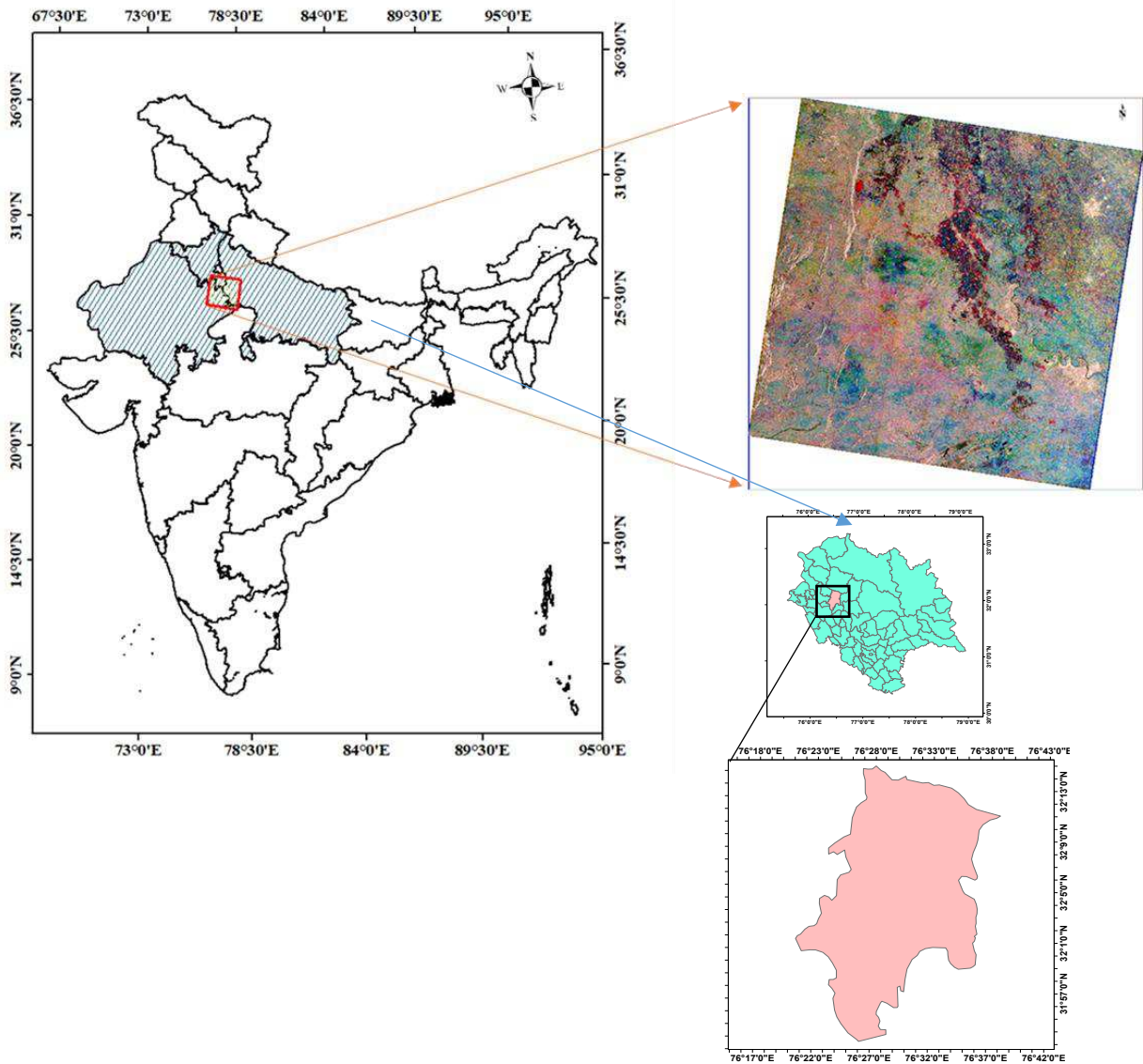


Figure 1 Study Area 1) with 3- Date HV Composite (15th Jul, 1st and 18th Aug) of Agra and adjoining region for paddy and Bajra-southern b) Palampur region in Himachal for tea plantation- northern



Fig.2 Field photographs of the a) Palampur study area while taking field observations during 11-15th October 2022
b) Team in Agra area while taking field observations during 26th-30th September 2022.

Table 1 Details of RISAT-1A datasets procured

Satellite	RISAT-1A (EOS-4)		
Acquisition Mode	MRS	FRS-2	FRS-2
Polarization	HH, HV	RH, RV	Quad
Frequency	C-band	C-band	C-band
Pixel Spacing (m)	18 x 18	3.6 x 3.6	3.6 x 3.6
Incidence Angle	37.80 ^o	47.2 ^o - 48.71 ^o , 37.70 ^o - 39.62 ^o	33.74 ^o , 32.07 ^o
Dates of Acquisition	15 th Jul 2022, 01 st Aug 2022 18 th Aug 2022, 4 th Sep 2022 21 st Sep 2022, 08 th Oct 2022	30 th Sep 2022 09 th Oct 2022(for Pearl millet)	16 th Sep 2022 23 rd Nov 2022

	26 th March 2022 to 21 st April 2023	21 st October 2022 and 31 st January 2023(for Tea)	
Swath km	160 Km	25 Km	25Km
Satellite repeat cycle	17 days	17 days	17 days

4. Methodology

RISAT-1A data was processed in platforms like ENVI (v 5.0), PolSAR Pro (v 6.0) and MiDAS (v 3.1) software. MRS data L2-Enhanced Terrain Geo-Referenced product was obtained in .tiff format. The data acquired in dual-pol HH and HV mode was calibrated using the calibration constant in product.xml as:

$$\text{backscatter in (dB)} = 20 \cdot \log_{10} (DN) - k(\text{dB})$$

Where, DN – Digital Number,

k – Calibration Constant (dB)

The HH and HV images were then filtered by Enhanced Lee adaptive filter with kernel size 5 × 5. FRS (quad and hybrid) SLC data containing amplitude and phase information was available in CEOS format. The data was pre-processed in PolSAR Pro. Refined Lee filter with 3x3 window size was applied to reduce the inherent noise. $[C_3]$ and $[T_3]$ matrices were generated from quad-pol data and Yamaguchi and Freeman-Durden decompositions were then applied to characterize the complex scattering efficiently. $[C_2]$ matrix generated from the hybrid data were applied with m- χ , m- α and m- δ decompositions. MiDAS v3.1 was utilized to geo-reference the images. Also decomposed products are available from

5. Results and discussion

5.1 MRS - Dual Polarization Mode

The acquisition of RISAT-1A data in MRS mode facilitates seamless operation and systematic coverage, encompassing a larger swath. This enables the potential for monitoring on a regional/ nation-wide scale and this serves as workhorse. Aligarh, Hathras, Mathura and Agra districts in Uttar Pradesh, Alwar and Bharatpur regions in Rajasthan and parts of Rewari, Gurugram, Faridabad districts of Haryana were covered in the 6 datasets spanning from July 2022 to October 2022. Backscatter responses and Radar Vegetation Index (RVI) were computed for crop identification and to characterize the crop growth. Dual-pol RVI was computed by:

$$RVI = \frac{4\sigma_o HV}{\sigma_o HH + \sigma_o HV}$$

Paddy classification based on transplantation date from multirate SAR on was carried out in the northern India was well picked up using systematic coverage 3 date RISAT-1A MRS Data. These datasets have proven the potential of the RISAT-1 mission, moreover the wider swath of 160 km over 115 km makes it a perfect choice for regional applications. Dual-pol (HH, HV), hybrid-pol (RH, RV) and full-pol mode for Rice and Pearl Millet monitoring was evaluated predominantly over Agra district.

a) PADDY

Rice exhibits a unique temporal backscatter profile that distinguishes it from all other crops. During the transplantation, the backscatter is typically low both in HH and HV due to the presence of puddled fields submerged by water (specular signature), followed by a gradual increase from the tillering stage to the heading stage. HV backscatter ranges from -20 dB during transplanting due to the puddled field conditions to -12 dB as crop growth progresses; whereas HH backscatter ranges from -15 dB from transplanting and up to -5 dB during heading stage (fig 3&4). These temporal responses are used to build the decision rules for classification, captured using 3-date data (R-15th Jul, G- 01st Aug, B- 18th Aug). The majority of fields were found to have transplanted around 1st August, 2022, in the RGB temporal stack, the magenta shade highlights these areas. in the rice belt regions stretching from Faridabad (Haryana) to Mathura and Agra (UP). With the difference in backscatter response across the stages, decision rule was formed for Paddy as Normal, Late and Early transplanted rice. The responses have been validated at multiple sites in India using Envisat, Radarsat, RISAT-1 & 1A (Haldar and Patnaik, 2010, Haldar and Chakraborty 2019, Bhattacharya et al., 2024).

The major phenological growth stages of rice includes: **Vegetative Stage** (germination to panicle initiation), **Reproductive Stage** (panicle initiation to flowering), and **Ripening Stage** (flowering to grain maturity). It is usually cultivated as irrigated or rainfed crop mostly by transplanting and at times by direct seeded technique. Throughout the crop growth period, spatial variability in the phenological stages was evident due to the adoption of diverse agronomic management practices in the region particularly staggered sowing dates, rice fields are seen in fig 3. These variations are influenced by a multitude of factors, including the availability of labour, water, weather conditions, and choice of cultivars. The Radar Vegetation Index (RVI) as illustrated in fig.8 captures paddy growth, condition and finally translates to yield. During 1st and 18th August the initial paddy stages are distinctly discernible in blue signature, then as the fields pass through the vegetative, tillering, panicle initiation and maturity through which RVI (0.2-1.2) is seen to increase till peak vegetative stage and then stabilises.

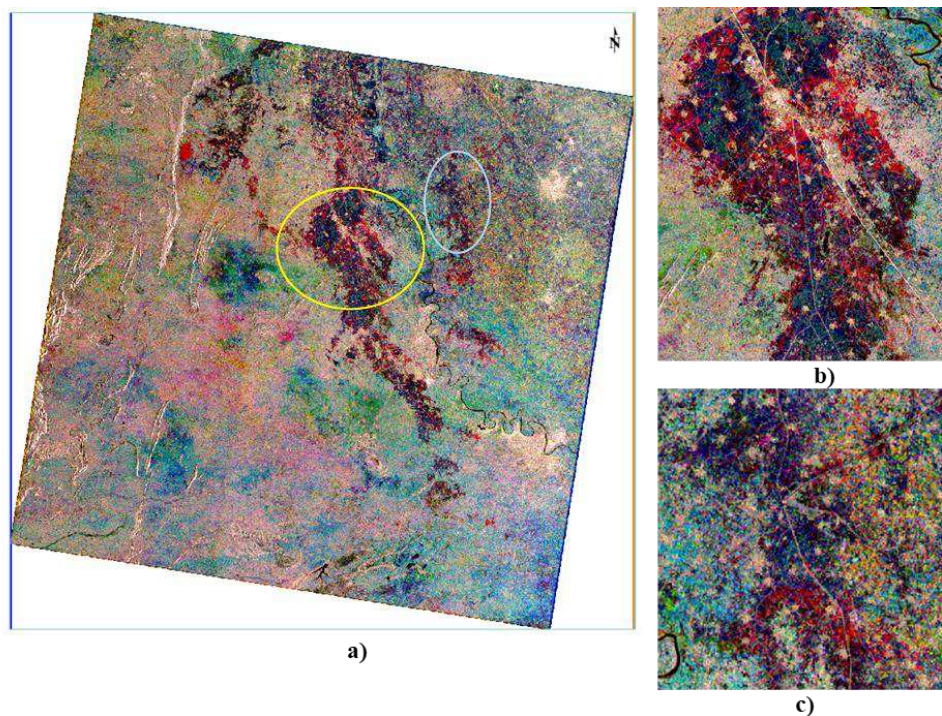


Fig. 3 MRS data a) 3- Date HV Composite (15th Jul, 1st and 18th Aug) b) Normal Transplanted Rice (1st Aug) c) Early Transplanted Rice

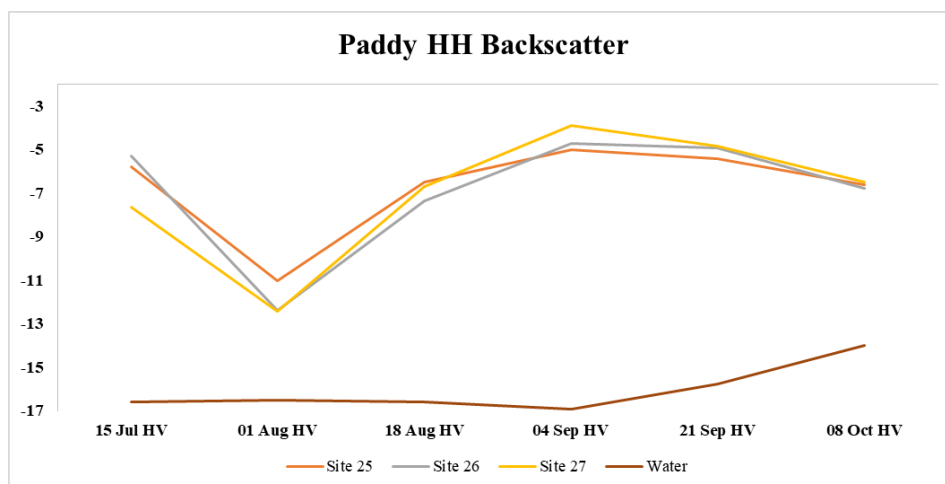
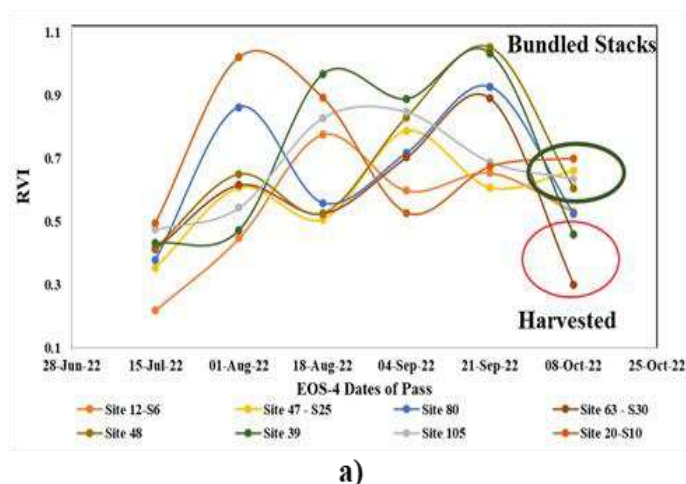
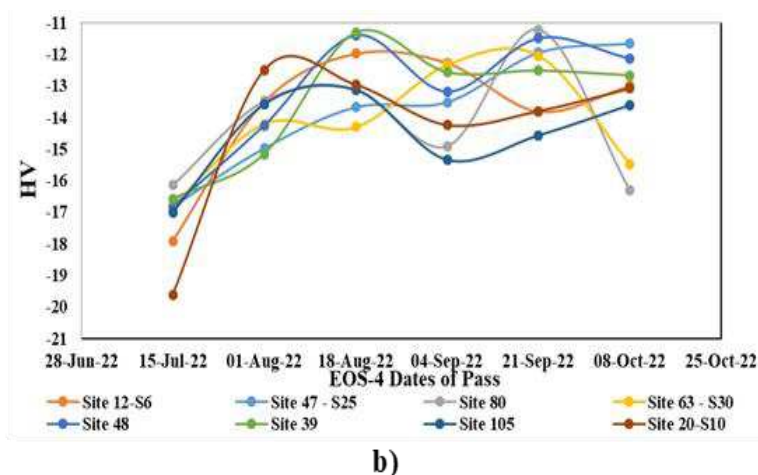


Fig 4 Temporal response of HH backscatter (dB) over the paddy fields at three sites vs water body.



a)

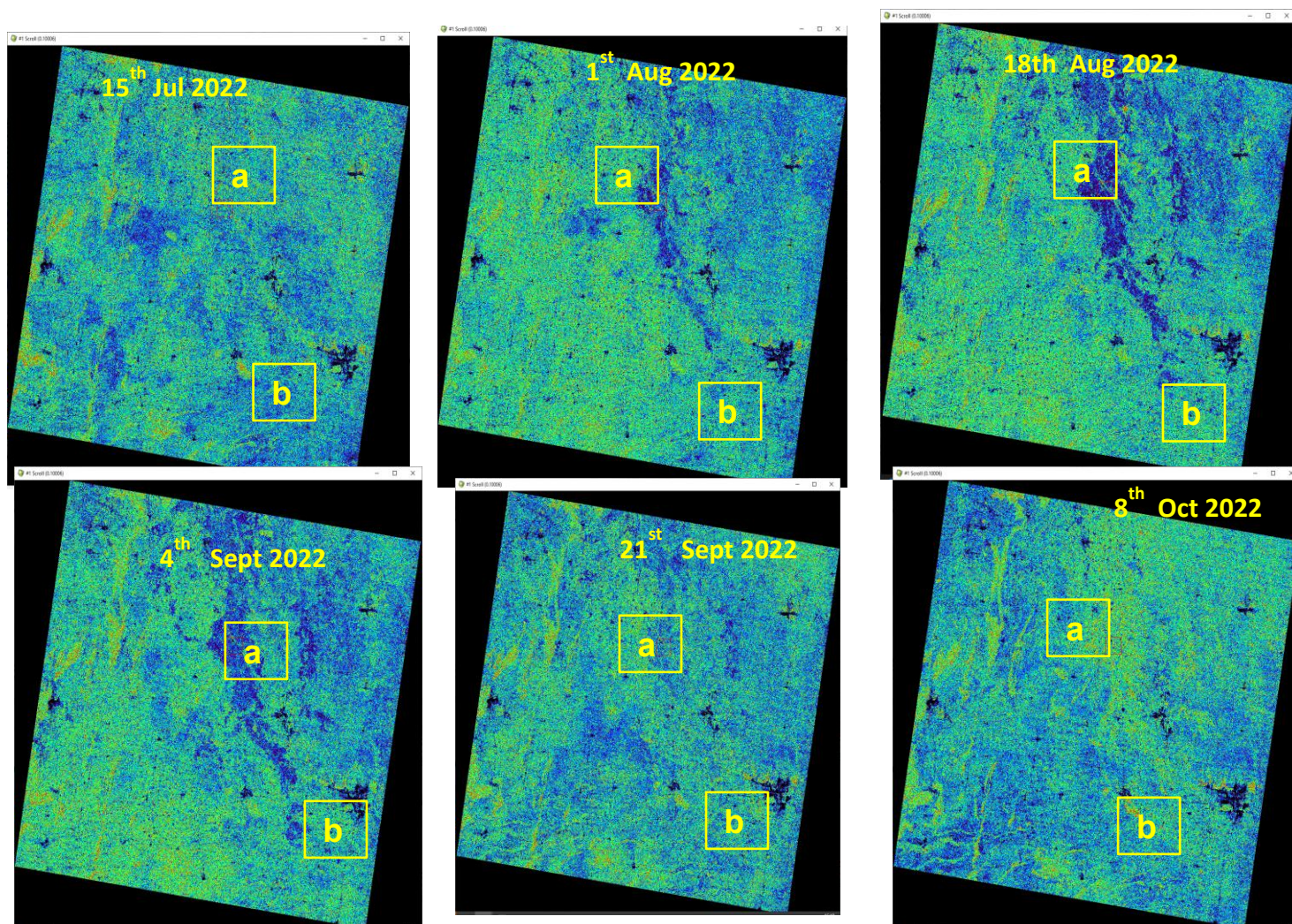


b)

Fig. 5 a) RVI and b) HV backscatter response of Pearl Millet Crop across fields

b) PEARL MILLET

In Agra, Pearl Millet (Bajra) is usually sown during end of June till first fortnight of July. In this region, Pearl Millet exhibits a high degree of temporal and spatial variability (SUFALAM report and Shanmugapriya et al., 2021, 2022). As a rain fed crop, there are variations in sowing dates among farmers, leading to variability in crop growth stages. The backscatter response of Bajra (Pearl Millet) exhibits a range of values during different stages of its growth. In HH polarization, the backscatter response varies from -9 dB during initial stages to -5.5 to -5 dB during the peak vegetative stage. In HV polarization, the backscatter response ranges from -16.5 dB to -12.5 dB during the peak vegetative stage (fig 5a and b). These distinctive variations in the radar backscatter response at different stages of the crop calendar were effectively utilized to identify the crop using a decision rule. Dual-pol RVI was also significant for monitoring the various stages of crop development (fig.8). It exhibits a distinct range of values, starting from 0.2 in bare field conditions and increasing to approximately 1.4 during the peak vegetative growth stage. The progress in the crop season, both paddy and pearl millet are well picked up by the temporal RVI images in fig. 8. As the crop matures and dry matter accumulates, RVI experiences a decline, reaching a range of 0.5-0.6. After harvest, the RVI values for bare fields exhibited a significant drop (around 0.2), while fields with bundled stacks display slightly higher RVI values.



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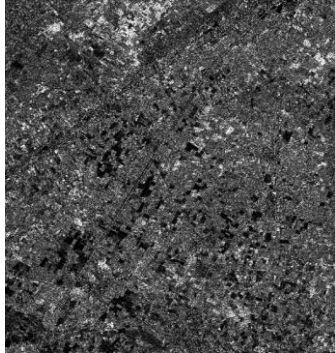
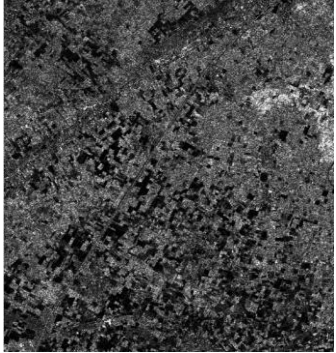
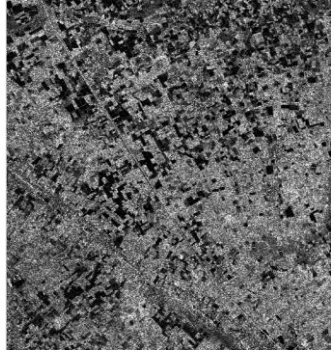
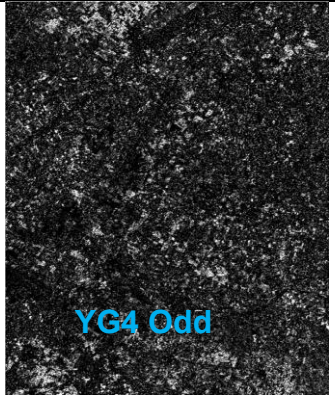
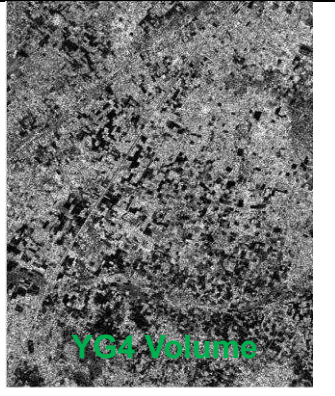
250 **Fig.8 .Temporal RVI images of *kharif* 2022 on July 15 coincides with Bajra sowing in the region**
 251 **(b), end July and early August with the transplantation of paddy seen in dark blue patch (a) in**
 252 **central part of the image. Paddy is seen in full growth in early October and Bajra by end**
 253 **September (b).**

254 5.2 Fine resolution FRS- Hybrid-polarised data for parameter estimation

255 Few compact polarised/ hybrid datasets were acquired on 30th September and 09th October
 256 2022. Field campaign was conducted over the regions of Agra in synchronous with the satellite pass on
 257 from 26th to 30th Sep 2022. Field parameters viz. wet biomass and crop height were collected by
 258 adopting stratified random sampling strategy. The operational advantages in hybrid mode has gained
 259 interest and the effective utility for nation-wide monitoring is now under the radar of research. Thus to
 260 evaluate the potential of hybrid data for monitoring high biomass crop like Pearl Millet was analysed.
 261 Several parameters including scattering responses from hybrid decompositions $m\text{-}\chi$, $m\text{-}\alpha$ and $m\text{-}\delta$ and
 262 Cloude - Pottier decomposition were evaluated for various biomass classes. The response of hybrid
 263 parameters was promising towards the crop biophysical parameters. By 30th September, the majority of

the crops in the fields had reached maturity and were ready for harvest. Around 10 days later, on 9th Oct, nearly all of the fields had been harvested, resulting in a prominent surface scattering observed over the fields.

The operational advantages of the hybrid mode, such as a wider swath coverage with lesser power requirement, self-calibration, and reduced susceptibility to noise, significantly enhance the capability for nationwide crop monitoring particularly with wide swath data. The coherency matrix elements shown in fig. 6a depicts the dominant surface scattering in the T11 with high surface scattering response seen in bright patches corresponding to the field preparation for next crop with ploughed bare field, the intermediate gray/darker values depict standing pearnillet crop in which odd bounce component will be minimum. The T22 depicts the double bounce scattering showing the part of Agra city as bright. T33 as volume scattering dominant signature of fields depicting pearl millet as the standing crop which has been late planted. The harvested fields/ ready to harvest field appear in darker tone in YG4 volume scattering component. The fig 6b shows RGB image, green as crop, blue as ready to harvest fields and dark blue is seen as harvested fields in the image below.

		
$T_{11} = 0.5 S_{HH} + S_{VV} ^2$	$T_{22} = 0.5 S_{HH} - S_{VV} ^2$	$T_{33} = 2 S_{HV} ^2$
		

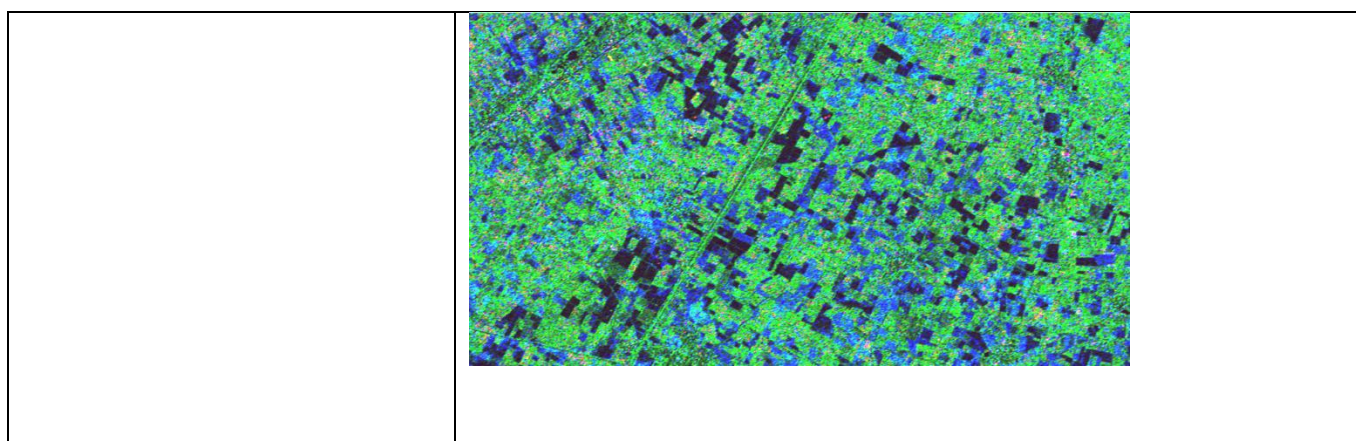


Fig. 6 a) Coherency Matrix elements derived from RISAT-1A data and b) the 3 Yamaguchi scattering components with RGB of Yamaguchi-4 Decomposition on 16th September 2022.

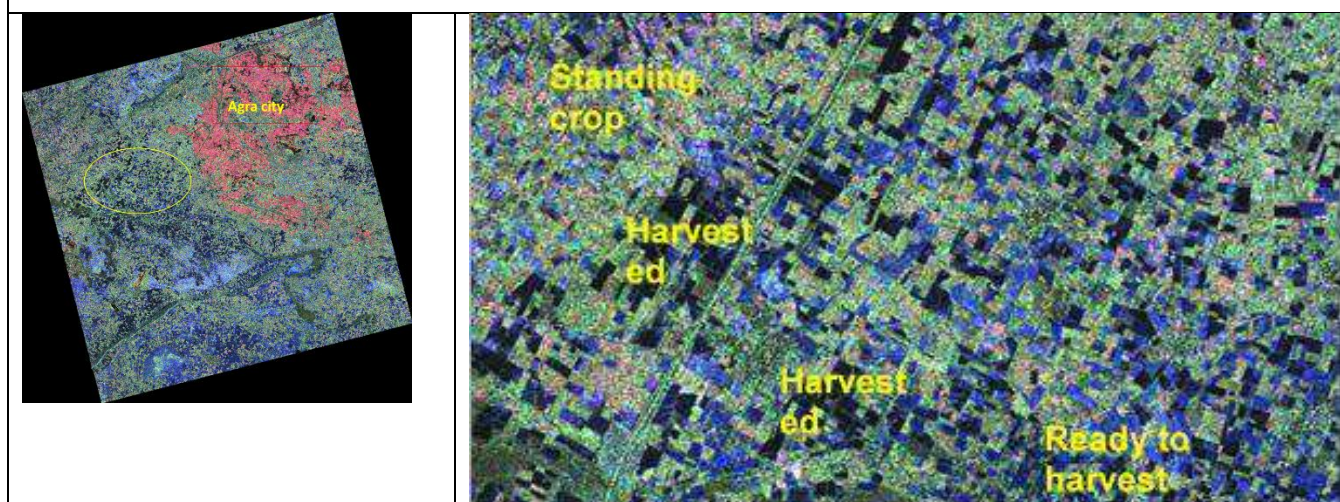
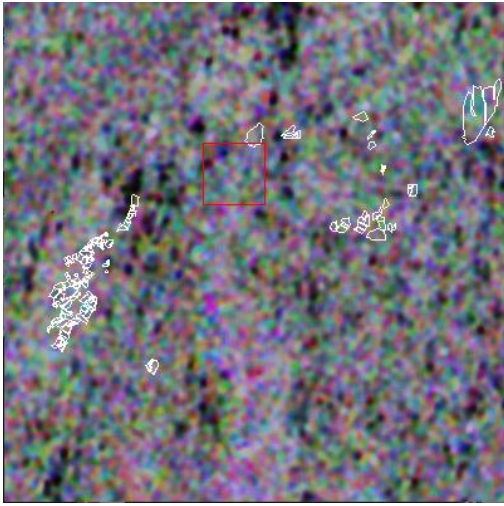


Fig. 7 a) Quad Pol data from RISAT-1A data and b) The RGB representing Double Bounce, volume and surface scattering, standing crop seen in green, mature crop in cyan/light blue and harvested fields in dark blue.

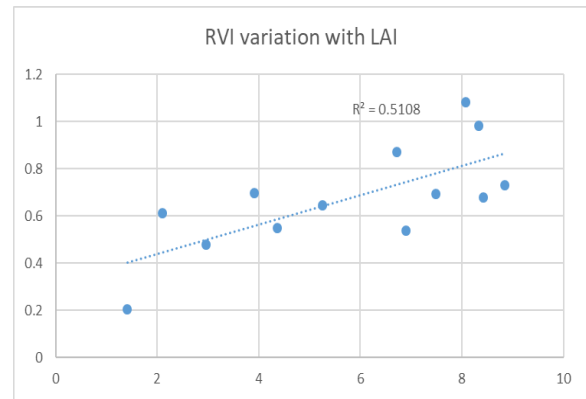
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279 c) Understanding Tea-plantations signatures with RISAT-1A (EOS-4) data

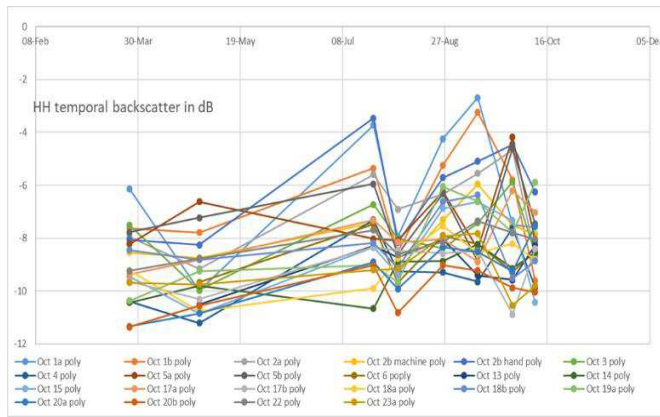
280 Tea gardens of Palampur Subdistrict of Kangra district, Himachal Pradesh, India were investigated to
 281 identify tea leaf picking and pruning operations. The dormant phase and the subsequent regrowth phase
 282 is marked cultural operations which are often hampered due to rainfall during monsoon. In most of
 283 these tea gardens picking operation starts in the month of March-April and end with pruning operation
 284 in the month of November-December. SAR dual-pol data as Radar vegetation Index (fig.9 b) was found
 285 to be useful to detect the regrowth phase and to monitor leaf picking during monsoon.



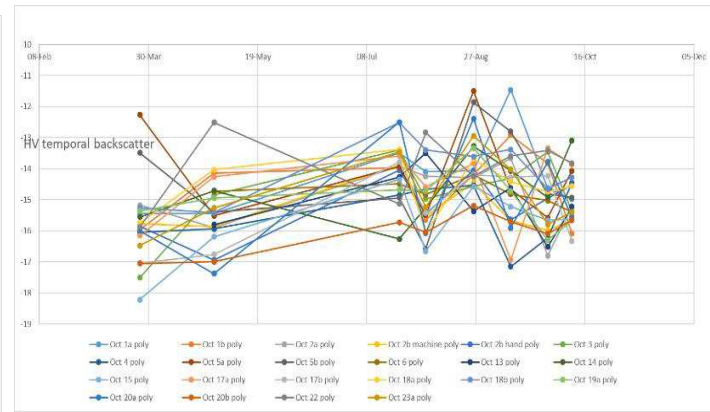
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b)



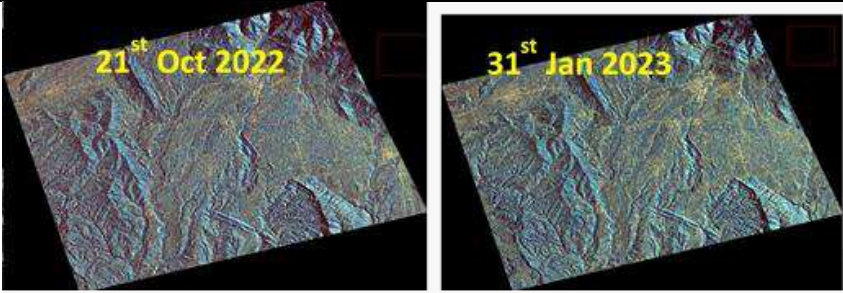
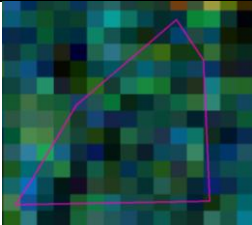
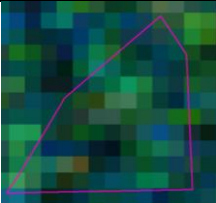
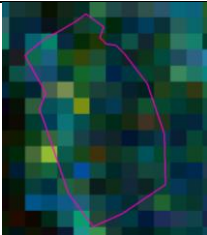
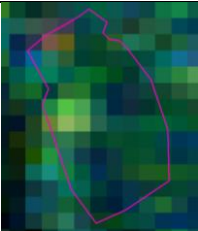
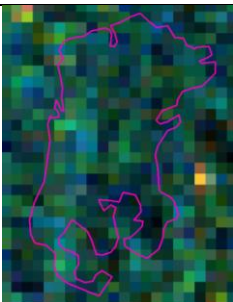
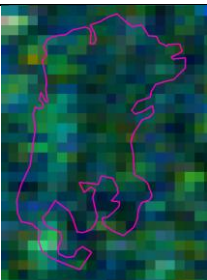
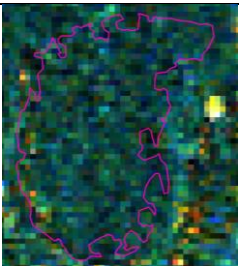
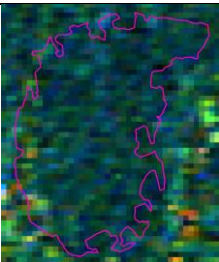
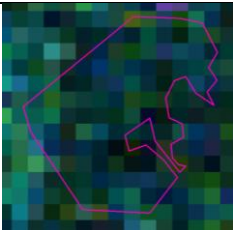
c)



d)

Fig.9 Palampur area a) MRS derived Radar Vegetation Index (RVI) data (26th March, 26th August and 10th October 2022) and b) RVI in response to LAI. The temporal profile in c) HH and d) HV backscatter depict the picking of tea leaves with dip and growth with rise.

The ability to see beyond wavelengths of visible- infrared, where wavelengths can detect vigor of crop, crop stress and damage of crop, is a key advantage of microwave remote sensing apart from numerous difficult weather circumstances common in humid –tropical and subtropical zone. Geometrical and dielectric properties of plants can be precisely detected and monitored (Halдар et al., 2016, 2018, Dave et al., 2017). There are different cultural operations like planting, manuring, irrigation, weed controlling, pruning, skiffing, plucking carried systematically in tea plantation.

		
Tea garden 1		
Tea garden 2		
Tea garden 3		
Tea garden 4		
Tea garden 5		
Fig. 10 The 2-date (October 21st 2022 and January 31st 2023) m-chi decomposed dataset depicting the hilly terrain of Palampur and surrounding		

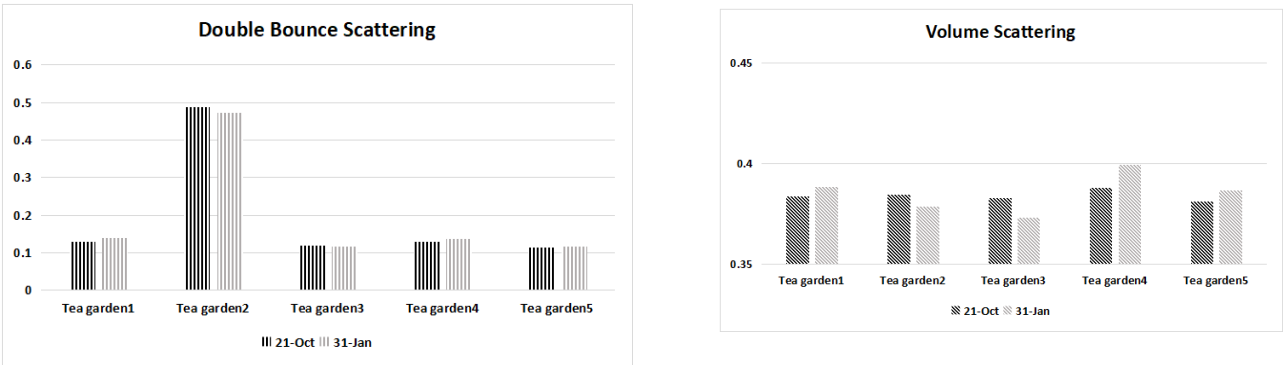
	region. The detailed depiction of the scattering component in the 2 dates are presented.
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308 The phenomenon of double bounce response in tea gardens is predominantly attributed to the pruned
309 base or stalk and also the presence of shade trees. These trees maintain a consistent presence throughout
310 the year, thereby resulting in a consistent double bounce response. In the case of Tea Garden 2, the
311 abundance of shade trees in closer proximity and non-harvested condition of tea plantation contributes
312 significantly to a heightened double bounce response. This effect is observed within shorter intervals,
313 emphasizing the impact of shade trees on the phenomenon. Tea garden2 gives much double bounce
314 response due to shade trees in less interval and non-harvested condition.

315 In the October 21st image dominance of surface scattering is seen due to approach of end of the picking
316 season and by January end, the regrowth is in progress leading to volume scattering in general, except 2
317 gardens no. 2 and 3 where picking was delayed (fig. 10 and 11).

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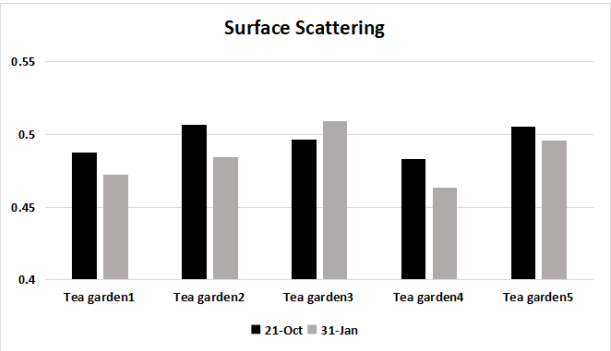
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327 **Fig. 11. October 21st 2022 and January 31st 2023 m-chi decomposed derived scattering**
328 **components (double bounce, volume and surface)**

The process of leaf picking or cutting of leaves by machines in tea plantations results in a smoother surface on the upper part of the tea plants. This smooth surface leads to a distinctive surface scattering response. Response on 21st Oct represents the end stage of picking, while the response on the 31st of January represents the dormant season in tea gardens. It is notable that in the majority of tea gardens, higher values of scattering are detected on the first date mentioned. So in most of the gardens on the first date higher values of scattering is received.

Timely picking of leaves in tea gardens on 21st of October is associated with a lower value of volumetric scattering, this time-phase corresponded to the last phase of picking. This is because timely picking ensures that a significant portion of the leaves has already been harvested, resulting in a smoother surface and reduced scattering response. In contrast, timely pruning gives higher value of volumetric scattering in 31st January image which corresponds to the regrowth of the vegetation after the dormant winter phase. This increase in scattering can be attributed to the regrowth process that begins after pruning which happened timely. The higher scattering values on the first date indicate that the picking of leaves is still ongoing, with a substantial amount of foliage remaining on the plants. The lower scattering values on the second date suggest a delay in the regrowth process following a late pruning, resulting in limited new growth and reduced scattering activity.

6. Conclusions:

The study demonstrated the feasibility and usability of the SAR data for crop monitoring applications for wide domain of field crops, millets and tea-plantation crop. RISAT-1A serves as the workhorse for monitoring most of the *kharif* crops and also the high biomass rabi-crops where sky is overcast during winters. This data demonstrated potential for Agroforestry and plantations applications and will be forwarded with NISAR data for high biomass agroforestry in near future. The utility of these data was demonstrated for field crop monitoring viz. paddy and millets as well as understanding the intricate signature and interaction of the value added satellite products -level 3 and 4 in terms of scattering matrix and components. High-resolution SAR FRS data in this domain particularly the decomposed data with the scattering components- double bounce, volume and surface scattering has immense potential in vegetation monitoring in general and Agriculture in particular. The later is very unique in providing this kind of datasets globally and we believe it will be utilised for numerous user applications in various facets of crop monitoring.

7. Funding: This research did not receive any funding. This was part of regular inhouse activity of the newer modes of EOS-4 data during 2022 and 2023.

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