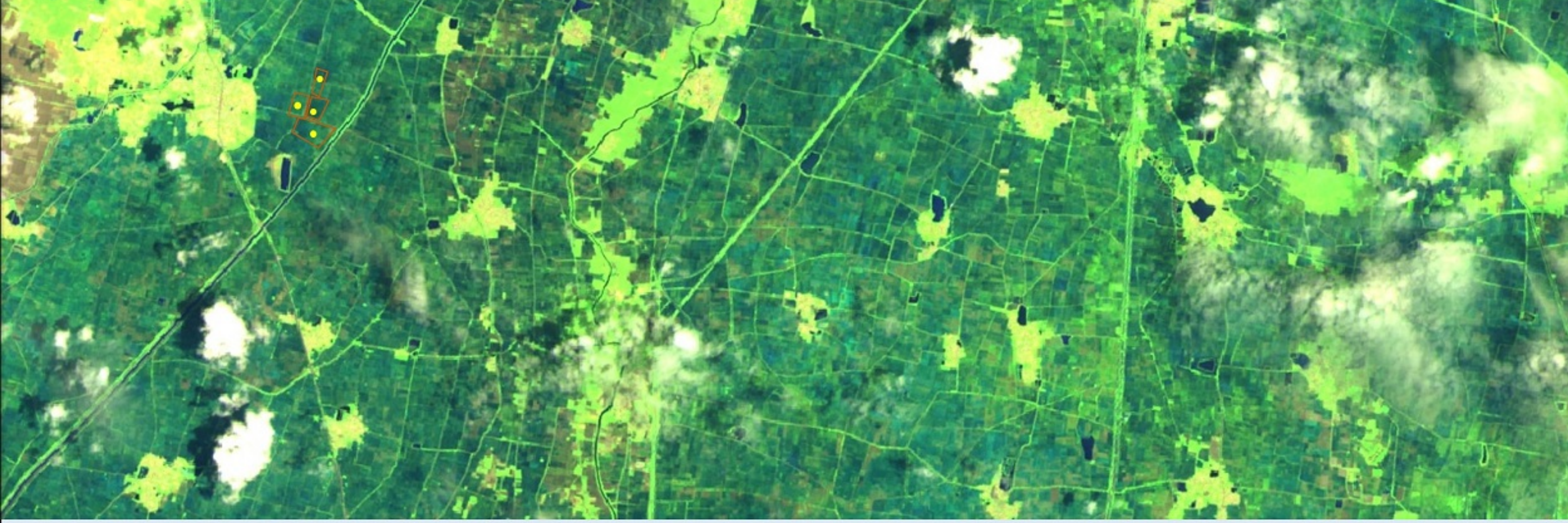
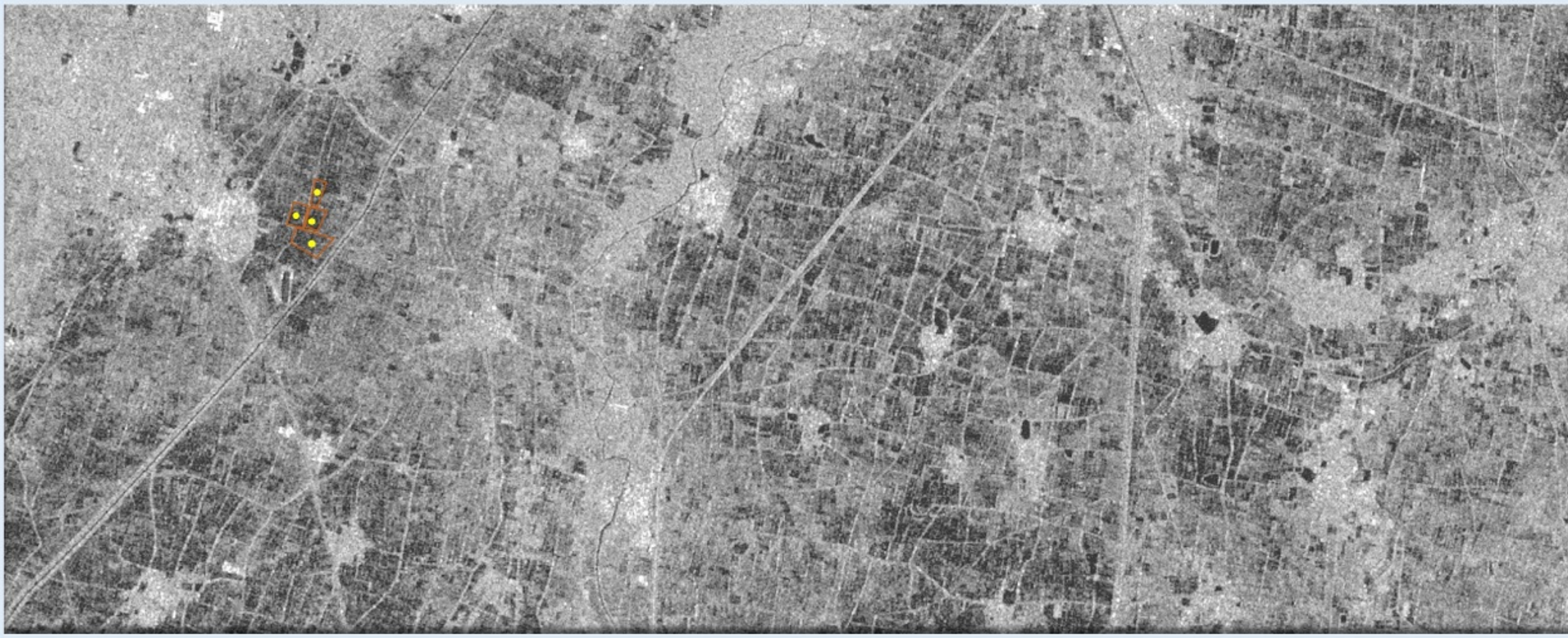


Experimental Field Campaigns at Vijayawada Test Site

Technical Report : MRS2019TR02

D. Mandal, V. Kumar, Y. S. Rao,
A. Bhattacharya, K. V. Ramana



Microwave Remote
Sensing Lab

V1

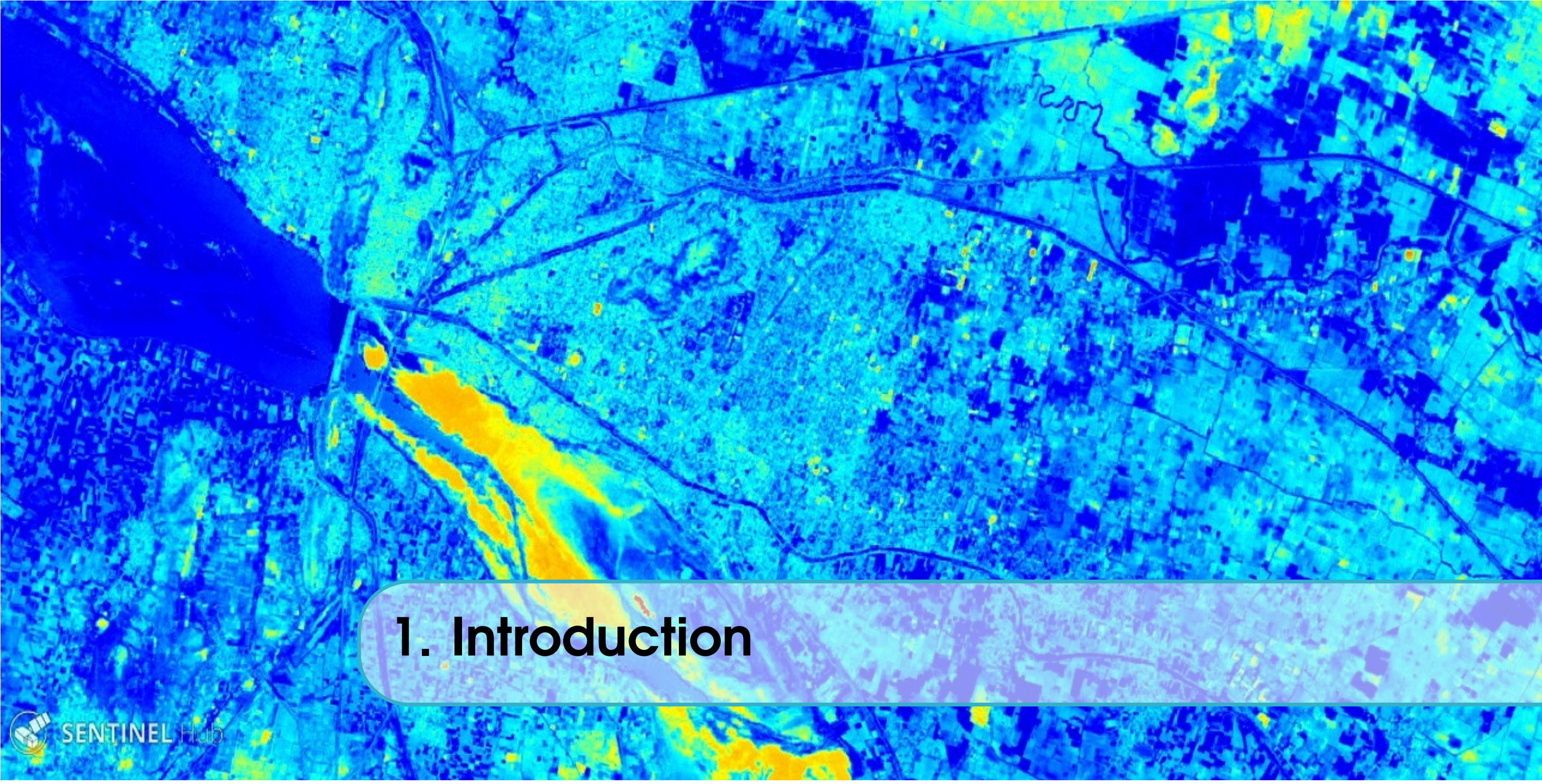
MICROWAVE REMOTE SENSING LAB, CENTRE OF STUDIES IN RESOURCES ENGINEERING, INDIAN INSTITUTE OF TECHNOLOGY BOMBAY, MUMBAI, INDIA 400076

http://mrslab.in/FieldCampaign/TSVIJ

This research was conducted with joint collaboration between MRSLab–IIT Bombay and Andhra Pradesh Space Application Centre (APSAC). The RADARSAT-2 satellite acquisitions were supported by the Canadian Space Agency and MAXAR Technologies Ltd. (formerly MDA) through SOAR-EI-5459 programme and JECAM SAR Inter-comparison Experiment. This research work is funded partly by the Indian Space Research Organisation (ISRO) sponsored project no. 17ISROC007.

First release (V1), March 2019

Contents



1. Introduction

1.1 Motivation

Agricultural resources are important dynamic natural resources and a major contributor to Indian economic growth. Accurate crop condition assessment, acreage estimation and on time yield assessment helps in providing a crucial information about the crops and leads to proper management of agricultural resources. In long term perspective, it is related to national and global food security. With large area synoptic coverage and timely measurements, remote sensing technology is able to fulfill all these requirements for crop related assessments. Remote sensing satellites are regularly used for crop acreage and production estimation, crop health monitoring. Synthetic aperture radar (SAR) capability to penetrate clouds and acquire data in all-weather condition makes it useful for monitoring and inventory purpose in Indian context. SAR signal can penetrate deeper into vegetation and give information about structure of leaves, stems and the background soil moisture content. The variation in SAR signal response due to crop structural properties and canopy moisture content from sowing to senescence stage is suitable for the utilization of microwave remote sensing for the crop type identification, growth monitoring and yield modeling.

1.2 Objective

The major focus of current research is : “Crop characterization using fully polarimetric RADARSAT-2 SAR data". However, with the availability of Sentinel-1 and Sentinel-2 at operation basis, leads towards a multi-sensor approach for crop monitoring. Thus the objectives are as follows:

- Crop classification and monitoring using multi-temporal polarimetric SAR data.
- Phenology estimation of geometrically different crops using polarimetric information content from quad-pol data
- Crop bio-physical parameter retrieval using multi-target inversion scheme from PolSAR data
- Combined analysis of SAR and optical data for plant traits

1.3 Experimental Plan

The proposed work involves acquisition of satellite imageries and in-synchronous crop related field measurements. As per the objectives of the project, analysis will be performed using fully polarimetric descriptors and polarimetric target decompositions. In addition we will try to use optical sensor data products for support.

R RADARSAT-2–C-band SAR Sensor (Quad-pol HH-VV-HV-VH) FQ Mode
Sentinel-1 C-bnad SAR Sensor (Dual-pol VV-VH) IW Mode
Sentinel-2 Optical Multi-spectral Sensor

1.4 Collaborative Network

Field experiment involved in several researchers from 02 different institutes of India, with around 8 people participating during the intensive measurements periods of the campaign. On the other hand, satellite datasets are acquired by the Canadian Space Agency (CSA) and European Space Agency (ESA) through Science and Operational Applications Research - Education International (SOAR-EI) Initiative programme[1], Joint Experiment for Crop Assessment and Monitoring (JECAM) SAR Inter-comparison Experiment programme[2] and Copernicus programme[3], respectively.

1.4.1 Ground Team

Microwave Remote Sensing Lab, Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, Mumbai, 400076 INDIA–

- Mr. Dipankar Mandal, Doctoral Student, Email: dipankar_mandal@iitb.ac.in
- Mr. Vineet Kumar, Doctoral Student, Email: vineetk008@iitb.ac.in
- Mr. Subhadip Dey, Doctoral Student, Email: subhadipdey23071994@gmail.com
- Dr. Avik Bhattacharya, Associate Professor, Email: avikb@csre.iitb.ac.in
- Dr. Y. S. Rao, Professor, Email: ysrao@csre.iitb.ac.in

A P Space Applications Centre, ITE & C Dept.-Govt of AP Vijayawada, Andhra Pradesh, 520010 INDIA–

- Dr K V Ramana, Vice Chairman and Scientist-G, Email: mknandabckv@rediffmail.com
- Mr. Appala Naidu, Supporting staff

[1] SOAR-EI: http://www.asc-csa.gc.ca/eng/funding-programs/funding-opportunities/ao/2017-soar-ei.asp
[2] JECAM: http://jecam.org/?/jecam-blog/sar-inter-comparison-experiment
[3] Copernicus policy: https://sentinel.esa.int/web/sentinel/sentinel-data-access

2. Discovering Test Site

2.1 Test Area

The Vijayawada test site is located in Krishna and Guntur district of Andhra Pradesh state, south-east part of India, has wide variety of land cover and agriculture crops as shown in Figure 2.1. It is situated adjacent to Krishna River. This area is irrigated with both river and bore well water. The scene centre is around 16°24'6.23" N and 80°41'2.41"E.

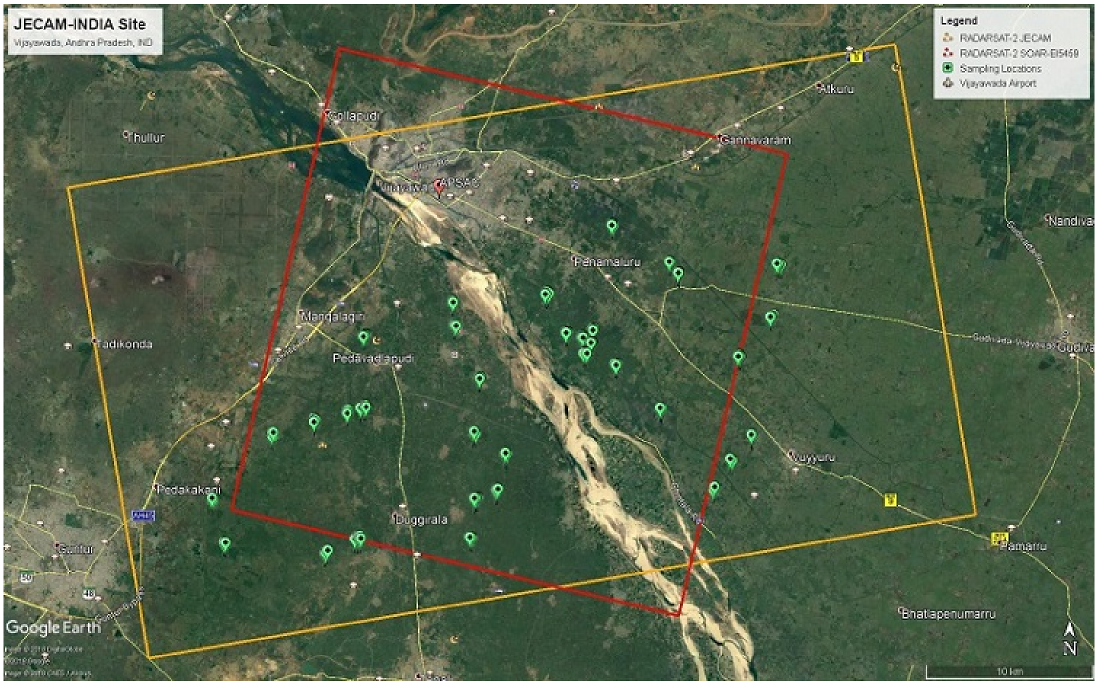


Figure 2.1: Test site location with sampling points and RADARSAT-2 pass (yellow and brown polygon) in Vijayawada, AP.

The test area belongs to AZ120-Krishna Godavari Zone in terms of Agro-Climatic Zone (NARP), thus falls under sub-humid to humid eco-region. The test site covers an area of $25 \times 25\ km^2$ and is characterized by major annual crops viz. rice, sugarcane, cotton. The secondary crops covered in the study area are turmeric, chilli, banana, pulses (green gram and black gram) and various vegetables [1, 2, 3].

The major crops are grown in two distinct seasons, monsoon or *kharif* (June-November) and winter or *rabi* (December-March). However, the present research is concentrated on the *kharif* season crop rice (*Oryza sativa*) and sugarcane (*Saccharum officinarum*).

2.2 Soil Texture

The predominant soils in test site are loamy to clayey Skeltal deep redish brown soils, deep Black clayey soil, Clayey to Gravelly clayey moderately deep dark brown soils (Fig. 2.2).

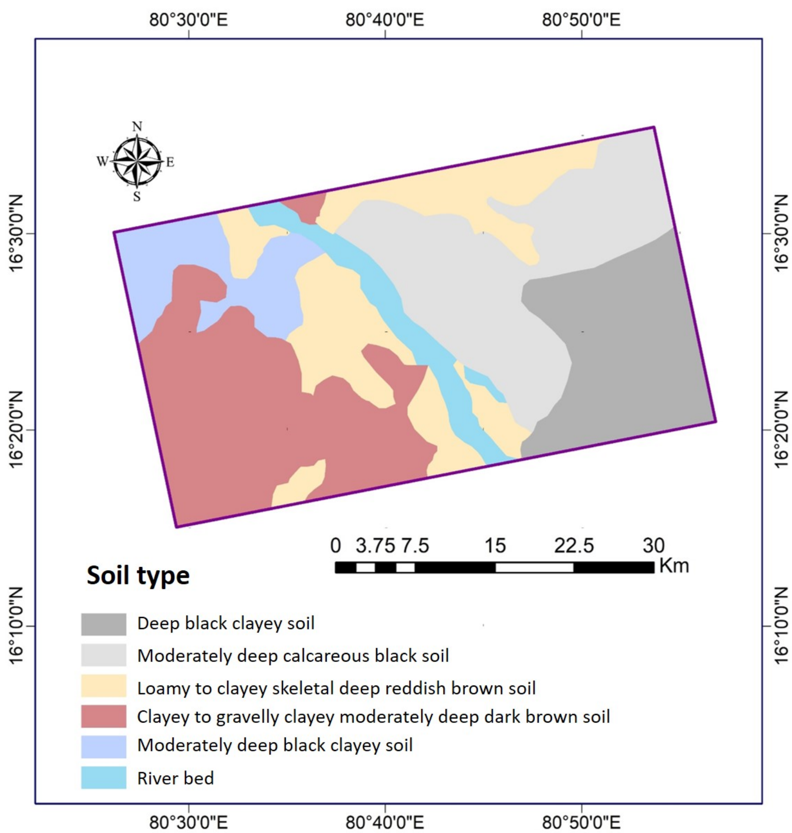


Figure 2.2: Soil texture variations over the test site.

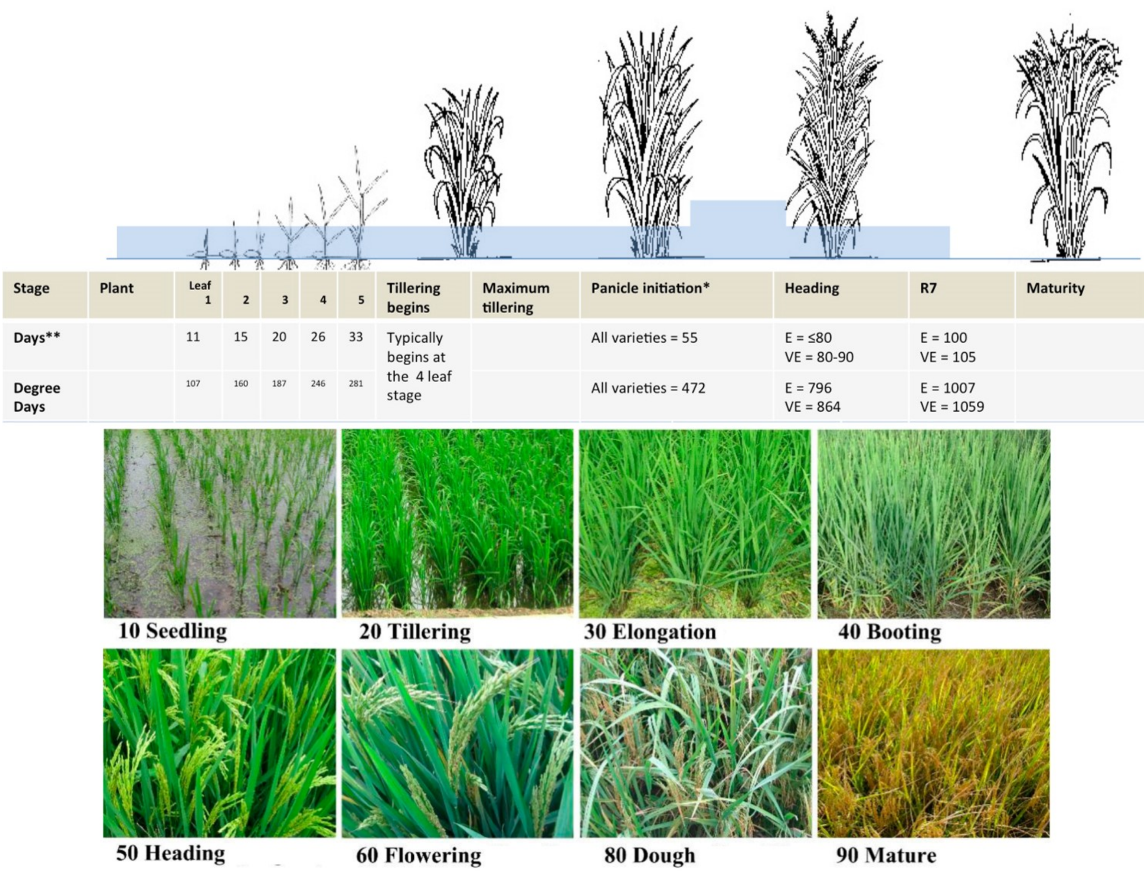
For the test area, the soil data is available from the technical report by the APSAC[1]. This database was published at a scale of 1:50000.

[1]District Survey Report-2018:https://www.mines.ap.gov.in/miningportal/downloads/applications/krishna.pdf

2.3 Crop cultivation practices

2.3.1 Rice (Oriza sativa)

In this region, rice is cultivated on irrigated or rainfed lowland conditions with transplanted rice or direct seeded rice. Hence, a spatial variability was observed within the time span for a different agronomic management in this region. Variations in rice cultivation practices depend on accessibility of irrigation water, weather conditions, e.g., effective day length and temperature, and selection of rice cultivars. The total growing period of different rice varieties ranges from 100 to 140 days. Normally, short-duration rice varieties take 100–120 days, medium duration 120–140 days, and long-duration 160 days.



Stage	Plant	Leaf 1	2	3	4	5	Tillering begins	Maximum tillering	Panicle initiation*	Heading	R7	Maturity
Days**		11	15	20	26	33	Typically begins at the 4 leaf stage		All varieties = 55	E = ≤80 VE = 80-90	E = 100 VE = 105	
Degree Days		107	160	187	246	281			All varieties = 472	E = 796 VE = 864	E = 1007 VE = 1059	

Figure 2.3: Rice phenological stages.

During the growing period, the major phenological stages of rice are as follows [4]:

- 1)Vegetative Stage:
- 2) Reproductive stage (panicle initiation to flowering): – a) Vegetative stage seedling (sowing to transplanting); b) Active vegetative stage (transplanting to the maximum tillering stage); c) Vegetative lag phase (maximum tillering to panicle initiation).
- 3) Ripening stage (flowering to harvest).

For transplanted rice case, prior to rice transplantation, the fields are flooded up to 2–15 cm by means of irrigation water. After transplantation, the recommended practice is to keep the water level at about 3 cm and gradually increase it up to 5–10 cm with the increasing plant height up to maturity. However,the soil remains saturated with no standing water during the ripening stage. All phenological stages are shown in Fig. 2.3.

Direct seeded rice:
The direct seeding of rice refers to the spreading of seeds in fields before or immediately after pre-monsoon showers; the method does not require raising of nursery and transplanting of seedlings. The seeds are directly sown in the main field by spreading manually or with the help of a tractor and attached implements at a depth of 3-5 cm. Based on the availability of water fields need to be irrigated 45-60 days after sowing and turned into a wet system.

R There are direct seeded and transplanted rice condition apparently observed in several parts of the test site.

R The varieties found under direct sowing are BPT 2270, BPT 5204 and NLR 523.

2.3.2 Sugarcane

Sugarcane requires about 25-32 C temperature for germination. This temperature requirement is met twice in Indian conditions, i.e., in October and February-March. Spring cane is planted in the month of February-March (especially Eksali planting is common in Andhra Pradesh). The crop is planted during January-February and harvested after one year.[2] The phenological growth stages are shown in Fig. 2.4.

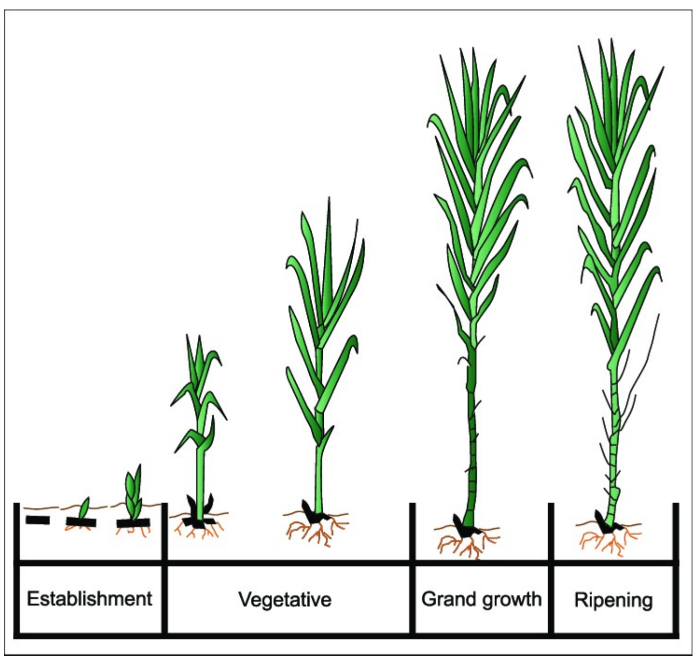


Figure 2.4: Sugarcane phenological stages.

Planting technique and cultivation practices
Amongst the various methods of plantation, trench method is usually adopted in the test site region,

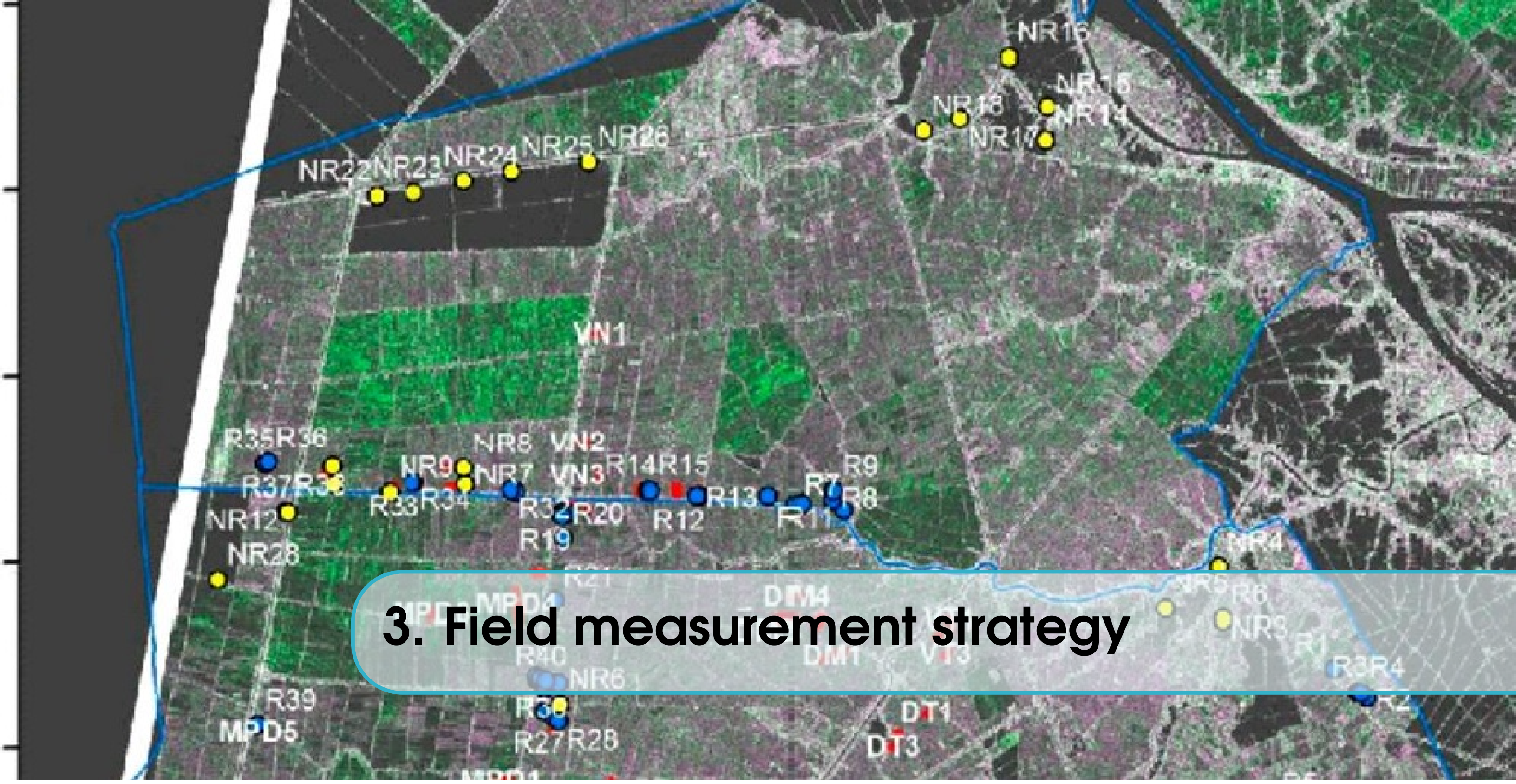
[2] IISR:http://www.iisr.nic.in/aicrp/download/Sugarcane_in_India.pdf

where the crop grows very tall and the strong winds during rainy season cause lodging of cane. Trenches are dug at a distance of 90-120 cm, with the help of ridger or by manual labour. The setts (small pices of sugarcane stem with budding nodes) are planted end to end in trenches. Double row planting is often adopted in this case. The trenches are filled up with loosened soil after planting.

Sugarcane is a long duration and irrigated crop. In tropical area like Andhra Pradesh, irrigations are to be given once in 7 days during germination phase (1 –35 days after planting), once in 10 days during tillering phase (36 – 100 days after planting), again once in 7 days during grand growth phase (101-270 days after planting) and once in 15 days during maturity phase (271 days after planting up to harvest) adjusting it to the rain fall pattern of the area.

Amongst the several inter-cultural operation, Tying and Wrapping are most essential in sugarcane cultivation just to provide mechanical support to the grown up plants to prevent lodging. Plants in adjacent rows are tied together (cross-wise). Tying should be done in the month of August when cane reaches about 2 m height.

Sugarcane crop matures within 10-12 months depending upon the season of the crop.The crop should be harvested when sucrose contents value reaches to minimum 16.5%. Usually this stage arrives during December-January when temperature is about or below 20°C. Under high temperature conditions, the sucrose gets converted into glucose resulting in poor quality of produce [5].



3. Field measurement strategy

3.1 Sampling locations

In-situ measurements were collected intensively from June 2018 to December 2018 with several field campaigns. During the campaign, $\sim$150 fields were selected for sampling. The nominal size of each field was $\sim$60 m$\times$60 m. Hand-held Trimble GPS instruments was used for finding the accurate location of ground truth points. Clustered sampling was used to collect the measurements from field as shown in Fig. 3.1. The sampling strategy planned by considering the JECAM SAR-Inter Comparison Experiment [6] and the Soil Moisture Active Passive Validation Experiment 2016 (SMAPVEX16-MB) [7, 8] protocols.

At each location, 5-6 fields were selected. In each field, sampling were done from two points. Vegetation and soil moisture were collected as following methods.

3.2 Soil moisture measurement

Surface soil moisture measurements will be acquired over selected agricultural fields coincident in time to flight overpasses. The hand held Delta Theta Probe will be used to measure soil moisture at near surface depths (5cm) at 2 locations in each field.

At each sample location, a total of 3 readings will be taken with the 1st reading at the top of a ridge, the 2nd reading in the middle of a ridge and the 3rd reading at the bottom of the depression between ridges (for sugarcane). For rice, as there are no discernible ridges, all three readings will be taken. Always insert the probe perpendicular to the soil surface as shown in the Fig. 3.2.

R Each sample location will avoid large cracks, dry clods or areas that have been heavily compacted by tractor wheels or foot traffic. Samplers must take care not to push the moisture probe in too far and cause compaction, especially if the soil is loose.

3.3 Vegetation sampling

The following vegetation properties will be measured for each sampling point (2 sampling point).

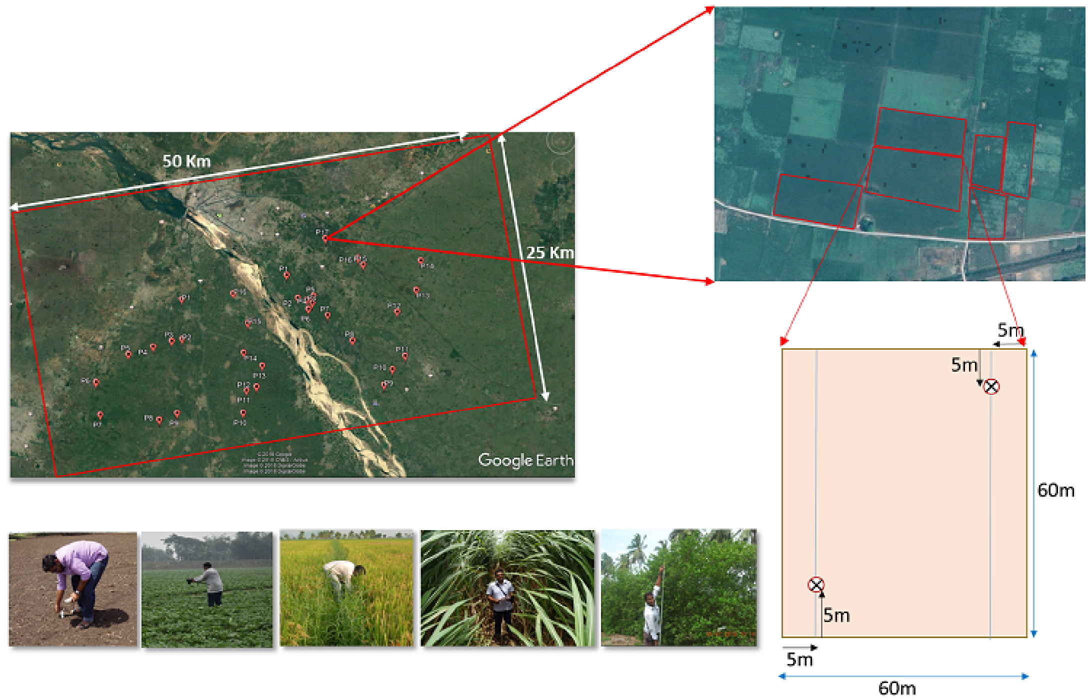


Figure 3.1: Test site with sampling locations.The brown box defines the RADARSAT-2 coverage.

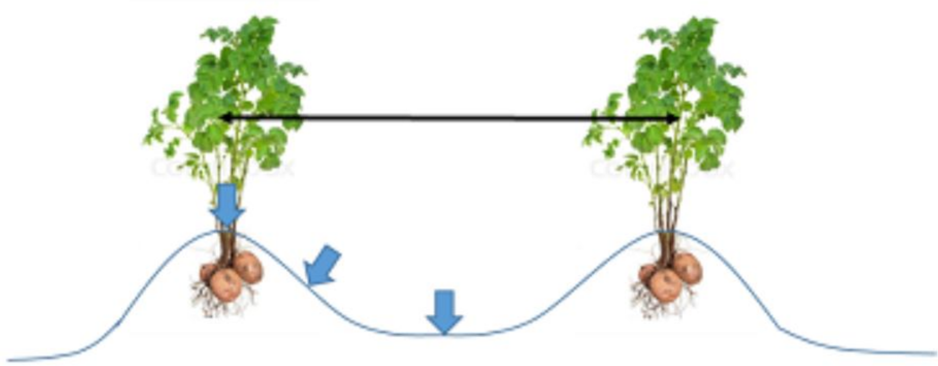


Figure 3.2: Probe locations in ridge-furrow system.

- VG1: Plant count
- VG2: Row spacing
- VG3: Plant Area Index (PAI)/LAI
- VG4: Plant height
- VG5: Phenology
- VG6: Leaf geometry (leaf inclination angle distribution, leaf geometry, leaf width, leaf

thickness, leaf density, leaf layer height), stem parameters (stem geometry, stem length, stem radius, stem density, stem layer height) and ear parameters (ear/head geometry, ear length, ear radius, ear density, ear layer height). (Intensive campaigns)

3.3.1 VG1: Plant count

The density of plants will be determined by counting the number of emergent plants in a row along a fixed distance of 1 meter. This will be replicated for a total of 5 counts per sampling point by moving perpendicular to the rows. Counts will be recorded on data sheets and used with row spacing to calculate plant density.

3.3.2 VG2: Row spacing

Row spacing will be determined by measuring the distance between rows at each location where the plant counts are made. At each location, after the plant counts are made, the meter stick will be turned perpendicular to the row direction. At the soil level, the total distance will be measured between the centers of the two plant rows immediately adjacent on either side of the row on which the plants were counted. Row spacing will be recorded on data sheets. Plant density (PD) will be calculated as

Plant Density PD = Average number of plants in 1m/ Average row width in 1m.

3.3.3 VG3: Plant Area Index & fCover

Plant area index (PAI) can be measured using digital hemispherical photographs. With this technique a wide-angle or fisheye lens captures all sky directions at the same time. When canopies are small, the photos are taken with the lens pointed towards the ground. For tall canopies (e.g., sugarcane), the camera is placed on the ground looking skyward. The fisheye photos record the geometry of the plant canopy obstructing the field of view of the soil or sky.

An advantage of this method relative to other in situ approaches (such as the LAI2000) is that the data capture is much less sensitive to sky conditions. Plant canopy analyzers such as the LAI2000 require diffuse sky conditions, restricting data capture to early morning or evening collection or collection under consistent overcast conditions. As well, high errors will occur when attempting to capture the LAI of very short vegetation (or early emerging vegetation) as the distance from the lens to the canopy is too small.

PAI will be captured using hemispherical digital photos. Five photos will be taken along two transects (10 photos in total) at each of the sampling sites (Fig. 3.3). These photos will be post processed using the Caneye software to provide an estimate of PAI. In the case of row crops, photos will be taken in the middle of the crop row.

- Take the first photo at sampling location (5m-5m edge).
- Take photos 2-5 at 2 meter increments along first transect.
- Cross over to second row, and take photos 6-10 at 2 meter increments along this second transect.
- When walking back on this second transect, be sure to offset the location of photos as shown in Figure.
- Record the photo numbers on the data sheet.

R When taking the photo, the operator should always face the sun.

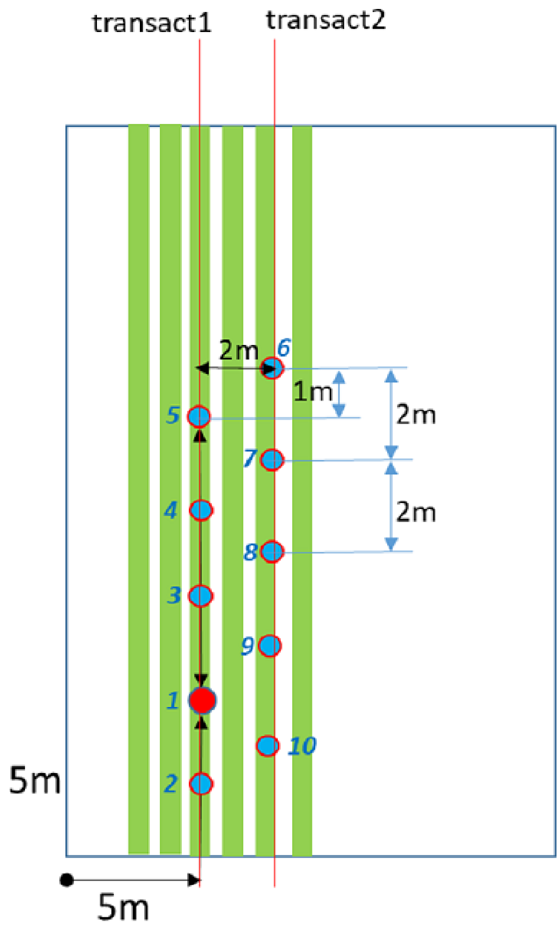


Figure 3.3: PAI sampling strategy.

3.3.4 VG4: Plant height

Crop height can vary significantly and increasing the number of measurements will help to improve the accuracy of the average crop height. In total, 10 heights will be measured, 5 in each of two rows. For narrow-row crops such as rice, the height will be measured to the top of the upper most part of the canopy, whether leaf or fruit. Leaves are to be left in their natural orientation, and not extended, for this measurement. Heights can be measured before or after biomass sampling (whatever is easiest) and recorded on data sheets.

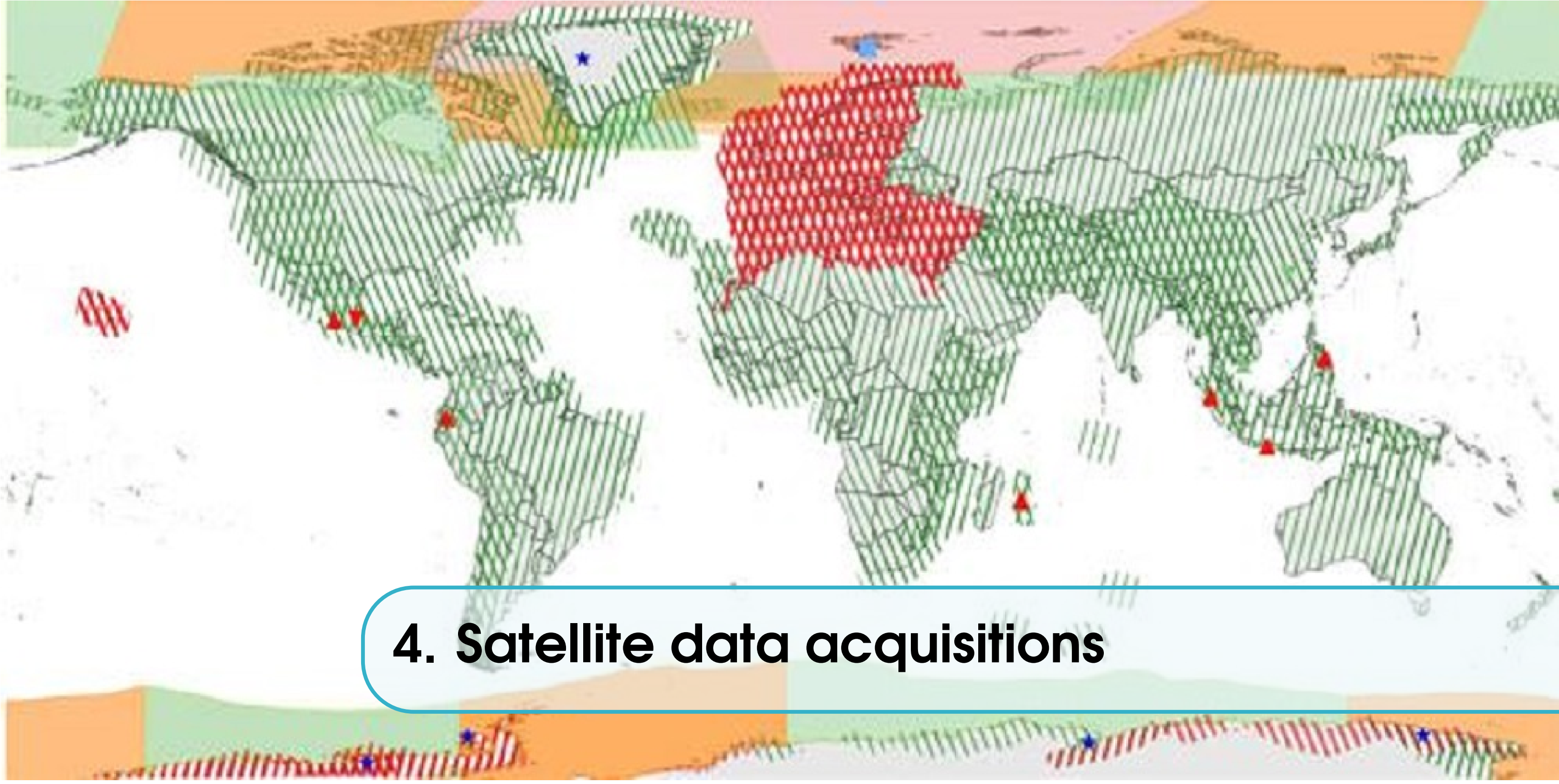
3.3.5 VG5: Plant phenology

The BBCH[1] scale will be used for phenology determination in each sampling location.

[1]Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie–`https://www.politicheagricole.it/flex/AppData/WebLive/Agrometeo/MIEPFY800/BBCHengl2001.pdf`

3.4 Campaign Schedule

The collection of satellite data and in-situ data took place over a whole vegetation period, starting in early June, where still some fields have been bare and ending in December with the end of the harvesting. The RADARSAT-2 data collection has been done in coordination with the in-situ measurements campaign.



4. Satellite data acquisitions

4.1 Intensive field campaign period

Table 4.1: Intensive field campaign period.

IOP	Period	Participants	Comment/Data
Campaign1	09/06/2018–10/06/2018	IITBombay & APSAC	YES
Campaign2	04/07/2018–06/07/2018	IITBombay & APSAC	YES
Campaign3	01/08/2018–03/08/2018	IITBombay & APSAC	YES
Campaign4	21/08/2018–23/08/2018	IITBombay & APSAC	YES
Campaign5	14/09/2018–15/09/2018	APSAC	YES
Campaign6	08/10/2018–09/10/2018	APSAC	YES
Campaign7	02/11/2018–03/11/2018	APSAC	YES
Campaign8	25/11/2018–26/11/2018	IITBombay & APSAC	YES
Campaign9	19/12/2018–20/12/2018	IITBombay & APSAC	YES

4.2 RADARSAT-2 overpasses/acquisition plan

4.3 SENTINEL-1 overpasses/acquisition plan

Refer Table 4.3

Table 4.2: RADARSAT-2 overpasses/acquisition plan.

Date of Acquisition	Orbit	Beam Mode	Availability
11/06/2018	Ascending	FQ15W	JECAM
04/07/2018	Descending	FQ13	SOAR-EI
05/07/2018	Ascending	FQ15W	JECAM
28/07/2018	Descending	FQ13	SOAR-EI
29/07/2018	Ascending	FQ15W	JECAM
22/08/2018	Descending	FQ13	SOAR-EI
23/08/2018	Ascending	FQ15W	JECAM
14/09/2018	Descending	FQ13	SOAR-EI
15/09/2018	Ascending	FQ15W	JECAM
15/10/2018	Descending	FQ15	SOAR-EI
09/10/2018	Ascending	FQ15W	JECAM
01/11/2018	Descending	FQ13	SOAR-EI
02/11/2018	Ascending	FQ15W	JECAM
25/11/2018	Descending	FQ13	SOAR-EI
26/11/2018	Ascending	FQ15W	JECAM
19/12/2018	Descending	FQ13	SOAR-EI
20/12/2018	Ascending	FQ15W	JECAM-DECLINED
27/12/2018	Descending	FQ8	SOAR-EI
13/01/2019	Ascending	FQ15W	JECAM

Table 4.3: SENTINEL-1 overpasses/acquisition plan.

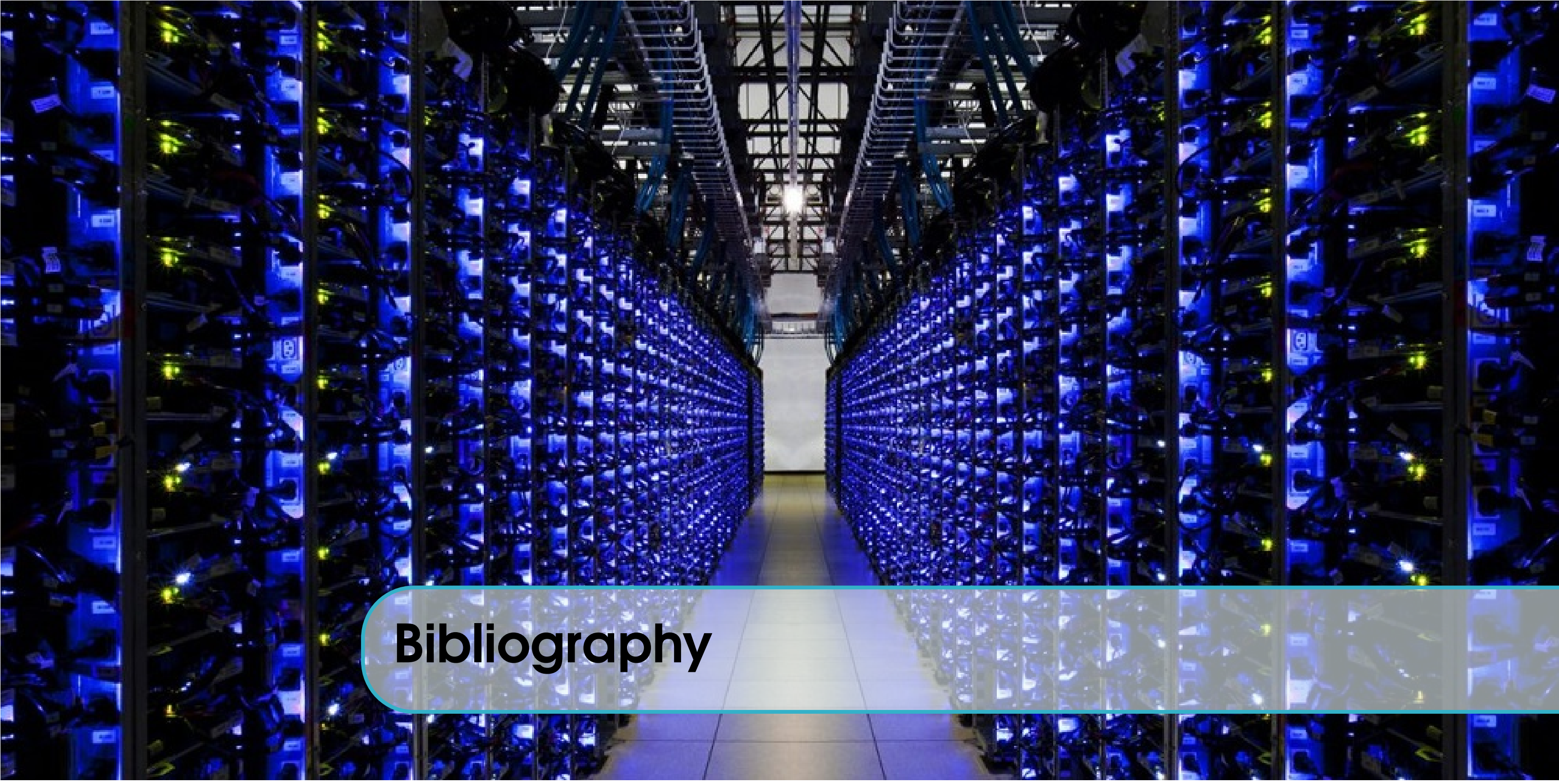
Date of Acquisition	Orbit	Product	Sci-hub availability	GEE availability
05/06/2018	Descending	SLC+GRD	YES	YES
17/06/2018	Descending	SLC+GRD	YES	YES
29/06/2018	Descending	SLC+GRD	YES	YES
11/07/2018	Descending	SLC+GRD	YES	YES
23/07/2018	Descending	SLC+GRD	YES	YES
04/08/2018	Descending	SLC+GRD	YES	YES
16/08/2018	Descending	SLC+GRD	YES	YES
28/08/2018	Descending	SLC+GRD	YES	YES
09/09/2018	Descending	SLC+GRD	YES	YES
21/09/2018	Descending	SLC+GRD	YES	YES
03/10/2018	Descending	SLC+GRD	YES	YES
27/10/2018	Descending	SLC+GRD	YES	YES
08/11/2018	Descending	SLC+GRD	YES	YES
20/11/2018	Descending	SLC+GRD	YES	YES
02/12/2018	Descending	SLC+GRD	YES	YES
14/12/2018	Descending	SLC+GRD	YES	YES

4.4 SENTINEL-2A/B overpasses/acquisition plan

Refer Table 4.4.

Table 4.4: SENTINEL-2A/B overpasses/acquisition plan.

Date of Acquisition	Platform	Cloud cover	Sci-hub availability	GEE availability
31/05/2018	S2B	Partly	YES	YES
10/06/2018	S2A	YES	YES	YES
15/06/2018	S2B	NO	YES	YES
20/06/2018	S2A	Partly	YES	YES
25/06/2018	S2B	NO	YES	YES
30/06/2018	S2B	NO	YES	YES
05/07/2018	S2B	YES	YES	YES
10/07/2018	S2B	YES	YES	YES
15/07/2018	S2B	YES	YES	YES
20/07/2018	S2B	YES	YES	YES
25/07/2018	S2B	YES	YES	YES
30/07/2018	S2B	NO	YES	YES
04/08/2018	S2B	NO	YES	YES
09/08/2018	S2B	YES	YES	YES
14/08/2018	S2B	YES	YES	YES
19/08/2018	S2B	YES	YES	YES
24/08/2018	S2B	YES	YES	YES
29/08/2018	S2B	YES	YES	YES
03/09/2018	S2B	YES	YES	YES
08/09/2018	S2B	Partly	YES	YES
13/09/2018	S2B	YES	YES	YES
18/09/2018	S2B	YES	YES	YES
28/09/2018	S2B	YES	YES	YES
03/10/2018	S2B	YES	YES	YES
08/10/2018	S2B	NO	YES	YES
18/10/2018	S2B	YES	YES	YES
23/10/2018	S2B	NO	YES	YES
28/10/2018	S2B	NO	YES	YES
02/11/2018	S2B	YES	YES	YES
07/11/2018	S2B	Partly	YES	YES
12/11/2018	S2B	YES	YES	YES
17/11/2018	S2B	YES	YES	YES
22/11/2018	S2B	YES	YES	YES
27/11/2018	S2B	NO	YES	YES
02/12/2018	S2B	Partly	YES	YES
07/12/2018	S2B	YES	YES	YES
12/12/2018	S2B	YES	YES	YES
17/12/2018	S2B	NO	YES	YES



Bibliography

[1] Kumar V, Rao YS. Analysis of full and hybrid polarimetric based descriptors for different land features. In: 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS); 2016. p. 4757–4760.

[2] Kumar V, Rao Y. Comparative analysis of RISAT-1 and simulated RADARSAT-2 hybrid polarimetric SAR data for different land features. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2014;8.

[3] Uppala D, Kothapalli RV, Poloju S, Mullapudi SSVR, Dadhwal VK. Rice crop discrimination using single date RISAT1 hybrid (RH, RV) polarimetric data. Photogrammetric Engineering & Remote Sensing. 2015;81(7):557–563.

[4] Mandal D, Kumar V, Bhattacharya A, Rao YS, Siqueira P, Bera S. Sen4Rice: A Processing Chain for Differentiating Early and Late Transplanted Rice Using Time-Series Sentinel-1 SAR Data With Google Earth Engine. IEEE Geoscience and Remote Sensing Letters. 2018;15:1947–1951.

[5] Shukla S, Sharma L, Awasthi S. Sugarcane in India: Package of Practices for Different Agro-climatic Zones. Indian Instituite of Sugarcane Research, Lucknow, India. 2017;p. 1–64.

[6] GEOGLAM. JECAM SAR-Inter Comparison Experiment; 2017. Available from: `http://jecam.org/?/jecam-blog/sar-inter-comparison-experiment`.

[7] McNairn H, Tom J J, Powers J, Bélair S, Berg A, Bullock P, et al.. Experimental Plan SMAP Validation Experiment 2016 in Manitoba, Canada (SMAPVEX16-MB); 2016. Available from: `https://smap.jpl.nasa.gov/internal_resources/390/`.

[8] Bhuiyan HA, McNairn H, Powers J, Friesen M, Pacheco A, Jackson TJ, et al. Assessing SMAP Soil Moisture Scaling and Retrieval in the Carman (Canada) Study Site. Vadose Zone Journal. 2018;17(1). Doi: `10.2136/vzj2018.07.0132`.