Bharathidasan University

Tiruchirappalli, Tamil Nadu

Programme: M. Tech Geoinformatics

Course: Microwave and Hyperspectral Remote Sensing

Title: Interferometry and polarimetry

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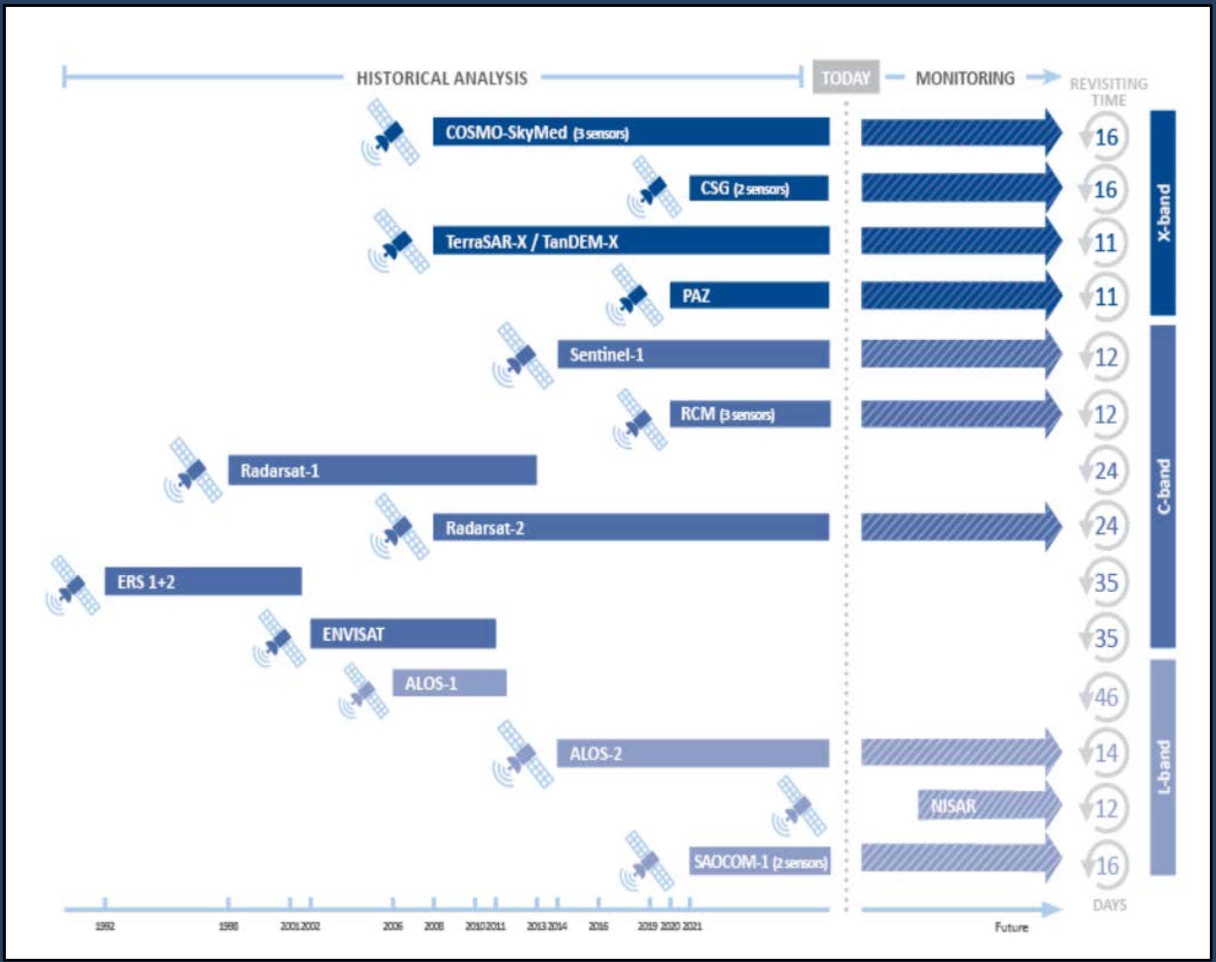
What is InSAR?

InSAR, or Interferometric Synthetic Aperture Radar, is a technique used to measure ground deformation. It combines multiple radar images of the same area to detect changes that have occurred between image acquisitions.

Introduction

- Synthetic Aperture Radar (SAR) Interferometry, also called as Interferometric SAR (InSAR), is a technique of producing digital elevation modes (DEMs).
- The technique provides a higher order of accuracy than the conventional stereo radargrammety.
- By processing SAR datasets, the evolution of surface deformation can be extracted as being useful for many applications.

SAR Satellites

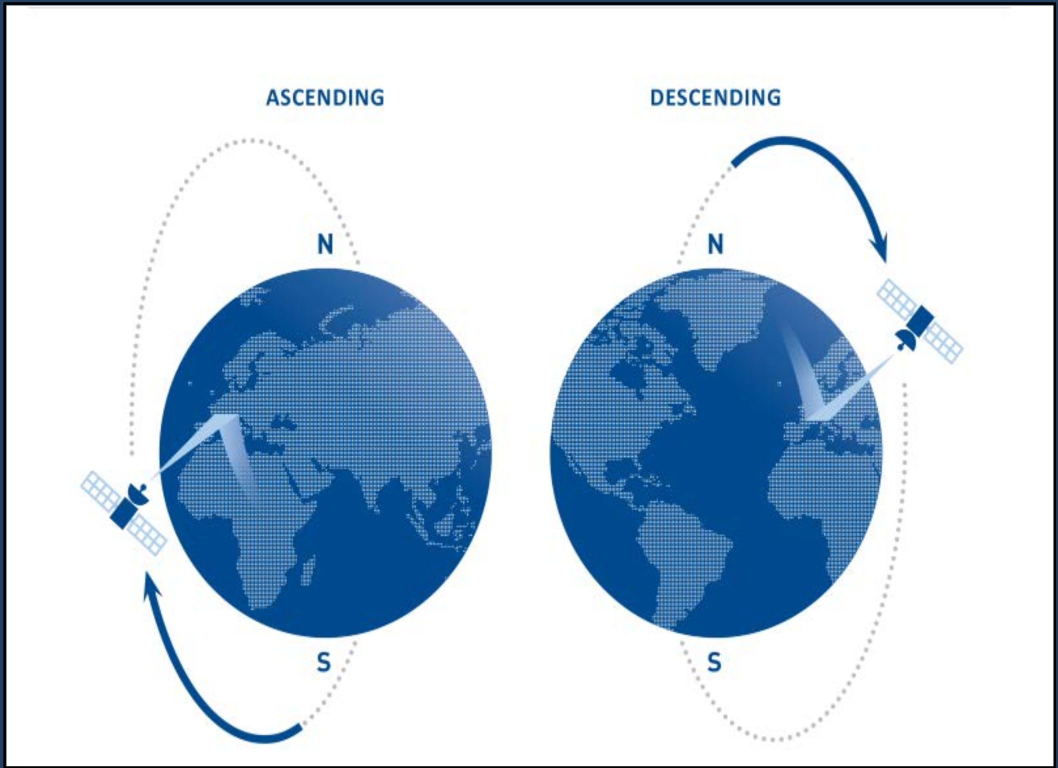


Orbit – Near-Polar orbit

Altitude – 500 to 800 km

The time taken for a satellite to re-pass over the same area is called the ‘revisiting time’

Ascending and descending orbits



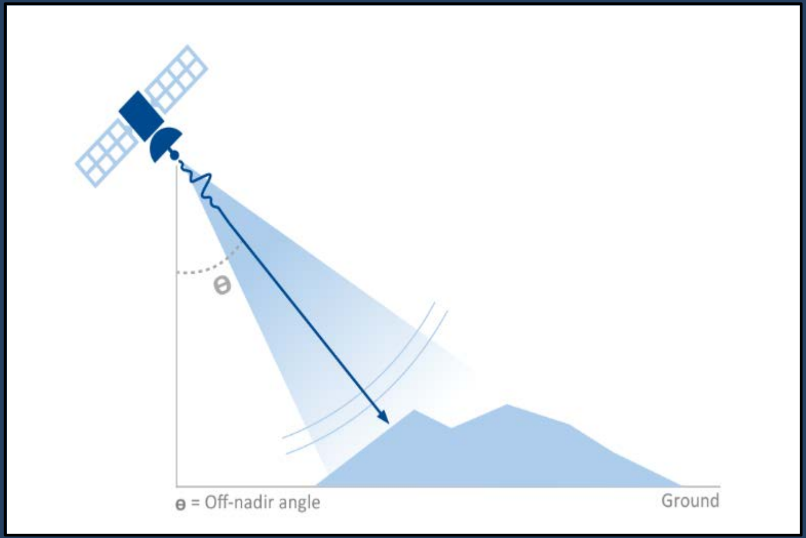
All SAR satellites travel from north pole
Towards the south pole for half of their
Trajectory. This direction is referred to as
Their descending orbit. Conversely, when
Satellites travel from the south towards the
North pols, it is said to be in an ascending
Orbit.

SAR image acquisition

A Satellite continuously emits millions of radar Signals toward the Earth's surface along the radar Beam’s line of sight (LOS)

The angle at which the sensor is pointed toward the Earth’s surface is referred to as the off-nadir angle.

The Off-nadir angle ranges from values of 20 to 50º

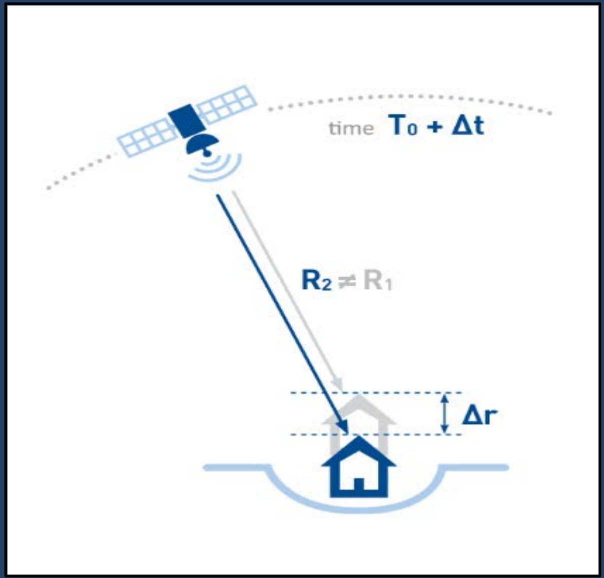


Interferometric synthetic aperture radar

Interferometric Synthetic Aperture Radar (InSAR), or SAR Interferometry, Is the measurement of signal phase change between two images acquired Over the same area, at different time.

When a point on the ground moves, the distance between the sensor and the Point changes and so the phase value recorded by the sensor will be Affected too.

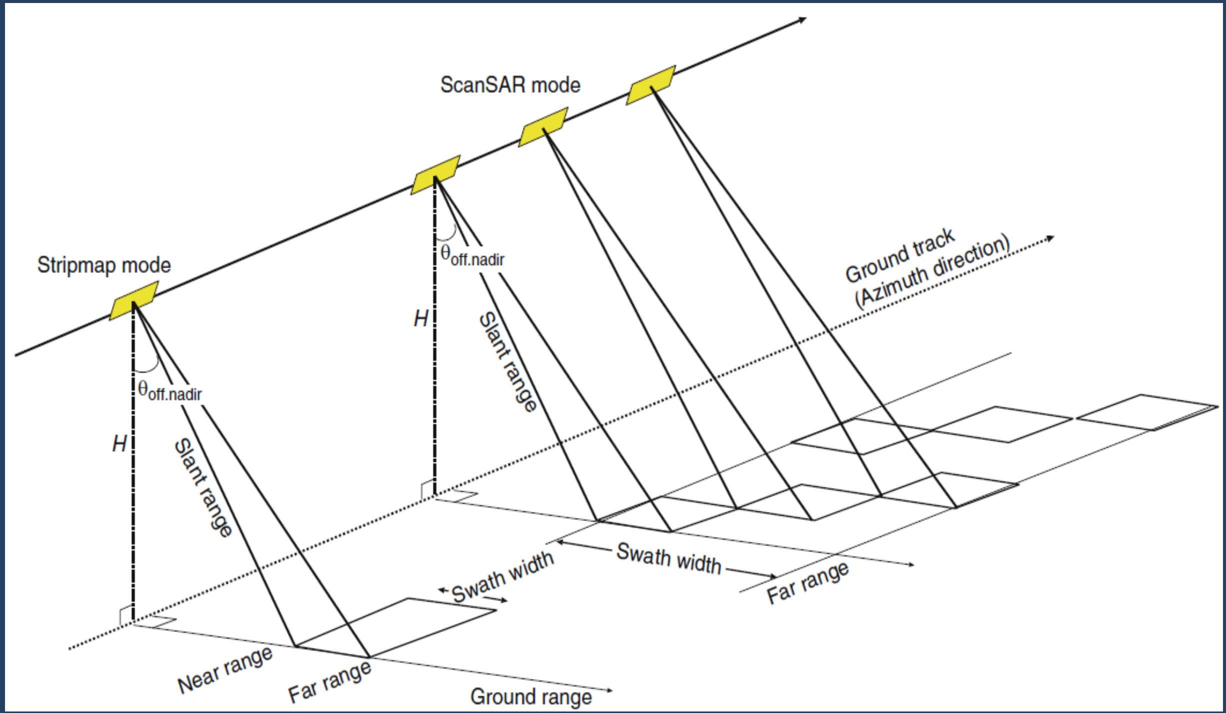
$$\Delta\varphi = \frac{4\pi}{\lambda}\Delta R + \alpha$$



Where λ is the wavelength, ΔR is the displacement in the line of sight(LOS) And α is a phase shift due to different atmospheric conditions at the time of the
Two radar acquisitions

Geometry of SAR imaging

1. Strip map Mode
2. Scan SAR Mode



IMPORTANT STEPS IN SAR INTERFEROMETRY PROCEDURE

SELECTION OF DATA SETS

1. Wavelength of the two SAR images – exactly same
2. Spatial baseline component (i.e. the normal baseline distance) – within the limits for a particular application.
3. Temporal baseline – Time difference between the acquisition of two SAR images, should be suitable for interferometry

CO-REGISTRATION OF SAR IMAGES

First a Coarse co-registration is carried out using data from satellite orbits, or using tie points selected in both images, after this, fine co-registration is implemented, for which various statistical methods specific to SAR images have been developed, such as: maximum value of coherence coefficient, cross-correlation of pixel amplitude, and minimization of average fluctuation of phase difference

GENERATION OF AN INTERFEROGRAM

Interferogram is generated by multiplying the complex SAR values of the slave image with the complex conjugate of the corresponding master image.

At this stage, it is necessary to remove the effect of flat topography from the fringe image, this step being called ‘flattening’.

PHASE UNWRAPPING

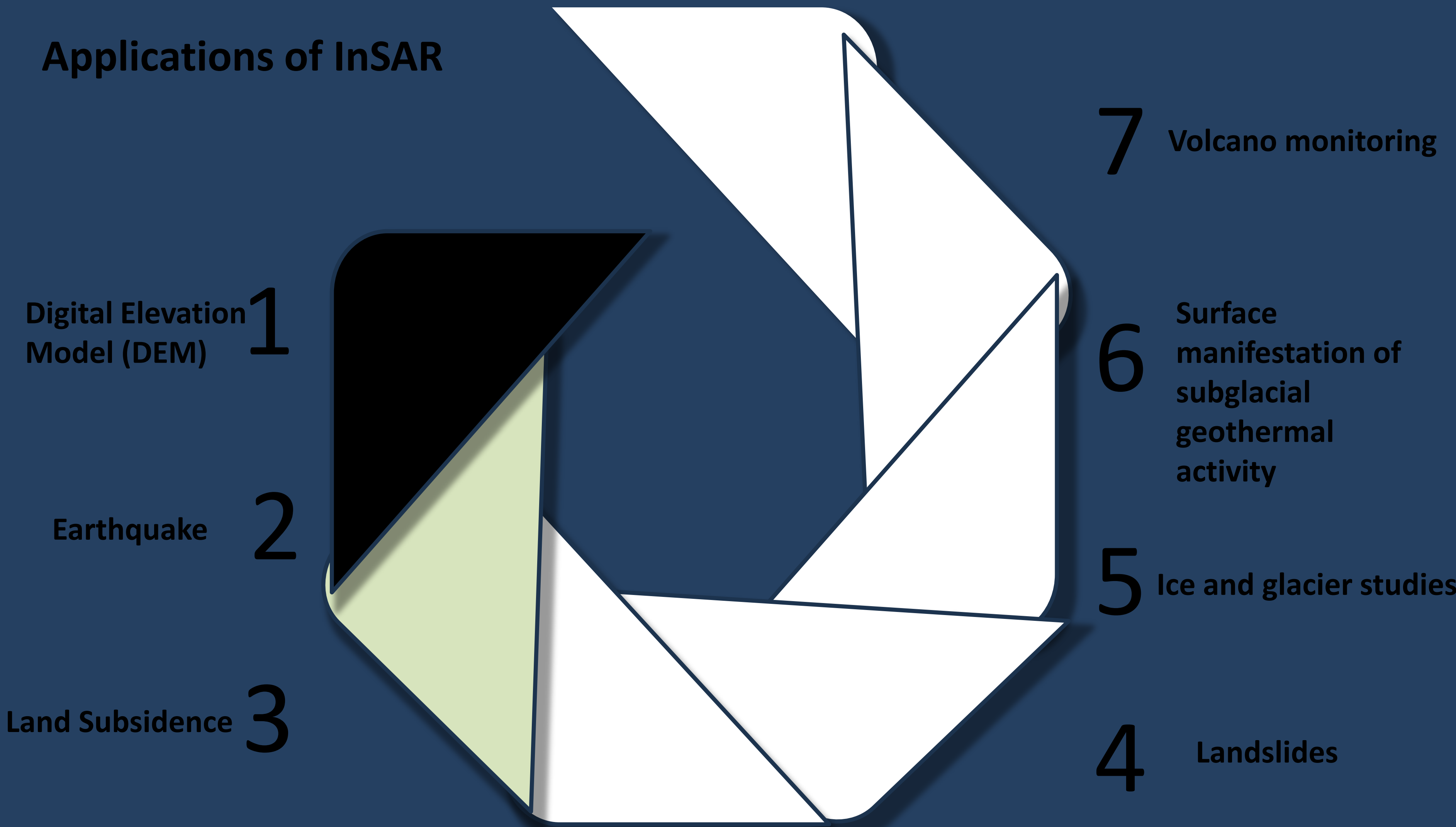
Phase unwrapping is a very important aspect of interferometry and leads to determination of the absolute phase from the measured phase. The phase unwrapping may be considered as adding an integer number of cycles to each pixel to obtain the absolute phase.

The various phase-unwrapping algorithms are 1) path following algorithms use pixel-by-pixel operation to unwrap a phase and bring the phase difference in adjacent pixels to within the range +Π to -Π 2) least-square algorithms minimize a global measure of the differences between the gradients of the wrapped input phase and the unwrapped solution.

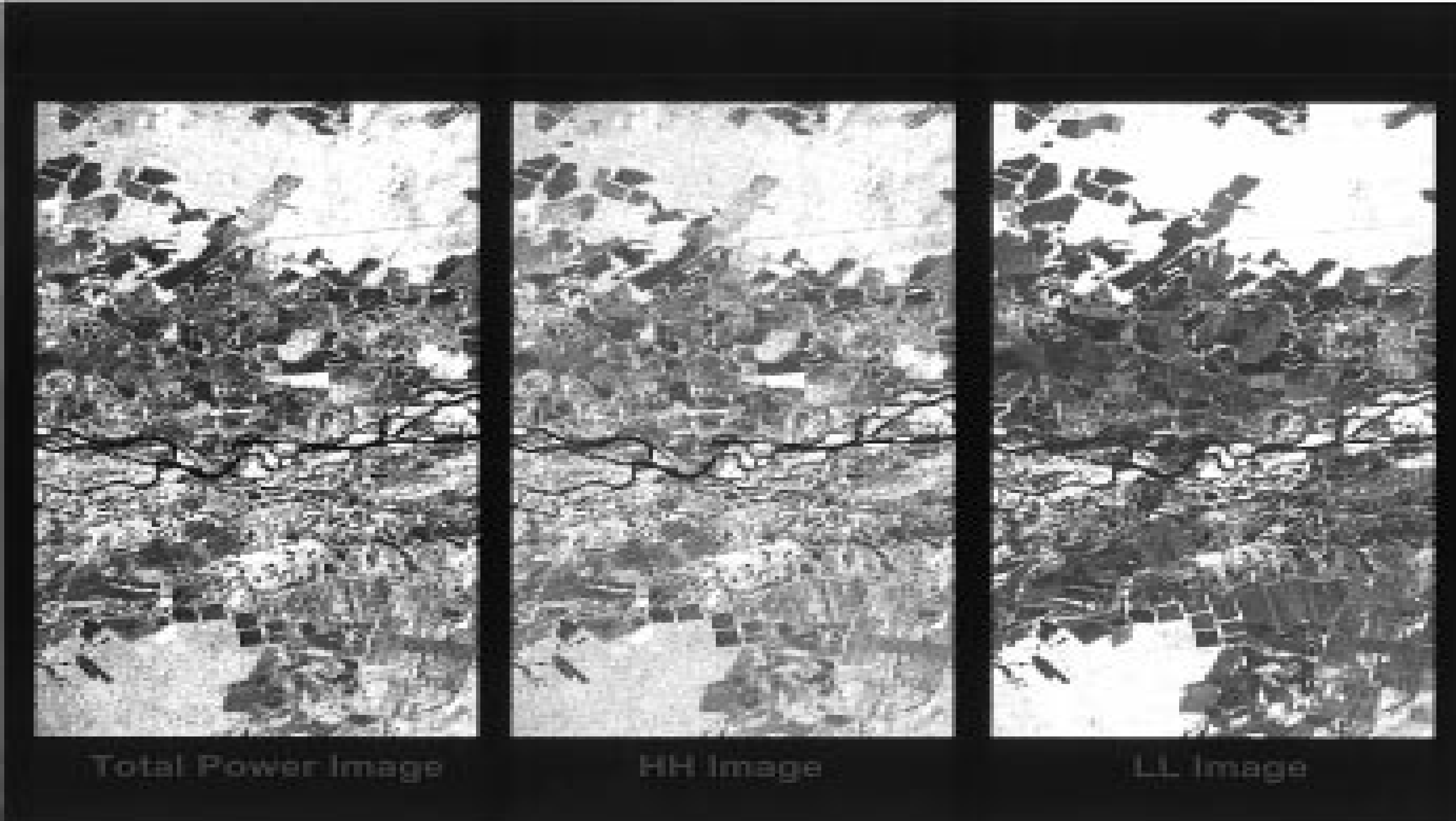
DEM GENERATION

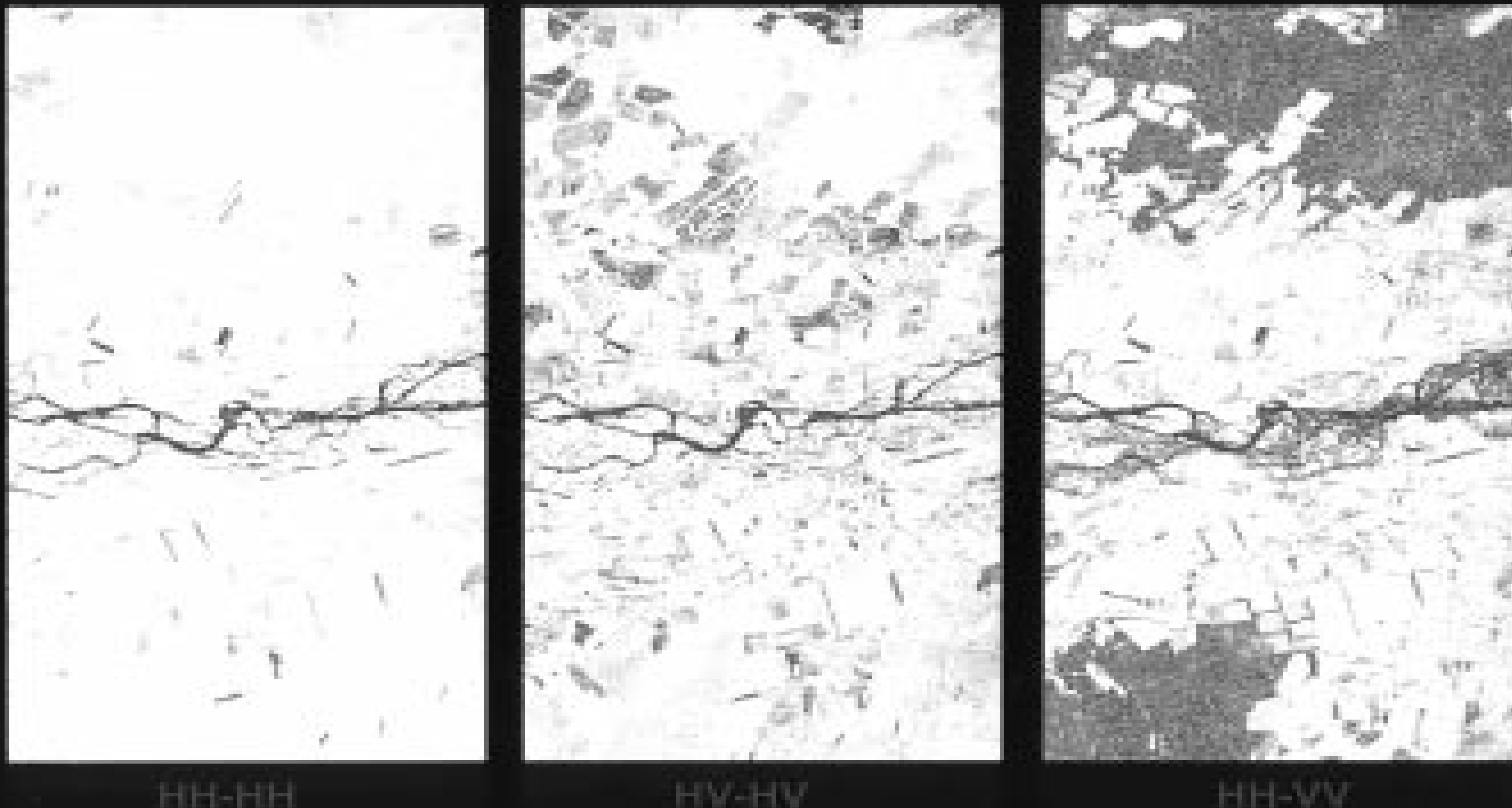
Height values at various points in the terrain are to be derived from the phase values in the interferogram. The interferometric phase image is a representation of the relative terrain elevation with respect to slant-range direction. The correspondence between slant-range and ground-range is quite irregular, as the SAR image carries effects of foreshortening and layover. Further, very accurate estimation of baseline is essential for accurate DEM Generation

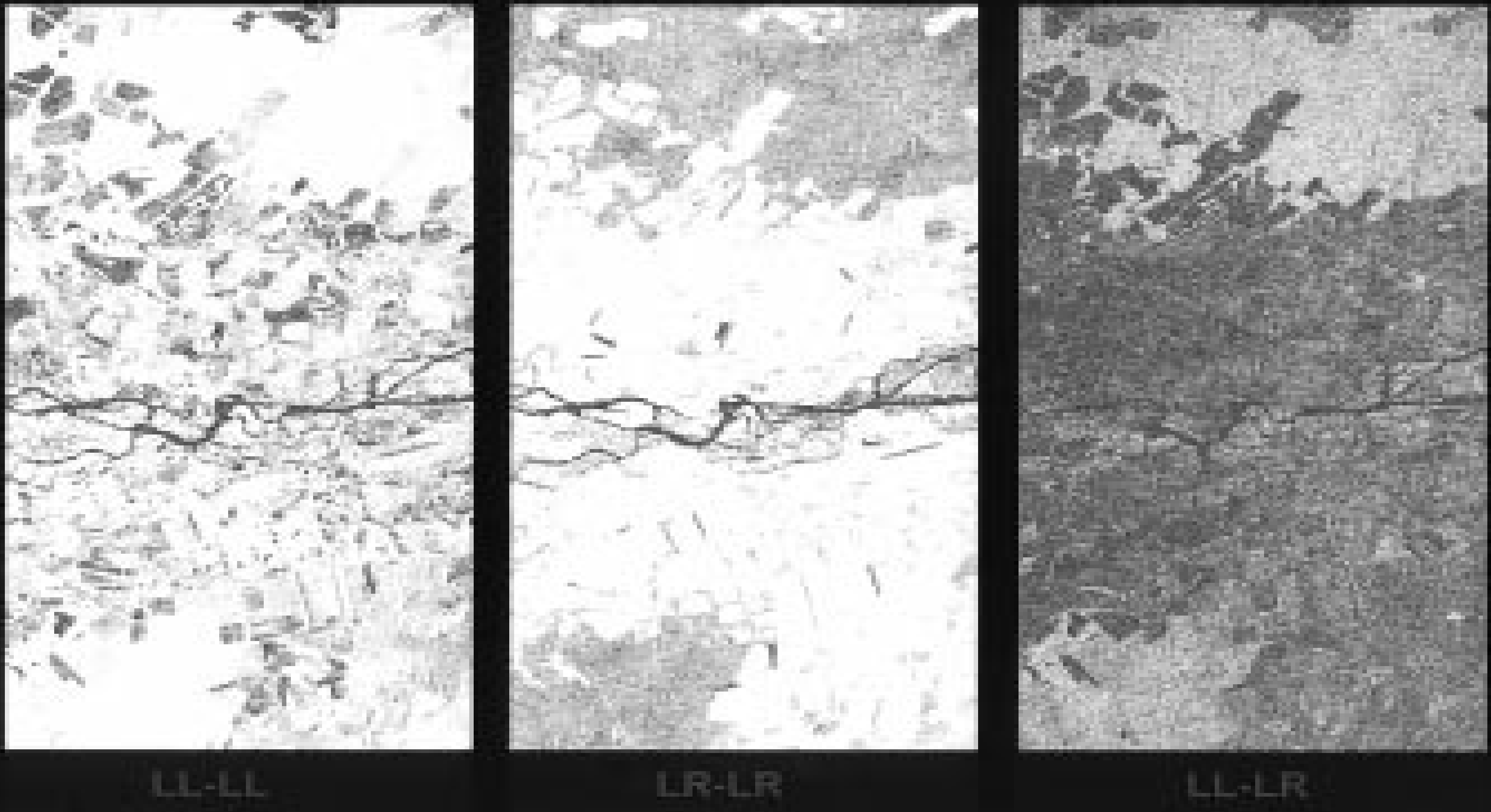
Applications of InSAR

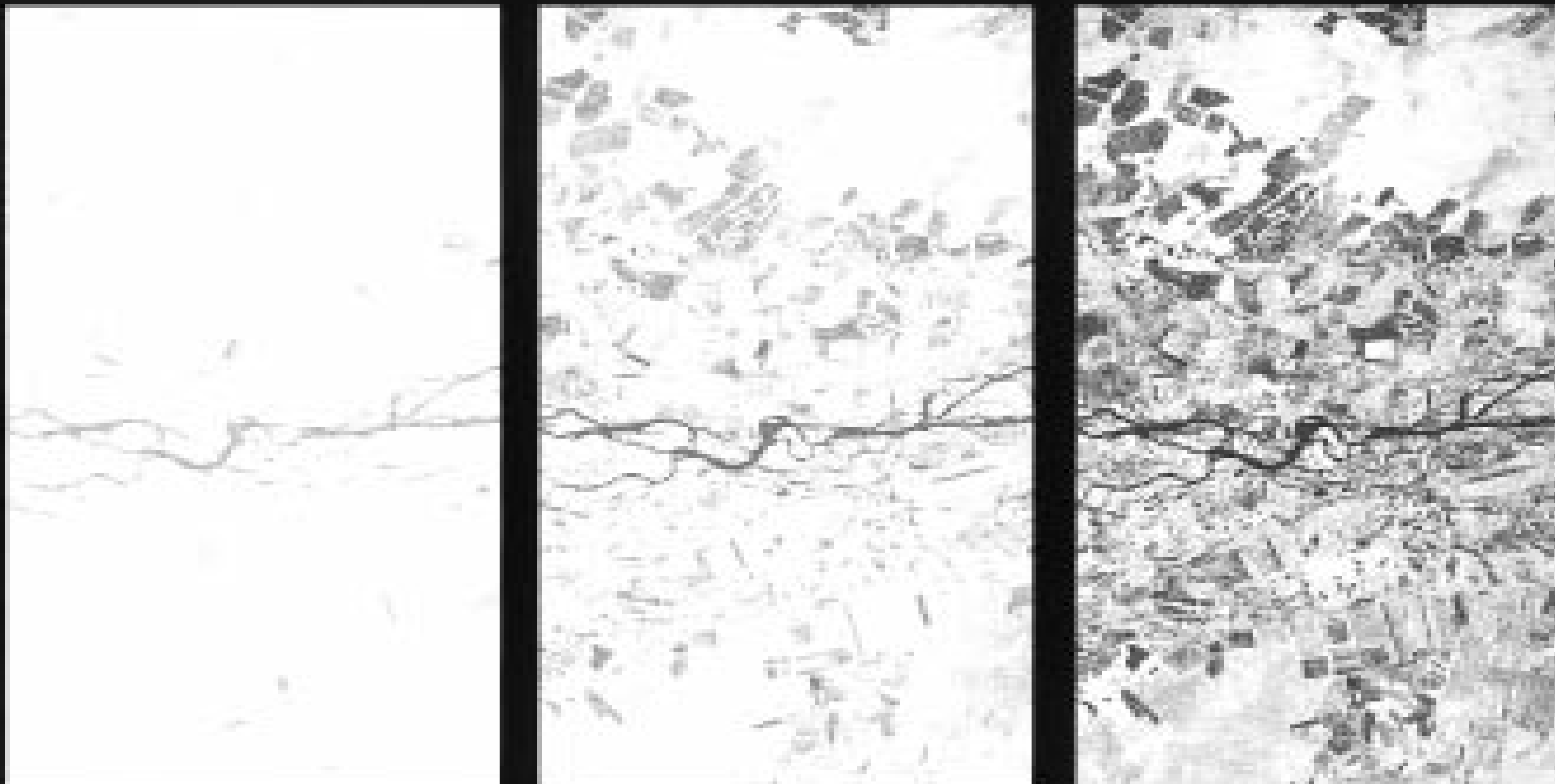


SAR POLARIMETRIC



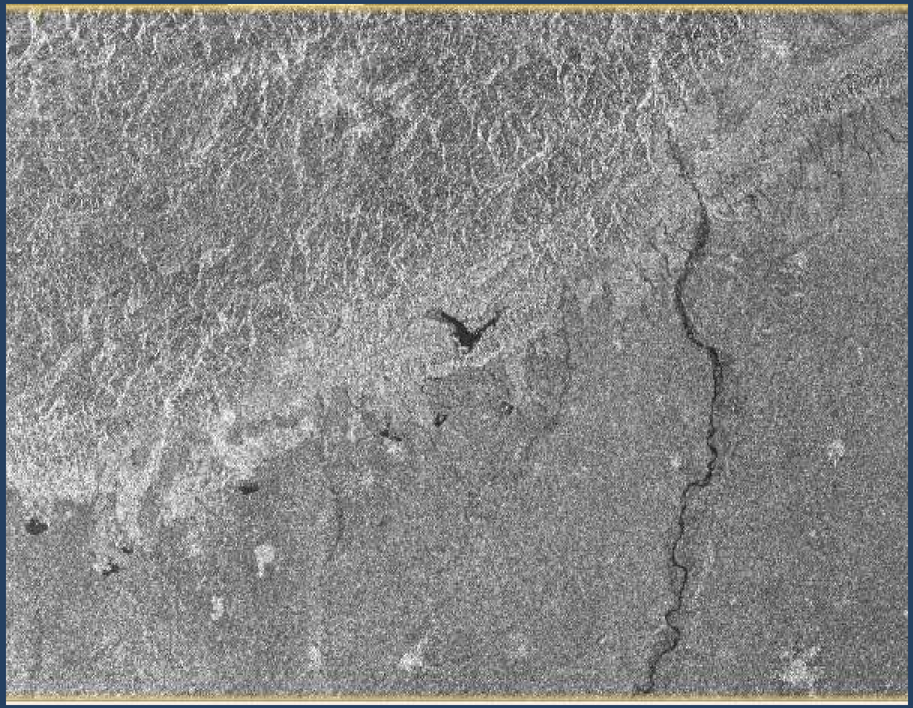

HH-HH
HV-HV
HH-VV

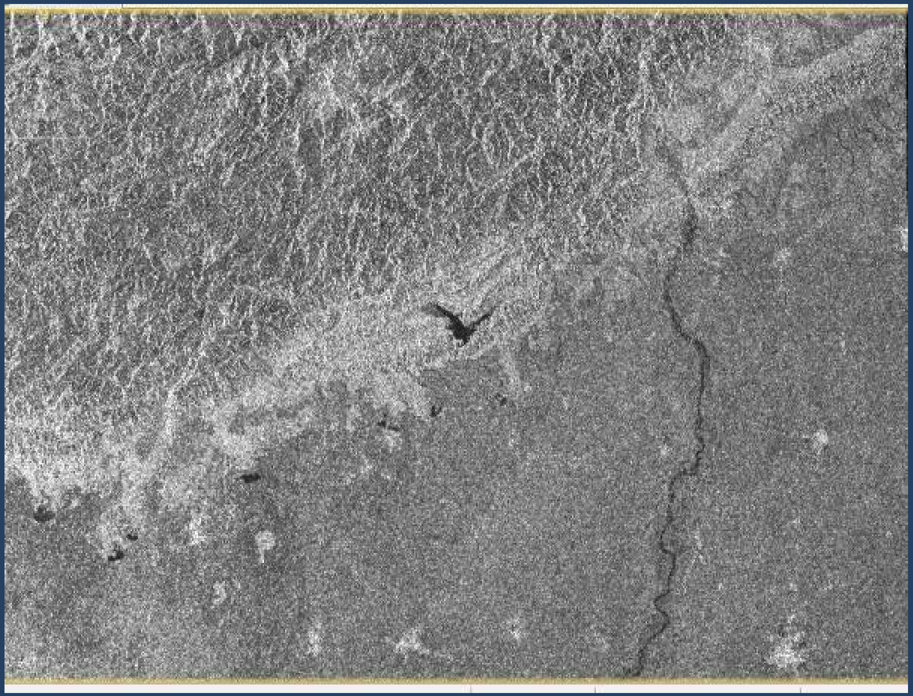

LL-LL
LR-LR
LL-LR



1st Singular Value 2nd Singular Value 3rd Singular Value

- VH Polarization
- VV Polarization





Forest Distribution mapping with microwave remote sensing

Kavita Kaushik and Deepak Kumar

Abstract

- Radar datasets have a high potential due to its ability to derive information from the surface.
- Utilize the capability of the c-band radar datasets provided by Sentinel 1A/B
- Microwave datasets can map the areas with frequent cloud-cover due to its cloud penetrating capabilities in day and night operations.

Introduction

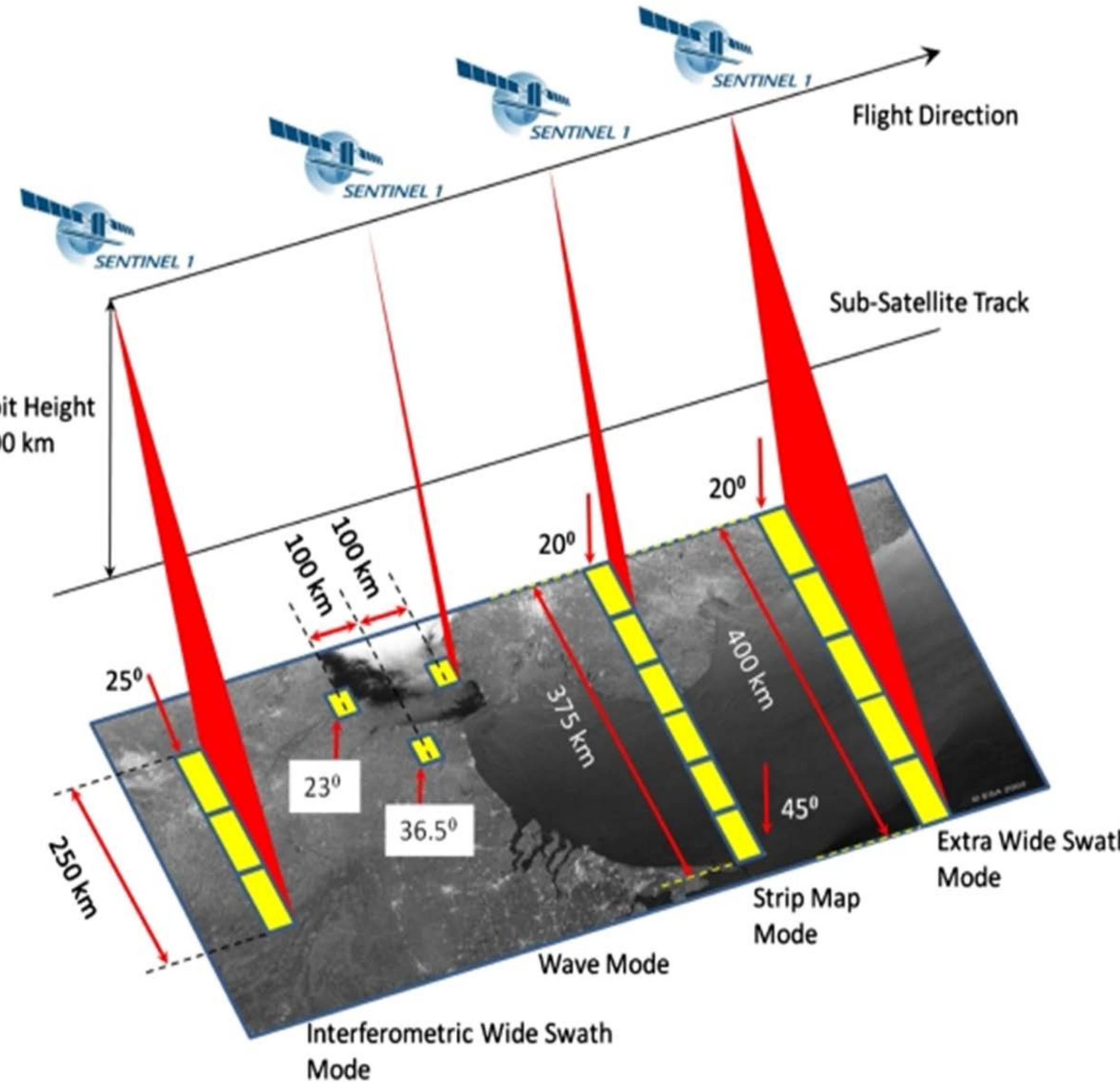
The current work focuses

- Concepts to understand the forest disturbances
- Basic understanding of the microwave image pre-processing methods for forest applications.
- Performing analysis for identification of forest disturbance with dual-polarization microwave datasets
- Understanding relationship between NDVI and radar vegetation Index (RVI) for forest disturbance mapping
- Analysis of NDVI to backscatter values in VH and VV polarizations.

Satellite Data Acquisition

- The SAR images were Acquired by the USGS (Sentinel 1A and Sentinel 2A were used)
- The sentinel 1A and 1B are capable to provide C-band synthetic-aperture radar datasets.
- The C-band has the spatial resolution of 5 m and a swath of up to 400km.

- The Current work utilized datasets with the following specifications:
  - Product type = GRD (Ground range detection)
  - Mission = Sentinel 1A
  - Acquisition mode = IW (interferometric wide)
  - Polarizations = VH and VV


SENTINEL 1
SENTINEL 1
SENTINEL 1
SENTINEL 1
Flight Direction
Sub-Satellite Track
Orbit Height
~700 km
100 km
100 km
20⁰
20⁰
25⁰
23⁰
36.5⁰
375 km
400 km
45⁰
250 km
Extra Wide Swath
Mode
Strip Map
Mode
Wave Mode
Interferometric Wide Swath
Mode

Sentinel-2 Bands	Central Wavelength	Resolution
BAND 1 – Coastal aerosols	0.433	60
BAND 2 – Blue	0.490	10
BAND 3 – Green	0.560	10
BAND 4 – RED	0.665	10
BAND 5 – Vegetation red edge	0.705	20
BAND 6 – Vegetation red edge	0.740	20
BAND 7 – Vegetation red edge	0.783	20
BAND 8 – NIR	0.842	10
BAND 8A – Vegetation red edge	0.865	20
BAND 9 – Water vapour	0.945	60
BAND 10 – SWIR – cirrus	1.375	60
BAND 11 – SWIR	1.610	20
BAND 12 – SWIR	2.190	20

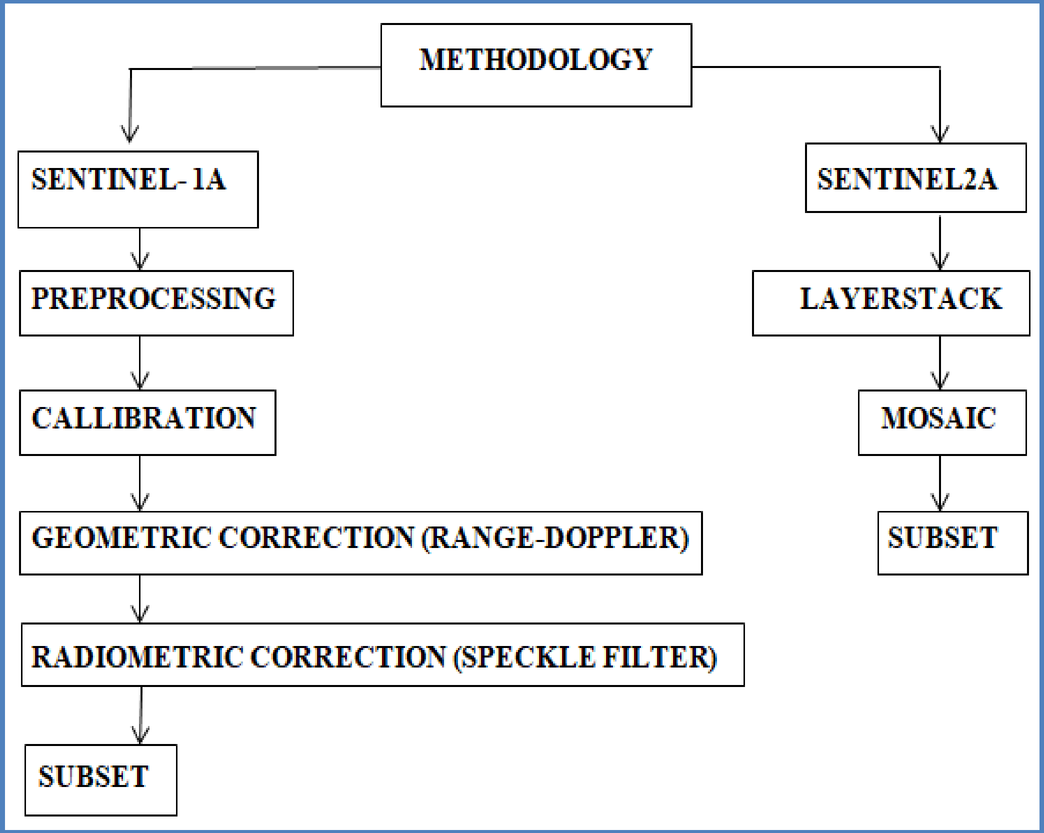
SOFTWARES USED

ArcGIS was used for extracting the values which were then used for corelating the values of NDVI and RVI image and for the analysis of backscatter values

For processing of radar images, for analysis regarding earth observations. For the processing of the optical (sentinel -2) images and for making the NDVI.

ERDAS Imagine is an image processing software and it allows processing with satellite imagery along with vector data

Methodology for data processing



METHODOLOGY FOR DATA PROCESSING

SENTINEL 1

01

CALIBRATION

Sentinel-1 Level-1 product is not radiometrically corrected by default.

For using the SAR the radar reflectivity has to be converted to its physical units to provide radar backscatter values with the process of radiometric calibration

02

MULTI-LOOK

Multi-Looking helps to mitigate the speckle present in the image for a better interpretation of the image. it means that the radar beam is divided into sub-beams which results in the introduction of speckle in the image but summing up these subs-beams together will reduce the amount of error in the imager in the form of speckle

2

1

03

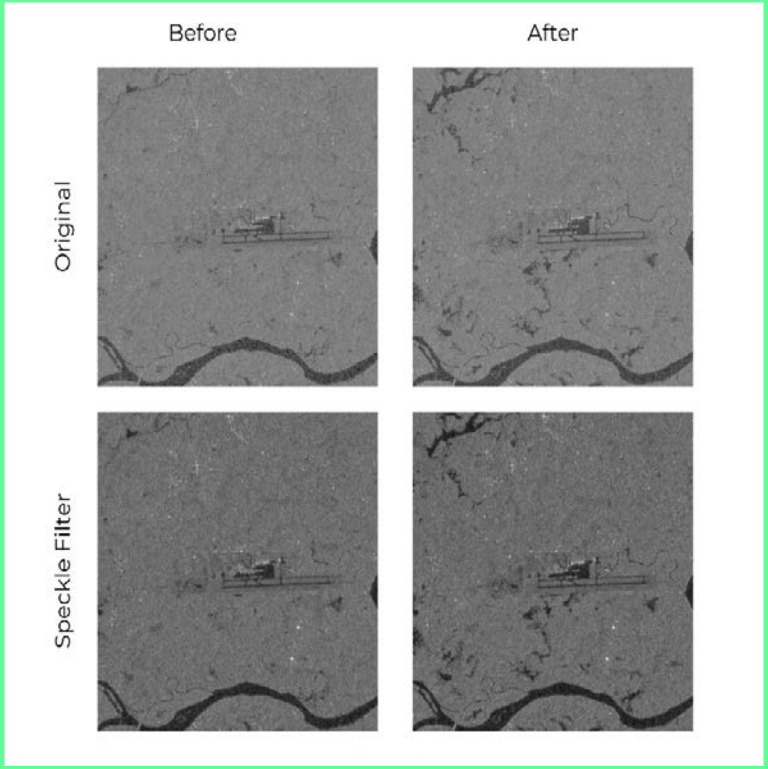
GEOMETRIC CORRECTION

The Geometric correction of the input data is performed by using the “Range Doppler Terrain Correction” method and its implemented through SNAP’s S1TBX software.

3

2

1



04

SPECKLE FILTER

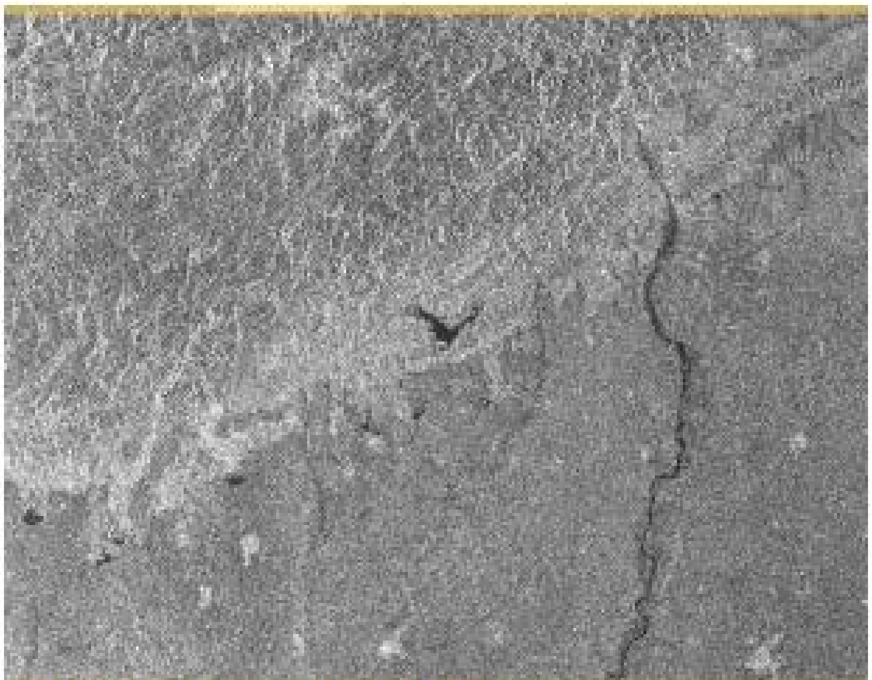
Speckle present in the radar image makes it difficult to interpret the image, as there may be chances of wrong information due to slight variations in it. It will be difficult to identify the feature, hence speckle filter is used to accurately derive the output.

4
3
2
1

SAR DATA PROCESSING

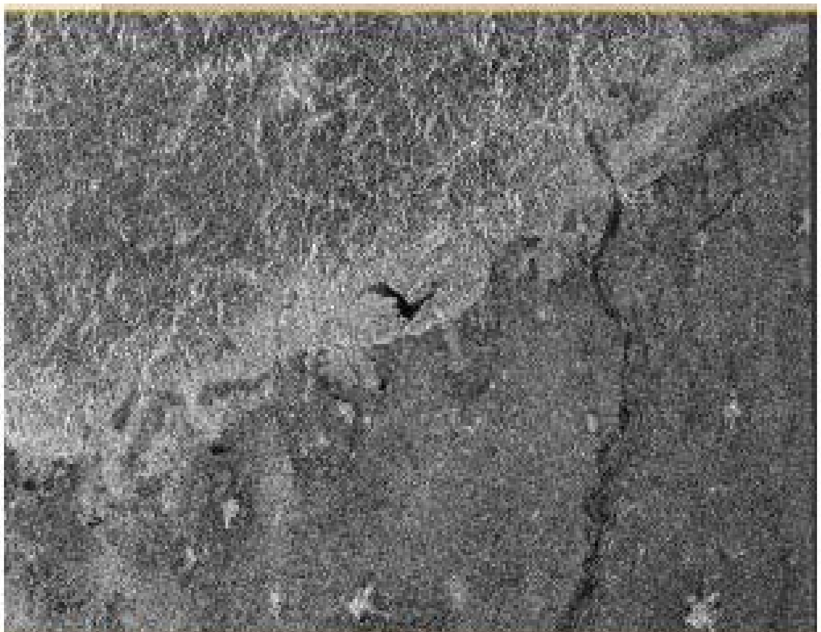
- The radar images were preprocessed before being used for analysis as they are geometrically and radiometrically corrected for better interpretation.
- The radar images for 3 months

RESULT AND ANALYSIS



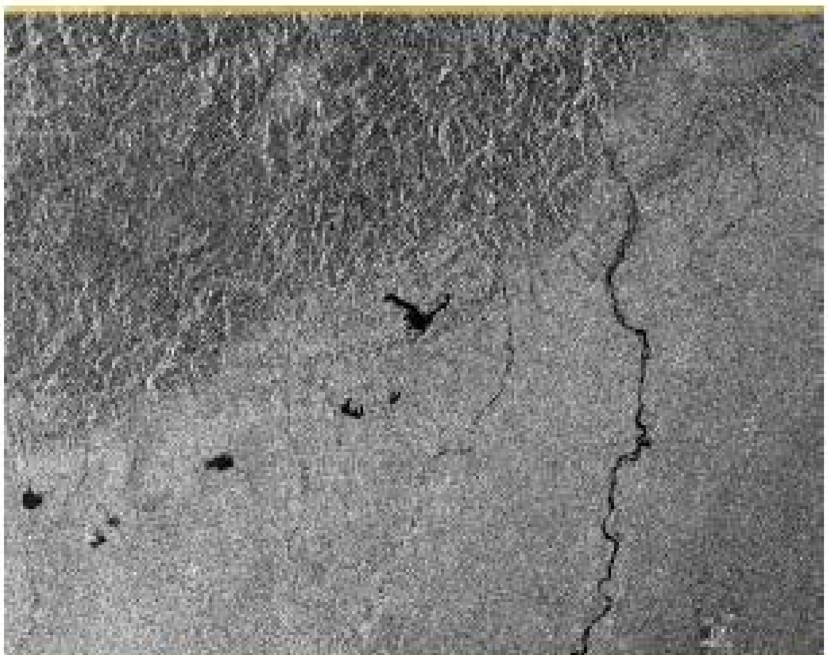
a) VH Polarization -February

b) VV Polarization-February

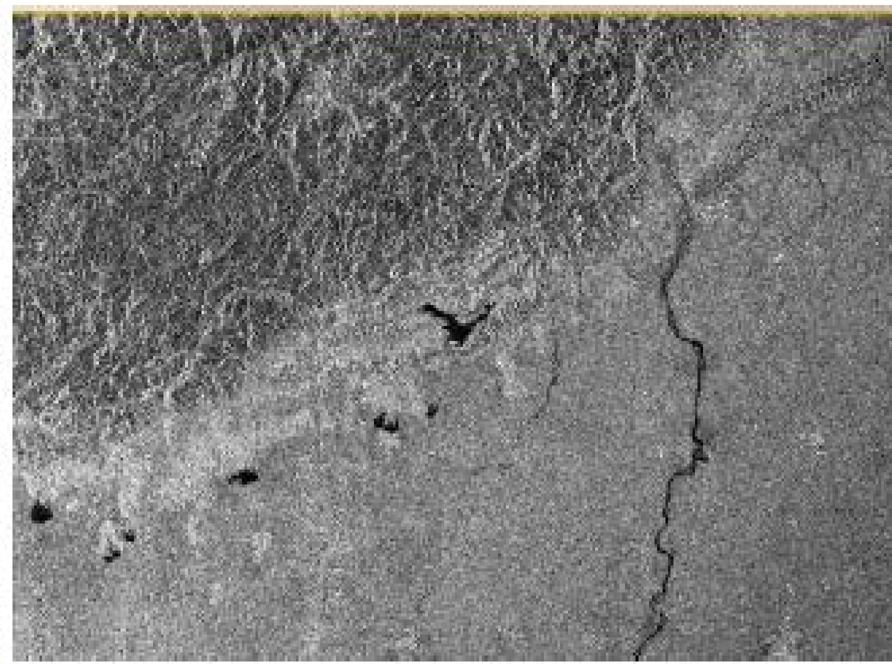


a) VH Polarization-May

b) VV Polarization-May



a) VH Polarization-October



b) VV Polarization-October

SAR data processing

1. Calibration:

- 1st step of preprocessing of the sentinel 1 image is to apply radiometric calibration, which is used to convert the data from digital numbers to decibels.
- It is performed through the SNAP software.
- INPUT: SAR GRD raw image (Sentinel 1A image).
- OUTPUT: Sigma nought calibrated radar backscattered image.

2. MULTILOOKING

- Multi-looking was used to mitigate the speckle present in the image for a better interpretation of the image.
- INPUT: The Sigma nought calibrated radar backscattered image
- OUTPUT: Multi look image.

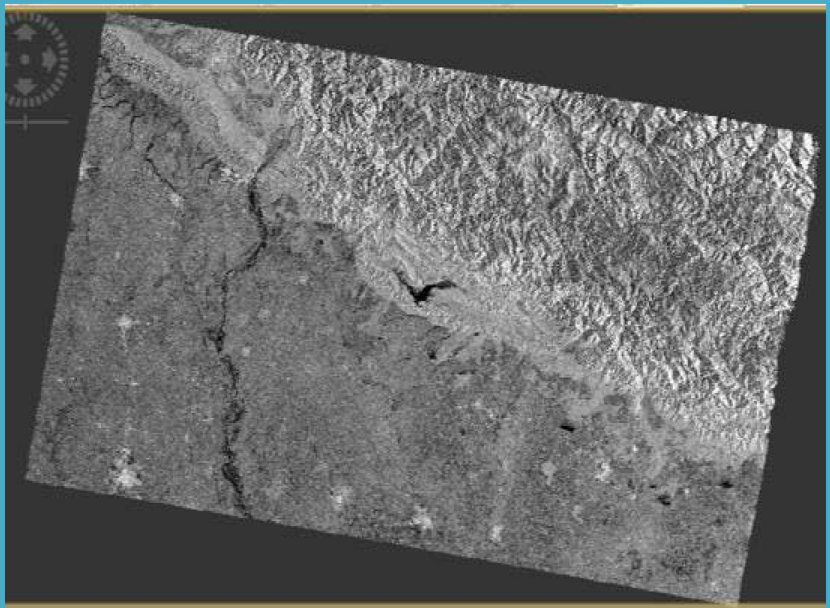
3. GEOMETRIC CORRECTION

- The geometric correction of the input data was done through the “Range Doppler Terrain Correction”. Data from the shuttle radar topography mission (SRTM) with a resolution of 1-arc second (30meters) to convert the image into map coordinate system. It was processed through terrain correction.
- INPUT: Multi look sigma nought calibrated radar backscatter image and DEM was automatically downloaded from SRTM data archive through SNAP.
- OUTPUT: Geometrically corrected sigma nought radar backscattered images.

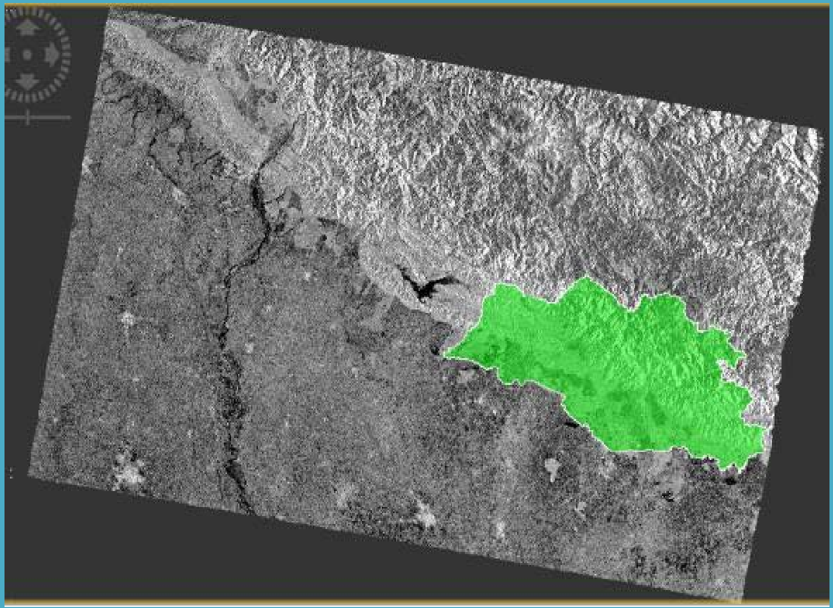
4. SPECKLE FILTERING

- Speckle filter was used to remove the noisy appearance of a homogenous area of the scene. For applying to filter we are using single product technique with lee sigma type filter.
- INPUT: Geometrically corrected sigma nought radar backscattered images.
- OUTPUT: Radiometrically and Geometrically corrected sigma nought radar backscattered images with reduced speckle effect

SUBSET

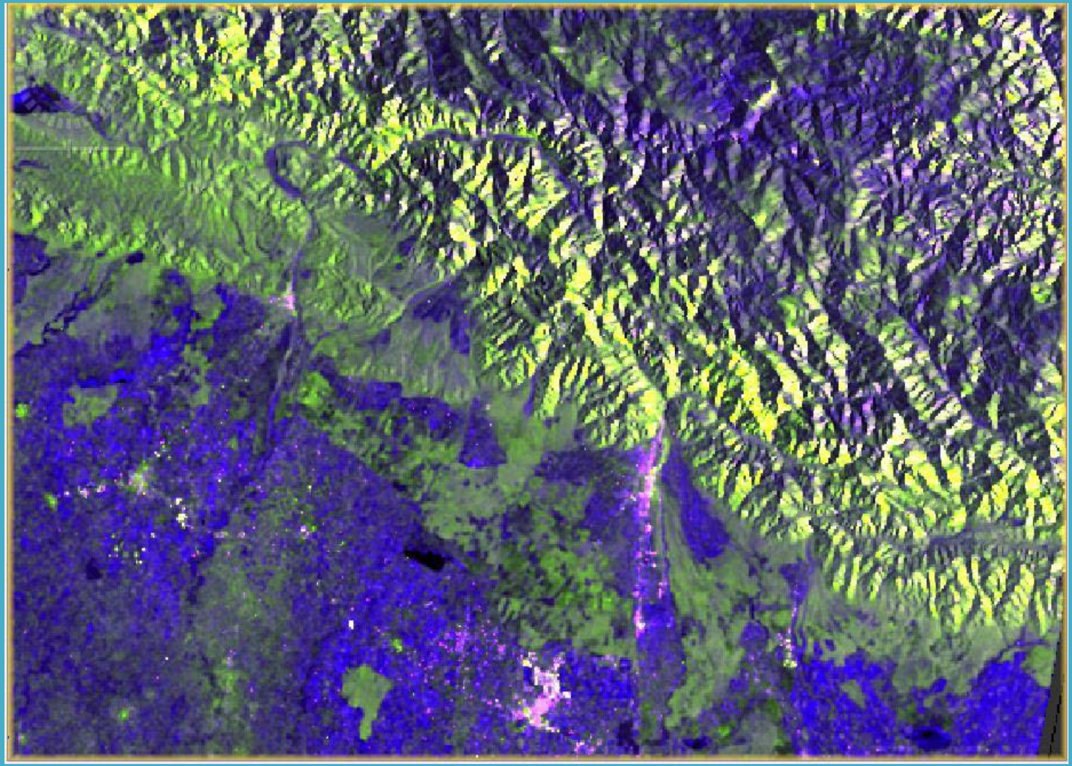


INPUT



OUTPUT

False color composition (FCC) of the study area

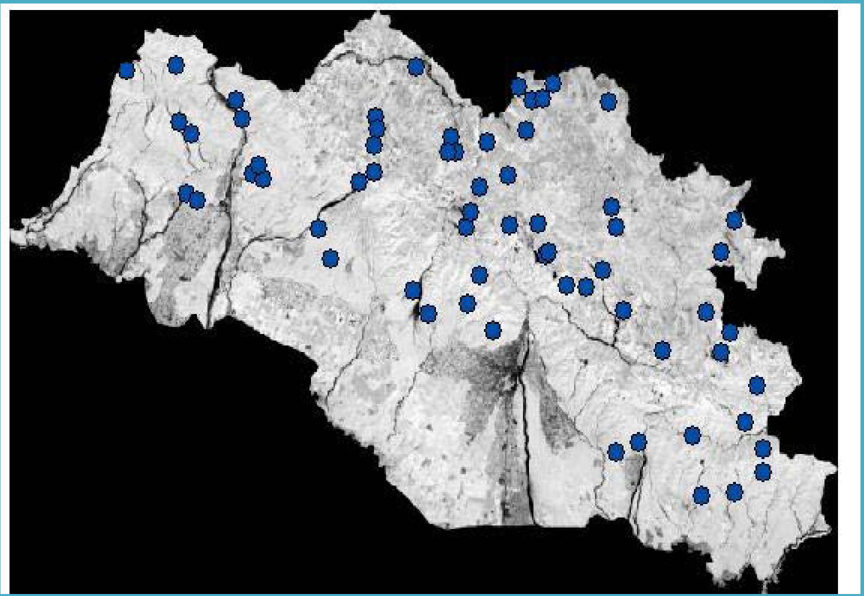


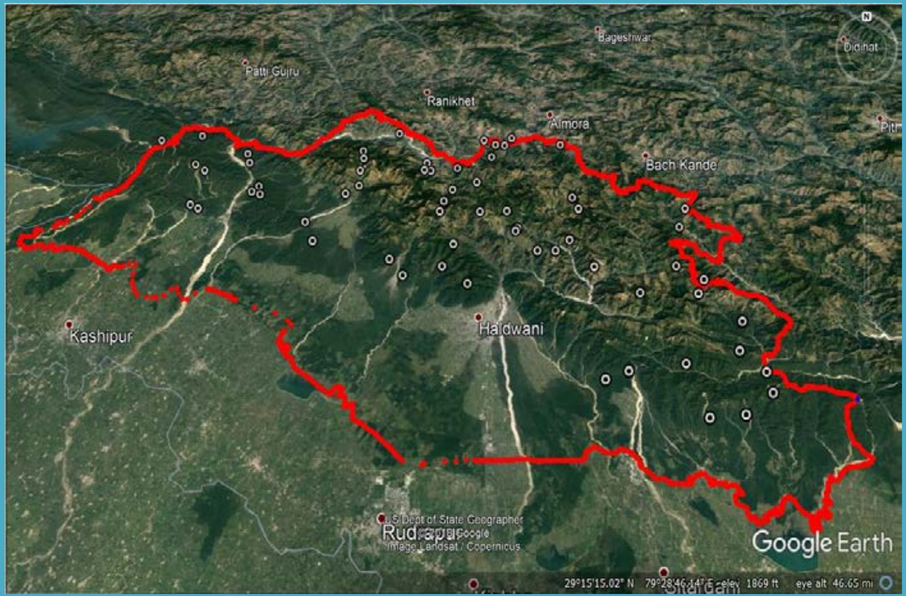
NDVI and RVI Image Generation

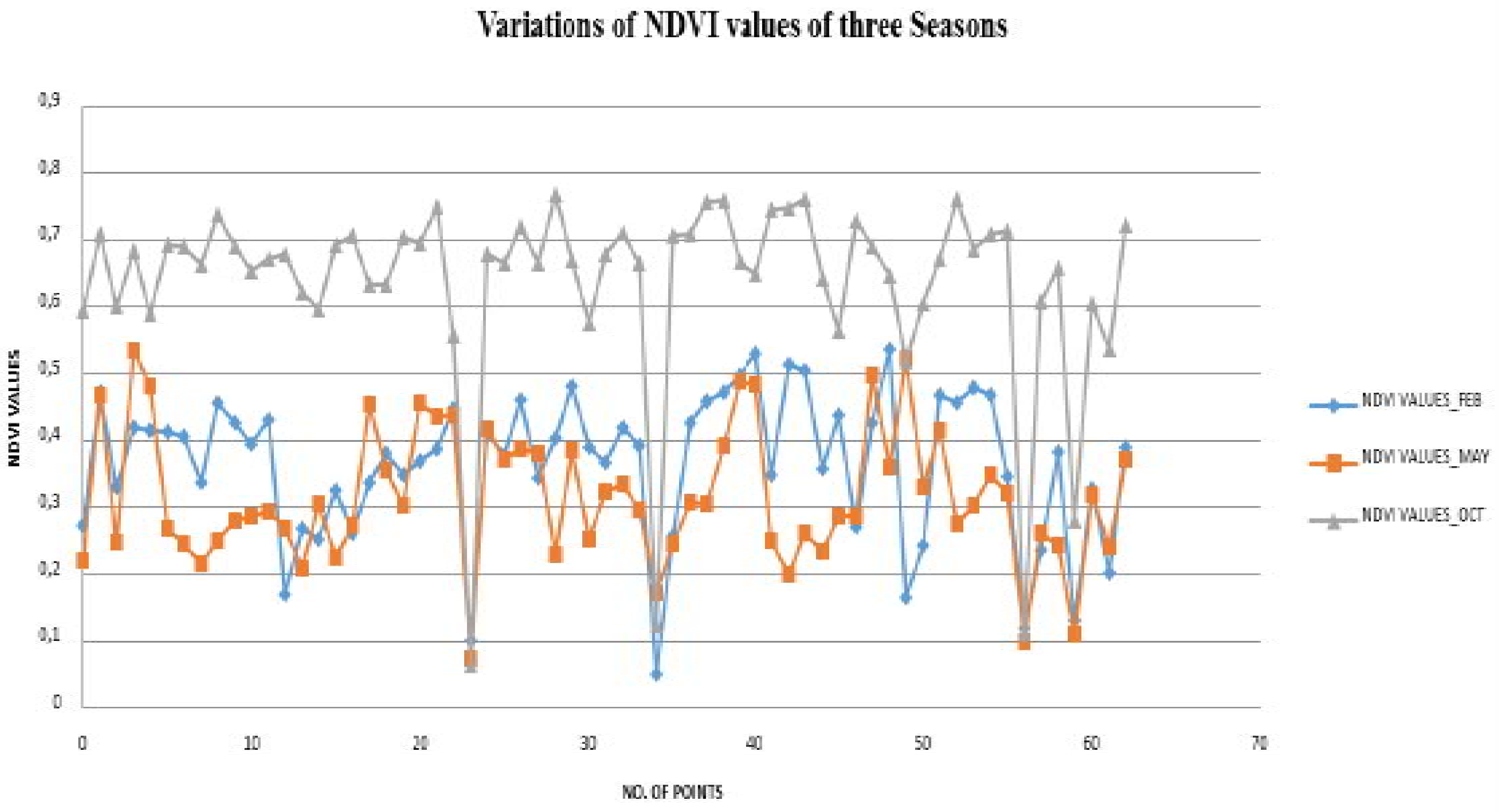
- NDVI typically refers to Normalized differential Vegetation Index, it is used to quantify forest supply and leaf area index. It is measured as the difference between NIR and red band. A higher NDVI value represents dense vegetation and a value close to 0 can be an urban area while the value in negative will represents a water body.
- RVI is widely used for vegetation cover mapping.

NDVI/ Months	February	May	October
Minimum (Low)	-0.186897	-0.10468	-0.26752
Maximum (High)	0.758754	0.739651	0.839569

Random points overlaid



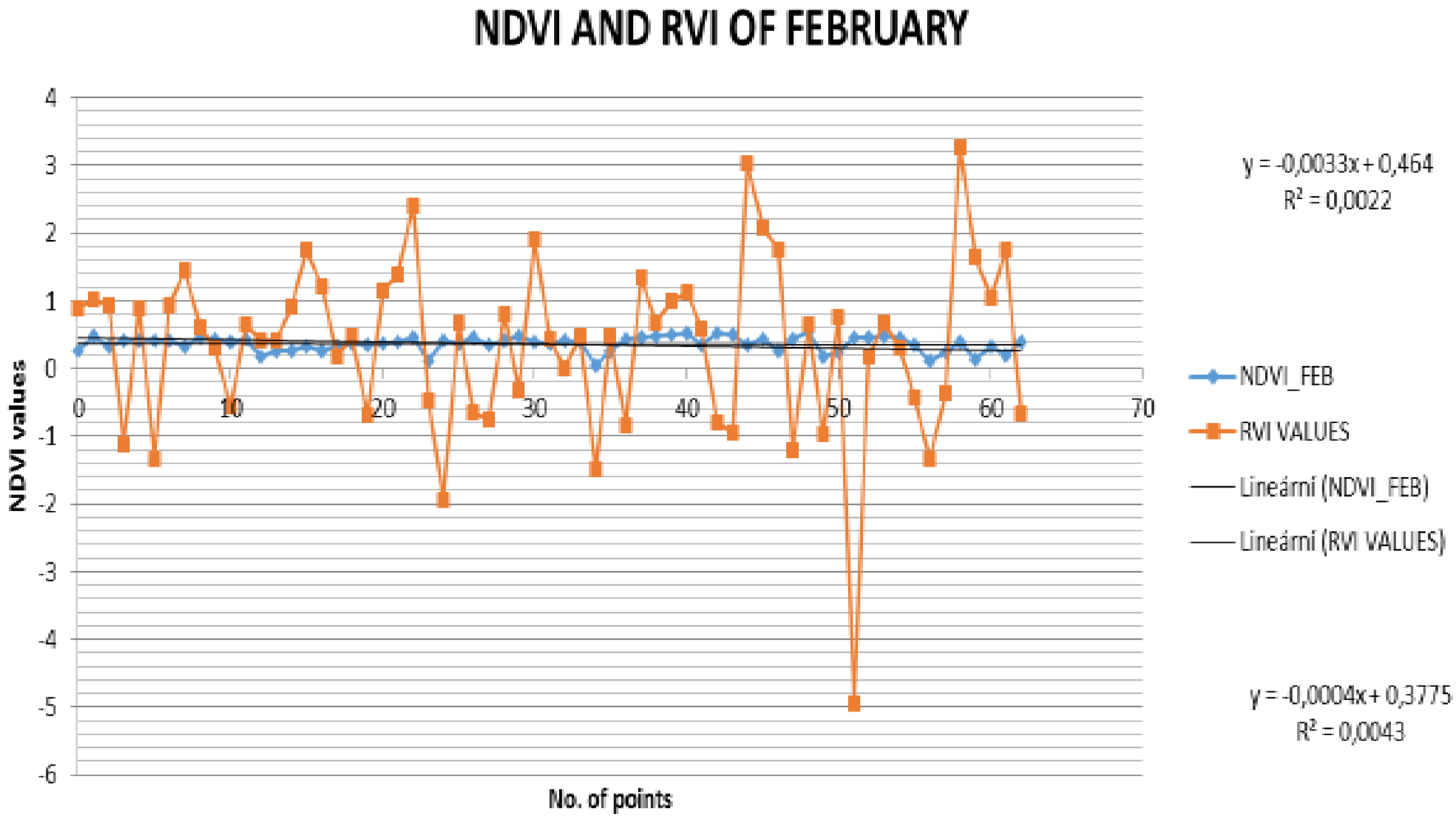




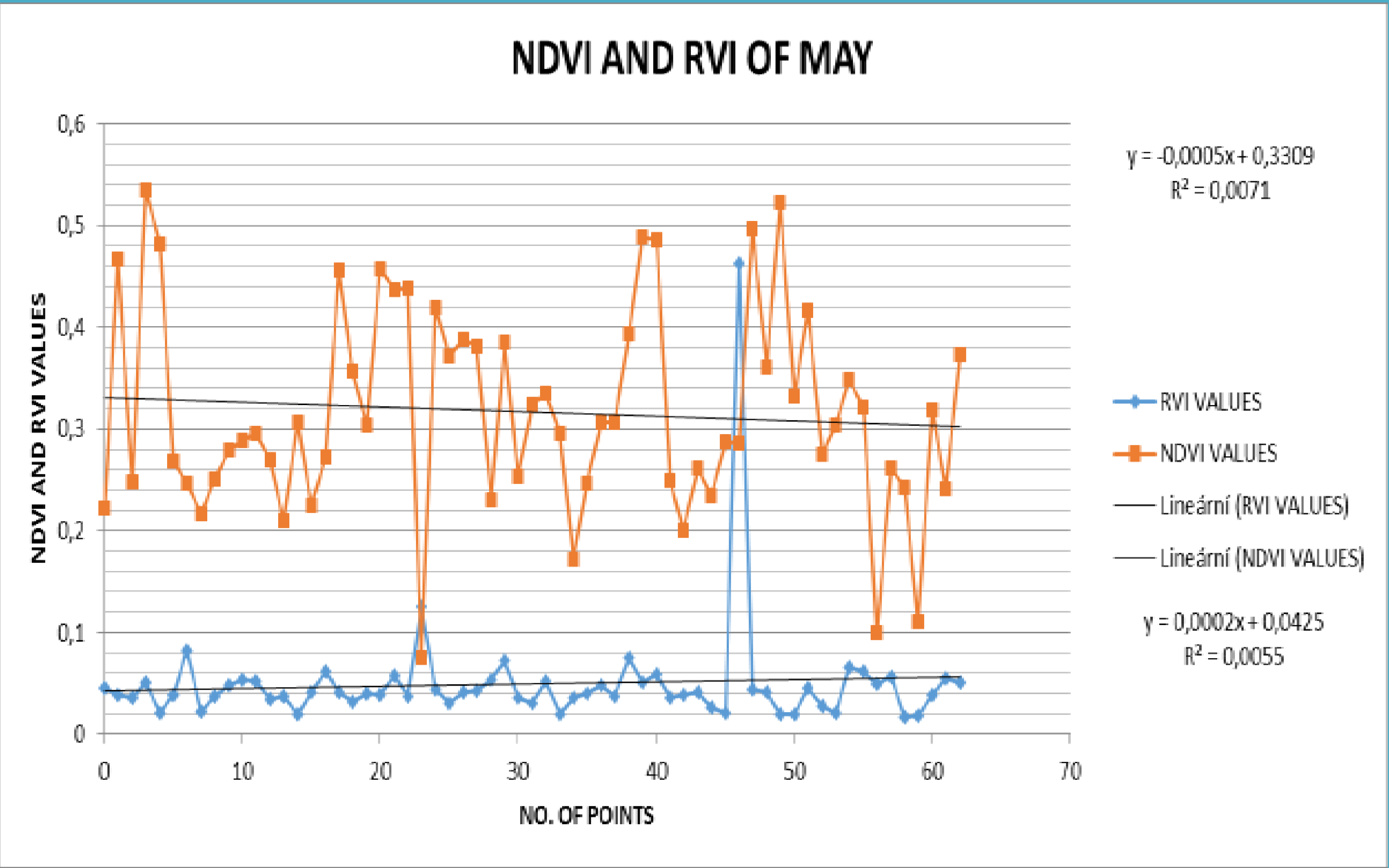
Variations of NDVI values of three Seasons
NDVI VALUES
NO. OF POINTS
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
10
20
30
40
50
60
70
NDVI VALUES_FEB
NDVI VALUES_MAY
NDVI VALUES_OCT

Summary NDVI and RVI value at selected points for three months

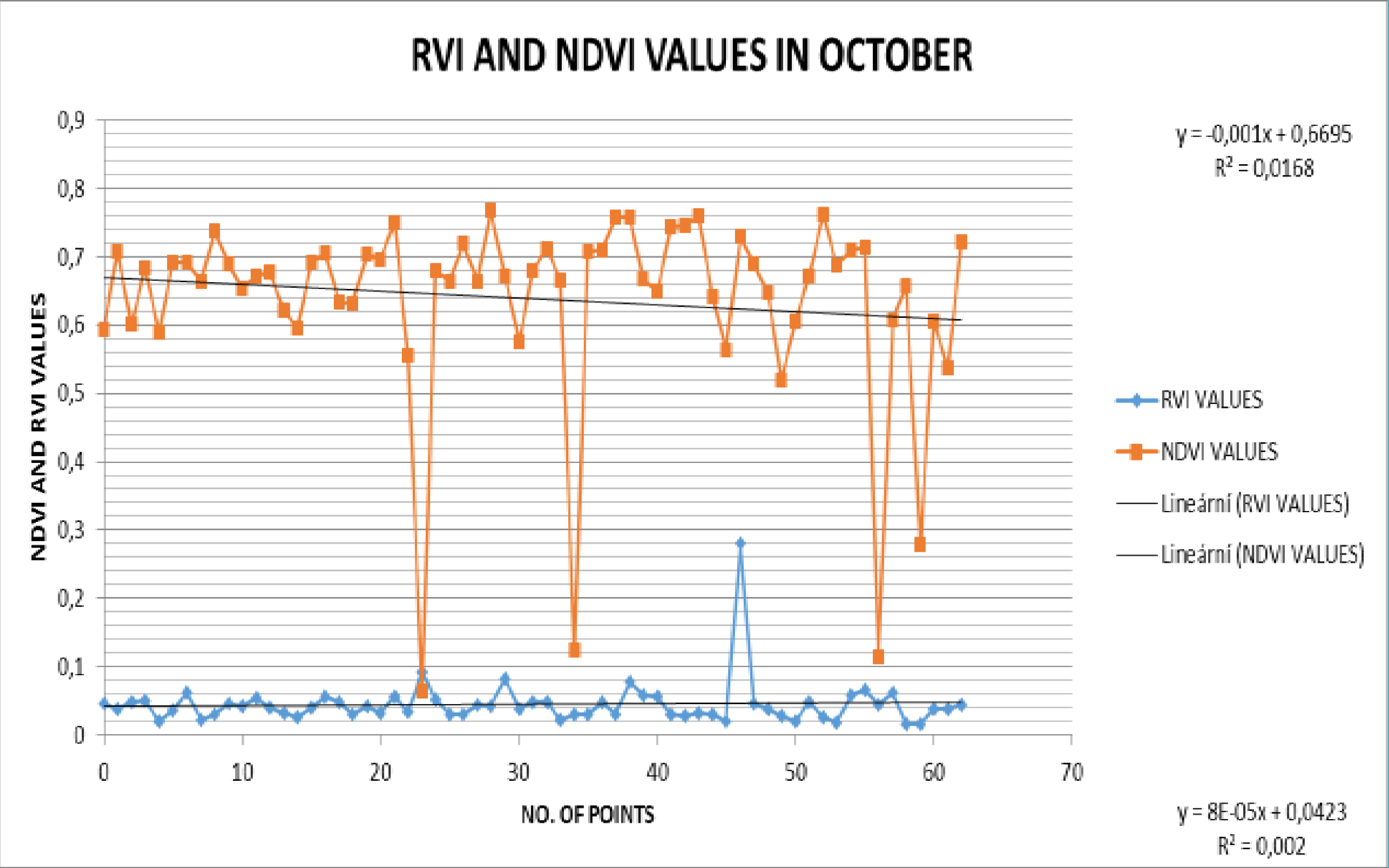
	FEBRUARY		MAY		OCTOBER	
POINTS	NDVI VALUES	RVI VALUES	NDVI VALUES	RVI VALUES	NDVI VALUES	RVI VALUES
1.	0.472916	1.019736	0.467529	0.038971	0.708731	0.038999
2.	0.421183	-1.13053	0.481481	0.020573	0.590244	0.020932
3.	0.416066	0.897092	0.455471	0.041743	0.633309	0.049163
4.	0.337321	0.178674	0.457607	0.038179	0.695807	0.033053
5.	0.369138	1.150835	0.436718	0.057269	0.750071	0.056771
6.	0.387742	1.380564	0.438117	0.036879	0.556463	0.033326
7.	0.447386	2.394394	0.418787	0.044396	0.679765	0.053036
8.	0.411088	-1.95284	0.488702	0.051017	0.668539	0.05782
9.	0.497908	0.989544	0.485364	0.058895	0.650028	0.055335
10.	0.529474	1.131414	0.497217	0.043727	0.690313	0.046621
11.	0.427188	-1.21348	0.416323	0.044983	0.671024	0.049215
12.	0.165237	-0.97579	0.534673	0.050599	0.683248	0.050421
13.	0.467355	-4.94484	0.522253	0.020036	0.519166	0.027548



NDVI AND RVI OF FEBRUARY
4
3
2
1
0
-1
-2
-3
-4
-5
-6
NDVI values
0
10
20
30
40
50
60
70
No. of points
y = -0,0033x + 0,464
R² = 0,0022
y = -0,0004x + 0,3775
R² = 0,0043
NDVI_FEB
RVI VALUES
Lineární (NDVI_FEB)
Lineární (RVI VALUES)



NDVI AND RVI OF MAY
NDVI AND RVI VALUES
NO. OF POINTS
0,6
0,5
0,4
0,3
0,2
0,1
0
0
10
20
30
40
50
60
70
y = -0,0005x + 0,3309
R² = 0,0071
RVI VALUES
NDVI VALUES
Lineární (RVI VALUES)
Lineární (NDVI VALUES)
y = 0,0002x + 0,0425
R² = 0,0055


RVI AND NDVI VALUES IN OCTOBER
y = -0,001x + 0,6695
R² = 0,0168
NDVI AND RVI VALUES
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
10
20
30
40
50
60
70
NO. OF POINTS
RVI VALUES
NDVI VALUES
Lineární (RVI VALUES)
Lineární (NDVI VALUES)
y = 8E-05x + 0,0423
R² = 0,002

Parametrization of NDVI values

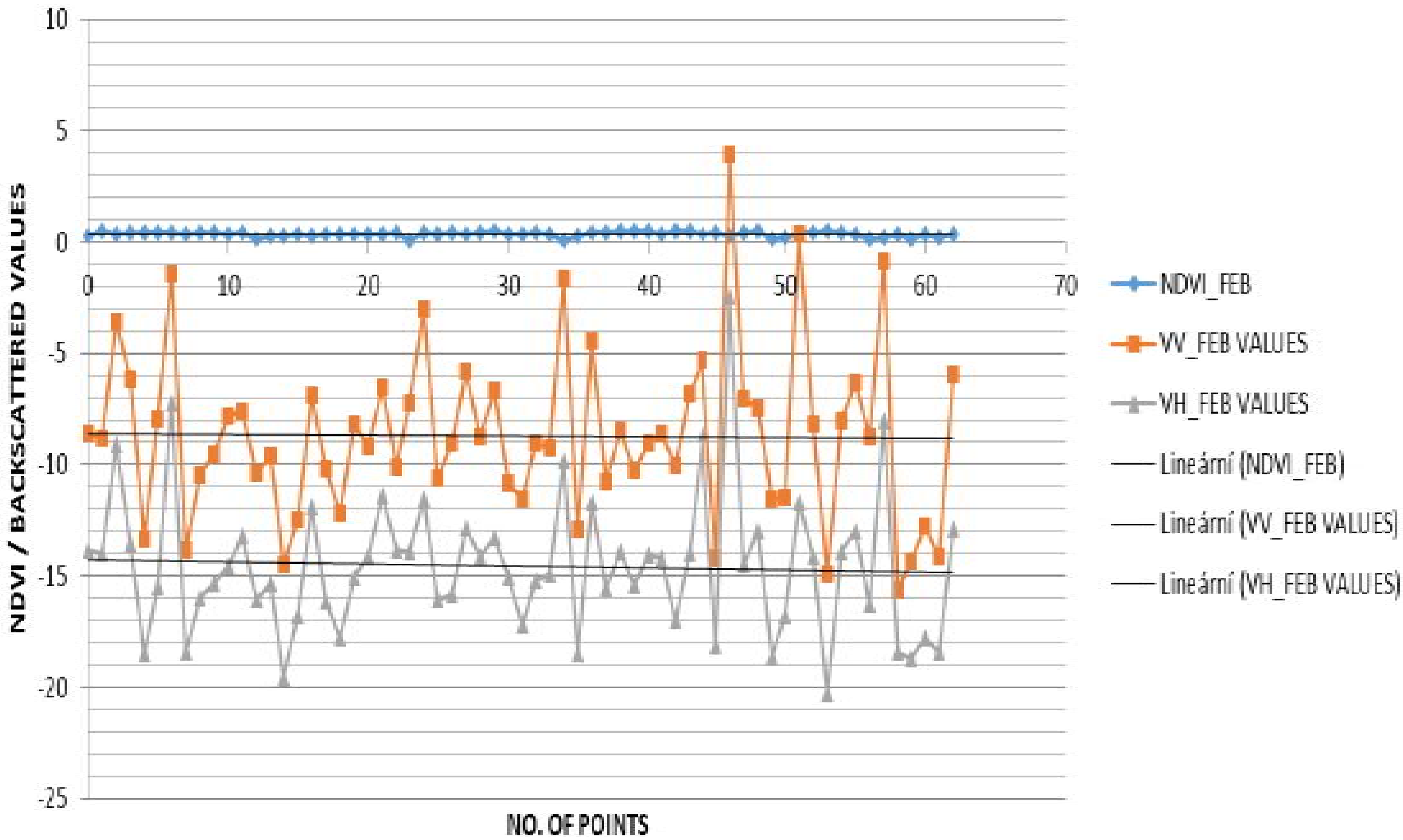
$$\mathrm{RVI} = \frac{4 \cdot \sigma_0 \mathrm{HV}}{\sigma_0 \mathrm{HH} + \sigma_0 \mathrm{HV}}$$

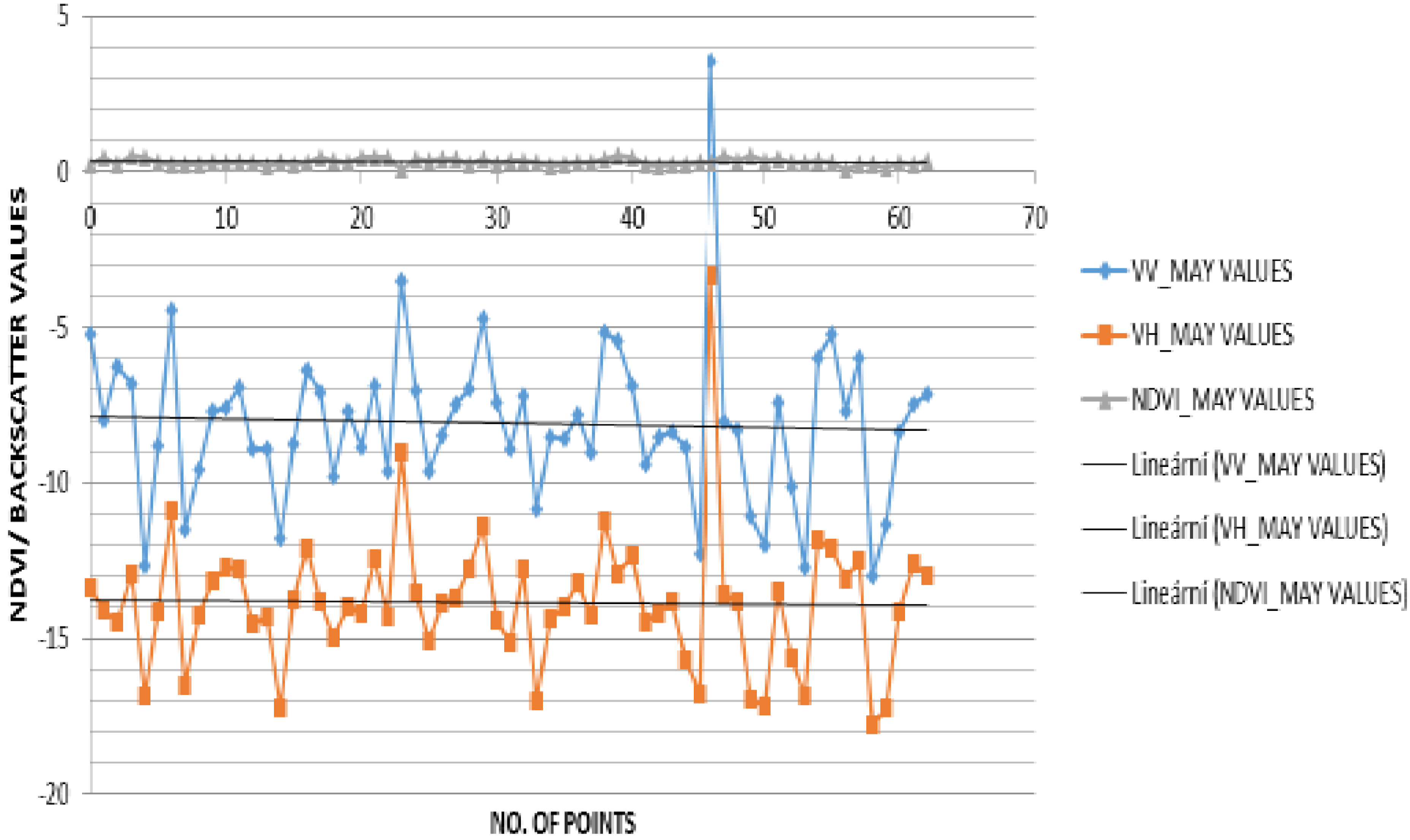
- Formula – using dual-pol with VV and VH polarization
- During February are highly fluctuating as there are many values which are below 0 whereas the same point in the other two images are above 0 and gave positive values. For may, the values are all above 0 and there is no negative values for any point. The graph for October shows a reverse relationship between the NDVI and the RVI as where the NDVI value is low the RVI values is higher and vice versa.

- The RVI value for May and October is almost same with a slight difference but the values of NDVI for the same points show variations, as for some points it is same but the majority of values in may is varying between 0.2 to 0.5 but the same points in October are showing high NDVI values ranging between 0.6 to 0.7.
- The difference between the two can be a result of soil moisture in the are which is captured in the radar imagery.
- The fluctuating values in February can be a result of any types of disturbance in the area.

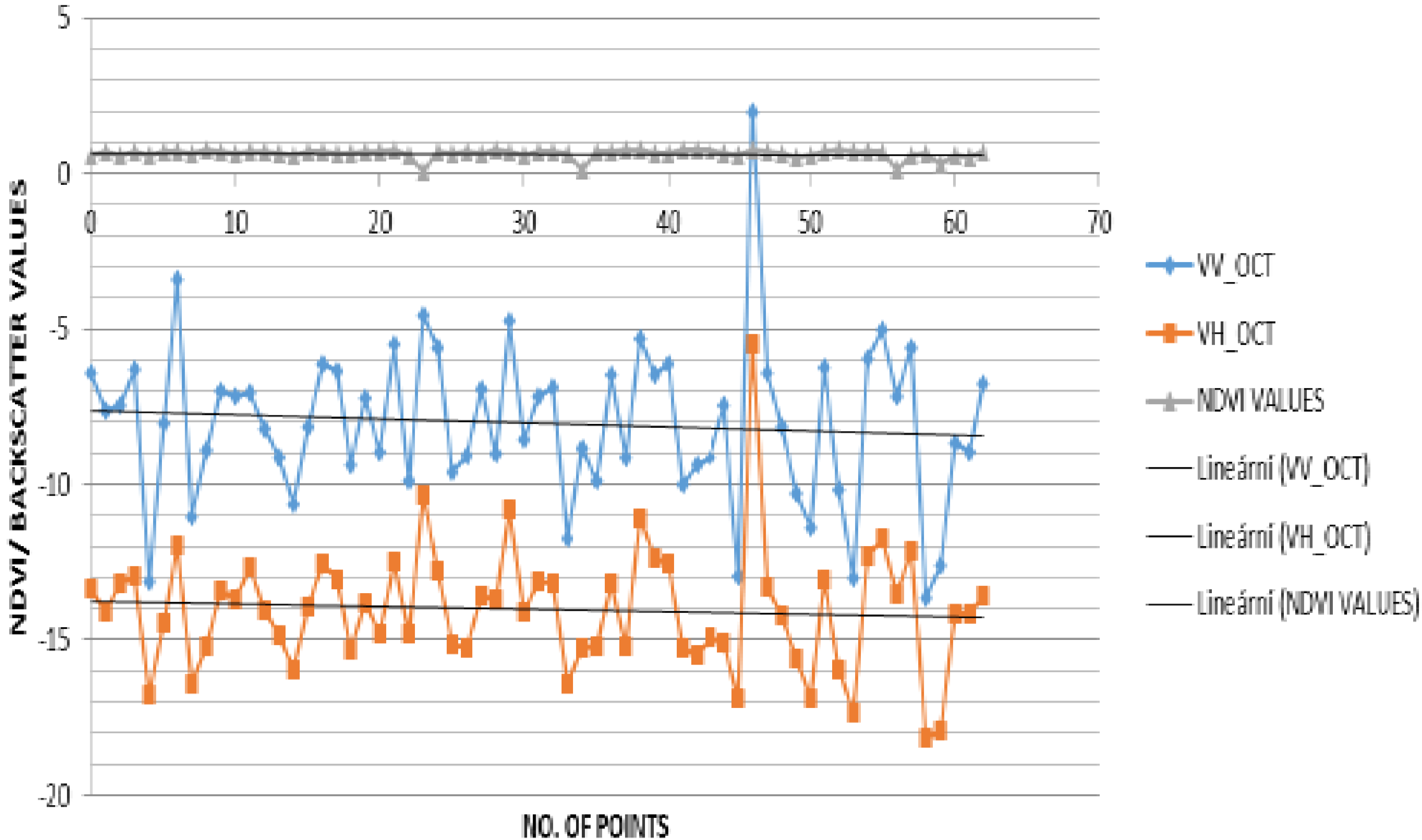
Comparative study of NDVI and Backscatter values

- Microwave remote sensing radar records the backscattered values.
- Every feature exhibits different backscattered values. If the dB value is more than 0 or positive it can infer to settlement or manmade feature, the value ranging from 0 dB to -10 dB approximately represent forest cover, -10 to -20 is an indicator of the vegetated area and the value more the -20 represents a water body.
- The Backscattered values of VV and VH polarizations were also calculated which represented that the VV polarization which is vertically transmitted and vertically received in sensitive to the forest cover.


NDVI / BACKSCATTERED VALUES
10
5
0
-5
-10
-15
-20
-25
0
10
20
30
40
50
60
70
NO. OF POINTS
NDVI_FEB
VV_FEB VALUES
VH_FEB VALUES
Lineární (NDVI_FEB)
Lineární (VV_FEB VALUES)
Lineární (VH_FEB VALUES)



NDVI / BACKSCATTER VALUES
5
0
-5
-10
-15
-20
0
10
20
30
40
50
60
70
NO. OF POINTS
VV_MAY VALUES
VH_MAY VALUES
NDVI_MAY VALUES
Lineární (VV_MAY VALUES)
Lineární (VH_MAY VALUES)
Lineární (NDVI_MAY VALUES)



5
0
-5
-10
-15
-20
0
10
20
30
40
50
60
70
NDVI/ BACKSCATTER VALUES
NO. OF POINTS
VV_OCT
VH_OCT
NDVI VALUES
Lineární (VV_OCT)
Lineární (VH_OCT)
Lineární (NDVI VALUES)

CONCLUSION

- The current work aims towards the processing of the SAR datasets for application the field of forestry.
- The backscattered sigma nought values were also analyzed for identifying the difference between the two polarizations which are used in the radar data as it is dual-pol data with the combination of VV and VH (Vertically transmit and vertically received and vertically transmitted and horizontally received) polarizations.
- NDVI (Normalized differential vegetation index) and RVI (Radar vegetation index) were calculated to find the correlation between these indices in mapping the disturbance in the area. NDVI was derived through the help of ERDAS Imagine software and the RVI was estimated through SNAP software

THANK YOU