Temporal Behaviour of Backscattering Coefficient from SCATSAT-1 in rice and wheat crops

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: 14/8/'17

Acknowledgement

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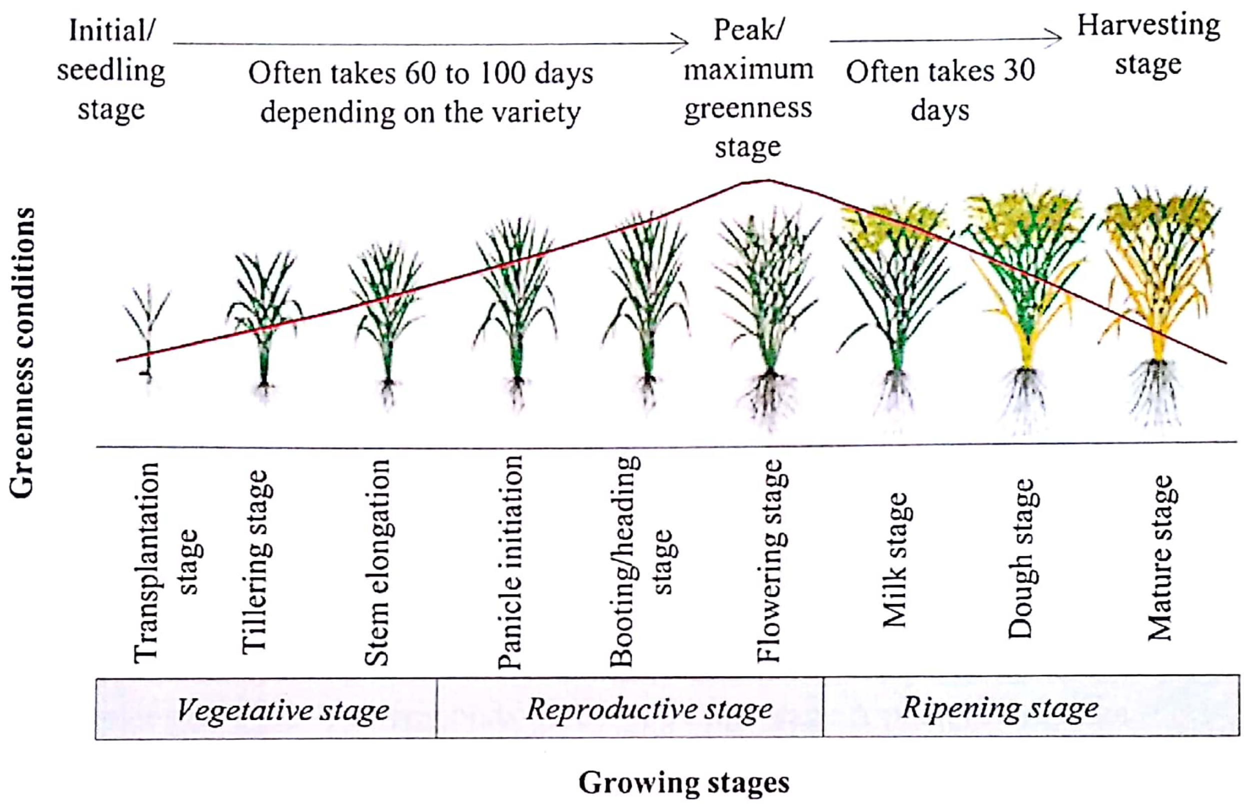
1. INTRODUCTION

SCATSAT-1 can provide the back scattering coefficient over the globe everyday. Though the main purpose of this scatterometer is for the determination of wind speed, direction and cyclone prediction over the oceans, however those data can also be used for retrieving various geophysical parameters over land surface despite of their coarse spatial resolution. Kennett and Li (1989) did the first global analysis of scatterometer over land surfaces based on SEASAT SASS data. Furthermore, various papers were published on the general possibilities of monitoring land surfaces (Messeh and Quegan 2000; Puliiainen et al., 1998). Ringelmann et al. (2004) have shown the use of QuikSCAT scatterometer for the estimation of planting date of wheat crop, Oza and Parihar (2007) had reported the potential of Ku-band scatterometer data of QuikSCAT for rice crop growth stage assessment. In an exhaustive experimental study carried out by Inoue et al. (2002) for rice crop using multi-frequency scatterometer, the observations confirmed the difference in sensitiveness of higher frequency bands (Ka, Ku, X) and lower frequency bands (C, L) to rice crop parameters like height, biomass, leaf area, etc. The SCATSAT 1 is a mini-satellite which will have the Ku-band pencil beam scatterometer (OSCAT-2) as the major payload.

Variations of the radar scatterometer signal are mainly caused by changes of the dielectric properties of the scattering surface and by changes of the scattering mechanism as introduced by changes of surface roughness and contributions by volume scattering. For vegetation, the main reasons of these variations are changes in moisture and the growth of vegetation. The high temporal sampling of the Ku-band scatterometer on the SCATSAT1 platform, and reasonable spatial resolution offers the potential to explore the use of the temporal signature of crop to derive different stages with least error in period. Hence the present study was planned to study the temporal behavior of the backscattering over two major crops of India viz., rice and wheat so that in future crop phenology could be assessed from the variation in temporal backscattering pattern. The description of major growth stages of rice and wheat is given below.

1.1 Crop Growth Stages:



The growth cycle of usual crop has the following divisions: germination, seedling establishment and leaf production, tillering , stem and head growth, head emergence and flowering, and grain filling and maturity.

Germination

When a kernel is sown, the germination process begins. The radicle and seminal roots first extend, followed by the coleoptile.The crown is usually separated from the seed by a sub-crown internode. The length of this internode is greater as the depth of planting increases. As the coleoptile emerges from the soil, its growth stops and the first true leaf pushes through the tip.

After seedling emergence, leaves are produced at a rate of about one every 4 to 5 days. Figure 4 shows a young seedling at the two-leaf stage. A total of eight or nine leaves are usually produced

Tillering

Tillering is an important development stage that allows plants to compensate for low plant populations or take advantage of good growing conditions. Tiller appearance is closely coordinated with the appearance of leaves on the main shoot. Tillers can form at the points of attachment of the coleoptile and the lower leaves on the main shoot.

During the time that tillering occurs, another less obvious but extremely important event occurs: the initiation of heads on the main shoot and tillers. Although the head at this time is microscopic, the parts that will become the floral structures and kernels are already being formed. When head formation is complete, the stem begins elongating. This corresponds to the "jointing" stage A plant usually has about five leaves at this time.

Stem and head growth

Lower stem internodes on the plant remain short throughout development. The fourth internode is usually the first to elongate in a plant with nine total leaves. This is followed in sequence by the internodes above it (figure 6). Each stem internode up the plant becomes progressively longer, and the last stem segment to elongate, the peduncle, accounts for a considerable proportion of the total stem length.

Stem elongation coincides with the period of rapid head growth in which the individual florets become prepared to pollinate and be fertilized. Throughout the preheading period, differences in the duration of the various developmental phases among shoots on the same plant help synchronize development.Head emergence and flowering

As the stem continues to elongate, the head is pushed out of the flag leaf sheath, a stage referred to as "heading." Within a few days after heading, flowering (pollination) begins in the head, starting first with the florets in the central spikelets. Within the next few days flowering progresses both up and down the spike. Flowering is usually noted by extrusion of the anthers from each floret although this can change depending on the variety and weather conditions. If the anthers within a floret are yellow or gray rather than green.

Maturity

Growth progresses in three distinct phases spanning about four weeks under usual conditions. In the first phase, the "watery ripe" and "milk" stages, the number of cells in the endosperm (the major starch and protein storage portion of the kernel) is established.

Finally, growth of the kernel declines about three weeks into grain filling and its weight approaches a maximum attained at physiological maturity. As the kernel approaches maturity, its consistency becomes "hard dough." illustrates the appearance of wheat kernels during this developmental sequence.

Kernel moisture does not always determine when physiological maturity occurs. A better indicator of maturity is when the head and the peduncle lose their green color.The green color is lost from the flag leaf blade when the kernel has attained about 95 percent of its final dry weight.

Some basics of microwave scatterometry with special reference to Ku band is given below.

1.2 – Microwave scatterometry

A scatterometer is a scientific instrument to measure the return of a beam of light or radar waves scattered by diffusion in a medium. Scatterometer is a microwave radar sensor which measures the reflection (or scattering effect) produced while scanning the surface of the Earth from an aircraft or a satellite. A microwave scatterometer operates by transmitting a pulse of microwave energy towards the Earth's surface and measuring the reflected energy. A separate measurement of the noise-only power is made and subtracted from the signal + noise measurement to determine the backscatter signal power. Sigma-0 is computed from the signal power measurement using the distributed target radar equation. Scatterometer instruments are very precisely calibrated in order to make accurate backscatter measurements. The first operational wind scatterometer was known as the Seasat Scatterometer (SASS) and was launched in 1978In 1996 NASA launched the NASA Scatterometer (NSCAT), a Ku-band fan-beam system. NASA launched the first scanning scatterometer, known as 'SeaWinds', on QuikSCAT in 1999. It operated at Ku-band. The Indian Space Research Organization launched a Ku-band scatterometer on their Oceansat-2 platform in 2009 and in September 2016 in SCATSAT1. The Ku band is the portion of the electromagnetic spectrum in the microwave range of frequencies from 12 to 18 gigahertz (GHz). Ku band is primarily used for satellite communications, most notably for fixed and broadcast services, and for specific applications. Compared with C-band, Ku band is not restricted in power to avoid interference with terrestrial microwave systems, and the power of its uplinks and downlinks can be increased. This higher power also translates into smaller receiving dishes and points out a generalization between a satellite's transmission and a dish's size. As the power increases, the size of an antenna's dish will decrease. For the end users Ku band is generally cheaper and enables smaller antennas, both because of the higher frequency and a more focused beam. Ku band is also less vulnerable to rain fade than the Ka band frequency spectrum.

2. OBJECTIVE

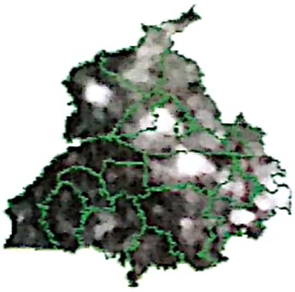
1. Temporal Behaviour of Backscattering Coefficient from SCATSAT-1 in rice and wheat crops
2. Comparison of MODIS and SCATSAT data of crops and establishing possible relationship between the two.
3. Finding transplanting date for the Rice crop using SCATSAT data.

3. Materials and Method

3.1 - Study area

The state of Punjab was taken as the study area for wheat while West Bengal (WB) was taken as study area for rice crop. These states have been carefully chosen because of the occurrence of large patch of the respective crop. The study area with sigma-0 data from SCATSAT-1 is depicted in below figures.

Punjab :



Soil: Punjab has soils with loamy texture or clay loam, and moderate water holding capacity which are best for wheat cultivation. Wheat is cultivated with adequate irrigation schedule in the state. Mainly five irrigations are given to a crop.

Rabi season weather:

Temperature (Celcius) :

Max avg temperature : 24.5

Standard deviation : 0.78

Min avg temperature : 9.7

Standard deviation : 0.88

Rainfall :

Mean Rainfall : 127 mm

Standard deviation : 72.6 mm

Wheat Production : 164.72 lakh metric tonnes (2016)

Area under production : 35100 Lakh Hectares (2016)

West Bengal :

Due to clayey loam soil, moist weather and proper irrigation conditions in WB, it is the largest producer of rice in India.

WB's clayey loam soil is well suited to the raising of rice crop.

Soil WB's clayey loam soil is well suited to the raising of rice crop.

Rabi season weather:

Temperature (Celcius) :

Max avg temperature : 34.5

Min avg temperature : 24.7

Rainfall :

Mean Rainfall : 443 mm

Wheat Production : 148 lakh metric tonnes (2014)

3.2 - Data

Daily Sigma-0 data over the crop season (rabi rice and wheat) along with the time series NDVI for the same period was used for this study. Crop mask from AWiFS data was used to delineate the crop area.

SCATSAT-1 scatterometer provides data of horizontal and vertical polarized waves which are focused on 2 km range area per granule. Since Punjab and West Bengal usually have linear soil plantations, they provide accurate readings without fragmentation. The Sigma-0 in both horizontal and vertical polarization data has been obtained from www.mosdac.gov.in and using FTP server hosting SCATSAT-1 data. The SH and SV .tif files that with BTH_ASC_DESC structure are downloaded.

The MODIS data is obtained from https://reverb.echo.nasa.gov using search term 13A2 series of data. Appropriate time period and area of interest are to be provided. The data can be ordered or downloaded on spot with limits on no of granules that can be downloaded simultaneously. The files with .hdf links are obtained and are downloaded using appropriate network download software or using command line.

3.3 Methodology

Softwares used: ENVI + IDL

Time period: 1st Nov 2016 - 23 May 2017

The first step of the procedure is to obtain SCATSAT-1 scatterometer data of Region of Interest in the interested time frame. The procedure of obtaining data has been explained above.

Then we stack the individual date data using Layer stack option onto each other.

We extract our region of interest from these images. In our case it'd be Punjab and West Bengal states using appropriate state boundary vectors.

Then apply appropriate crop mask that includes data about crop grown in the ROI.

We classified the output into different categories using unsupervised classification using iso-data classification option.

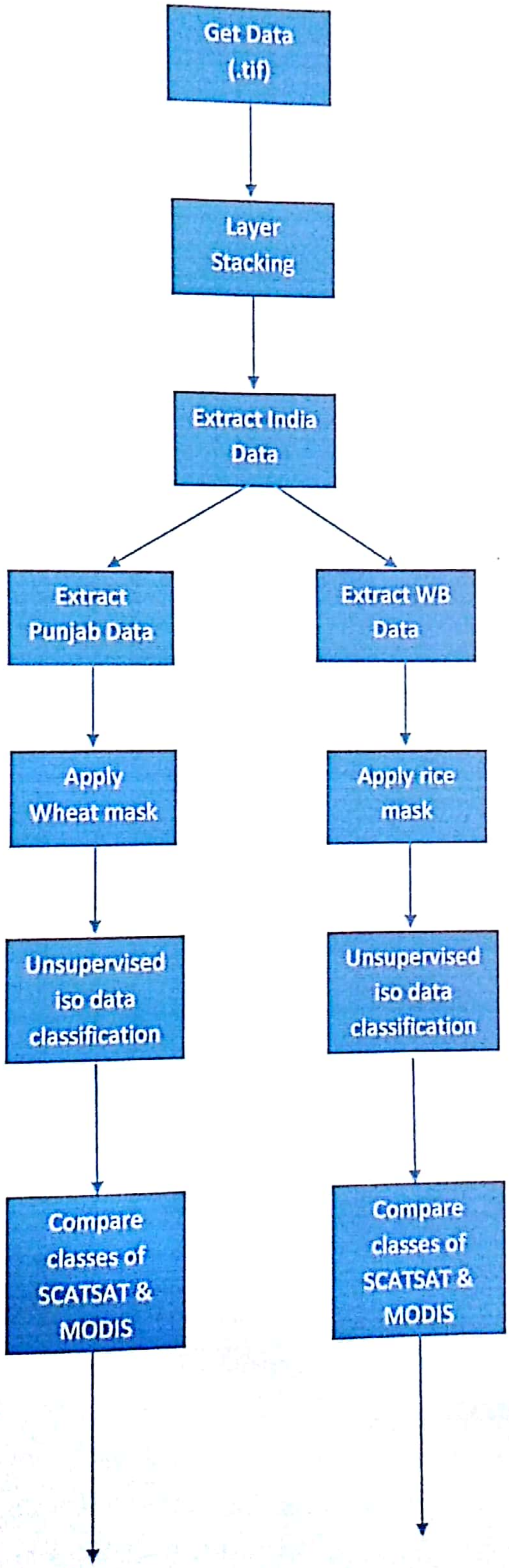
We compared matching classes between MODIS and SCATSAT-1 data classifications which gives us insight into relationship between them and patterns.

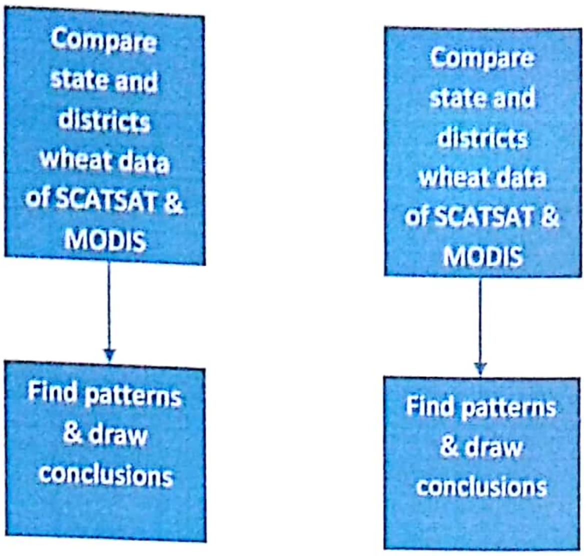
We obtained the ASCII data from these images and draw graphs for states and their districts showing patterns of the sigma value(SCATSAT) or NSVI value (MODIS) with respect to date.

We established relationship between the two types of graph patterns and inferred general relationships between them that can be used in predicting sowing date as well as in future study.

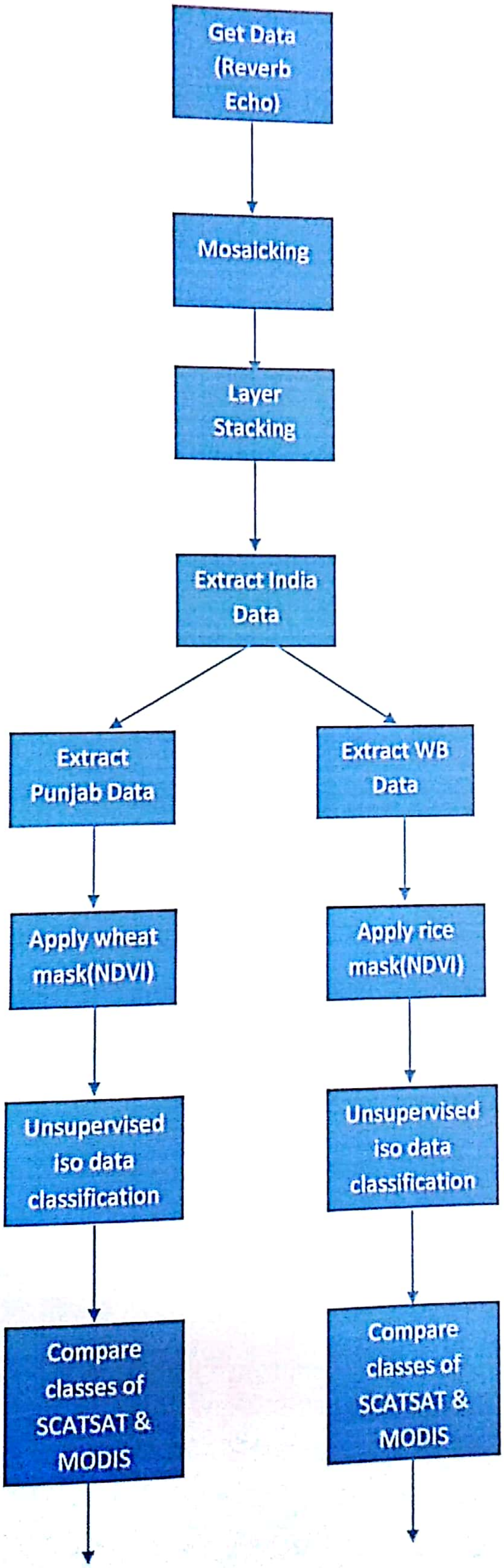
The following flow charts summarize the work procedure of the study.

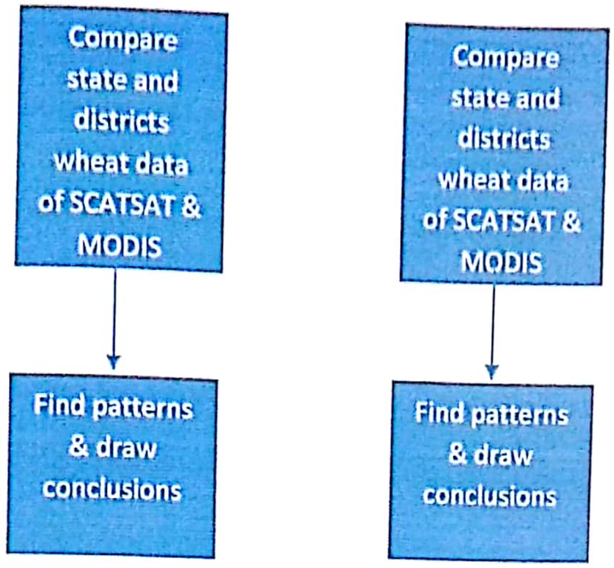
Procedural Chart [backscattering coefficient from SCATSAT-1] :




Compare state and districts wheat data of SCATSAT & MODIS
Find patterns & draw conclusions
Compare state and districts wheat data of SCATSAT & MODIS
Find patterns & draw conclusions

Procedural Chart [Timeseries NDVI from MODIS] :



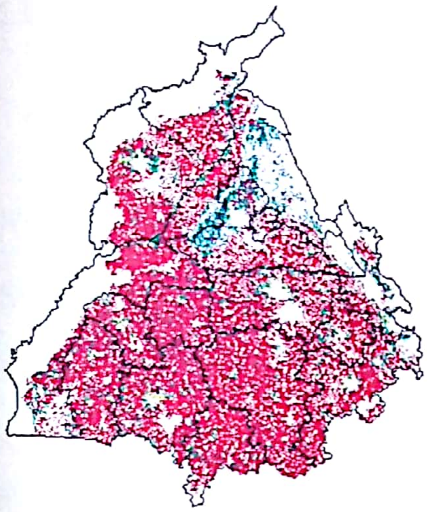

Compare state and districts wheat data of SCATSAT & MODIS
Find patterns & draw conclusions
Compare state and districts wheat data of SCATSAT & MODIS
Find patterns & draw conclusions

4. RESULTS

Wheat :

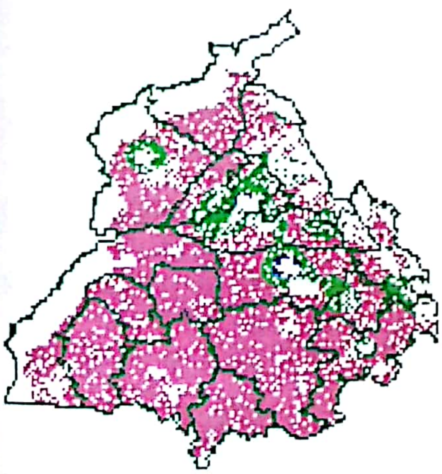
ISODATA [Iterative self-organizing data analysis] clustering classification:

Timeseries NDVI [MODIS]:

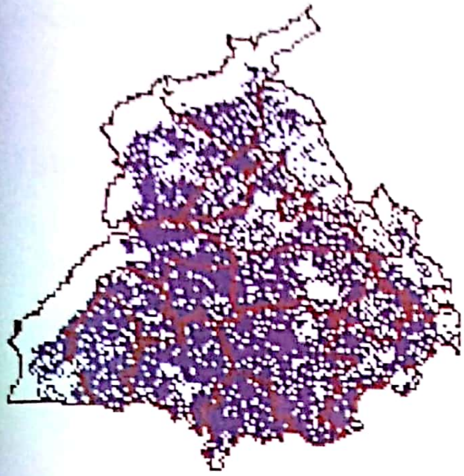


Backscattering coefficient [SCATSAT-1]:

SCATSAT-SH



SCATSAT-SV



No of classes:

SCATSAT:

SH – 3

SV – 1

MODIS:

NDVI – 2

Class matching :

Cyan – Green class match [SH-NDVI]

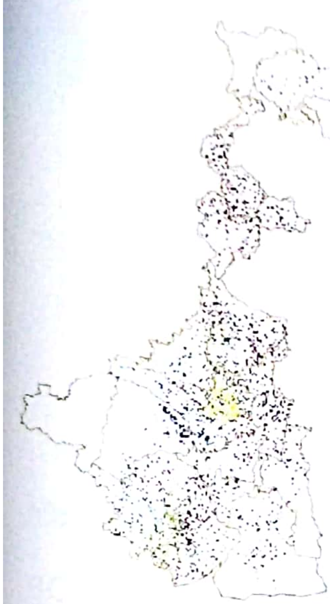
Pink – light purple class match [SH-NDVI]

Purple – pink class match [SV-NDVI]

Rice

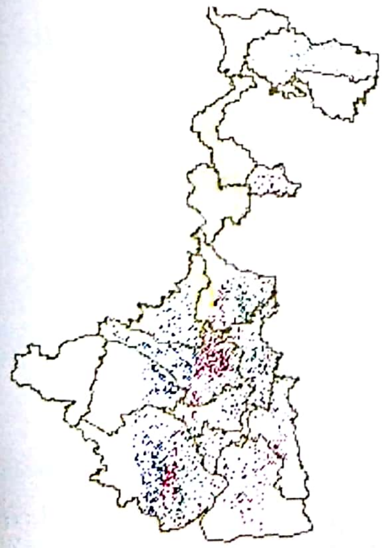
ISODATA [Iterative self-organizing data analysis] clustering classification:

Timeseries NDVI [MODIS]:

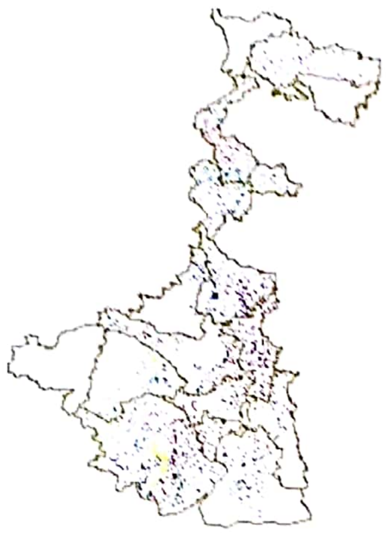


Backscattering coefficient [SCATSAT-1]:

SCATSAT-SH



SCATSAT-SV



No of classes:

SCATSAT:

SH – 8

SV – 9

MODIS:

NDVI – 8

Signature study of rice and wheat crops using SCATSAT-1 data gives results such as classifications of crop based on growth area and growth condition. We can compare the classifications obtained with two methods.

The graph plotted between MODIS NDVI and SCATSAT SH / SV sigma values w.r.t. date is used to infer relationship between the two.

The dip in graph of NDVI is observed maybe due to irrigation of plant in the period. Number of crests in NDVI graph matches with number of irrigations in the period.

The relationship observed between the two for wheat crop can be used to find transplanting date of crop. Transplanting date comes out to be first positive change in NDVI – 15 days.

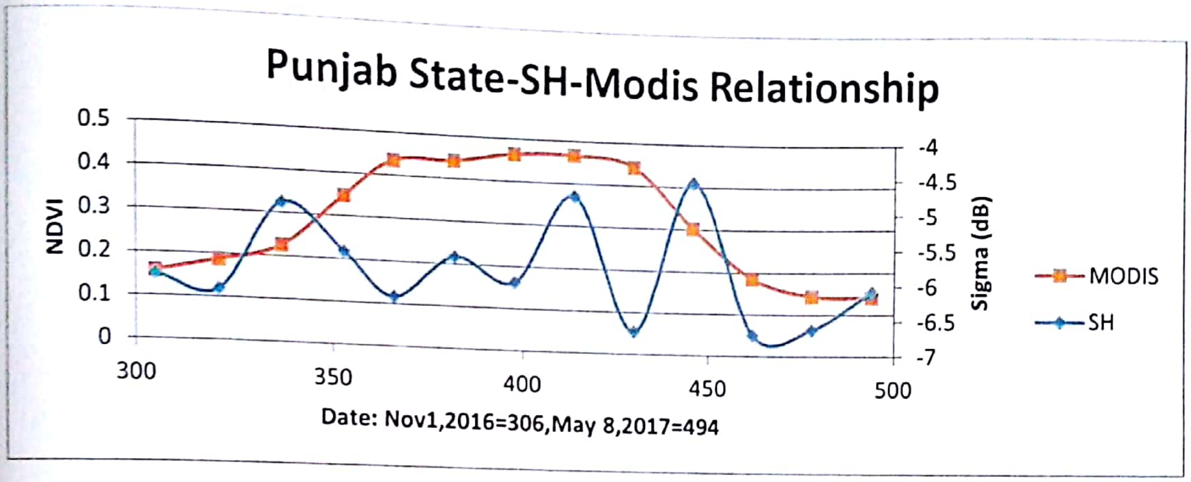
Graphs and relationships inferred are documented below followed by conclusion and references.

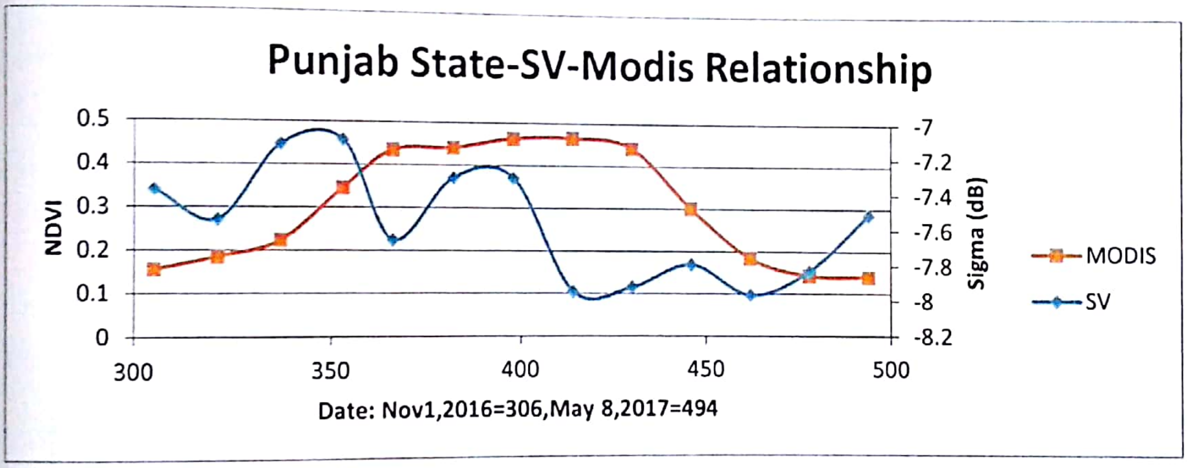
The following graphs for time series NDVI and backscattering coefficient are used to find relationship between the two and to further use that relationship to find transplanting date if possible and in future studies.

WHEAT :

State: Punjab

Relationship obtained for Punjab and its districts:





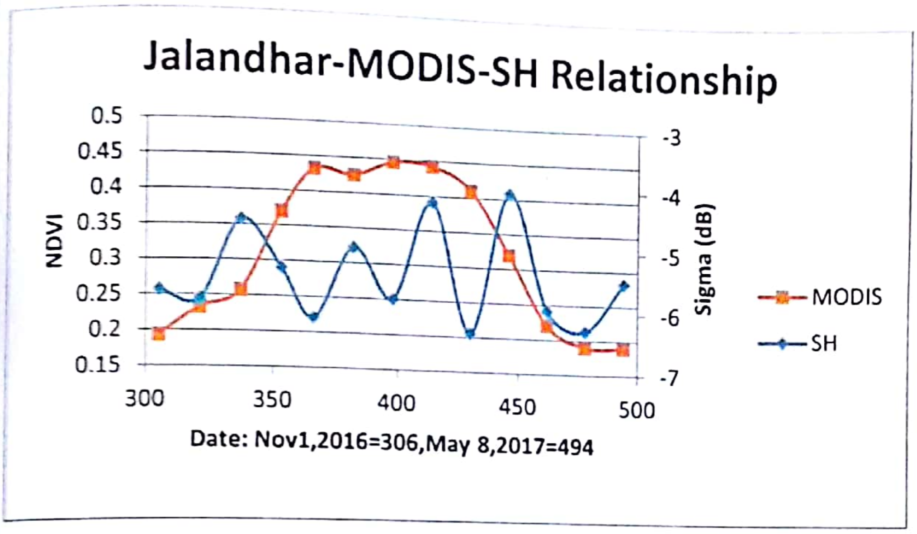
Infletion date :319

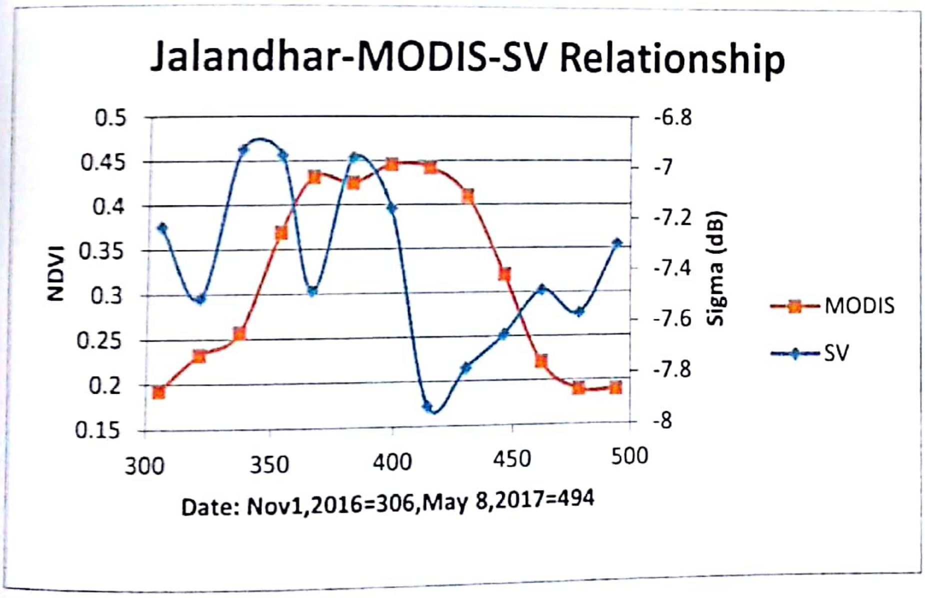
Peaks date SH: 337,382,412,446

Peaks date SV: 353,398,446

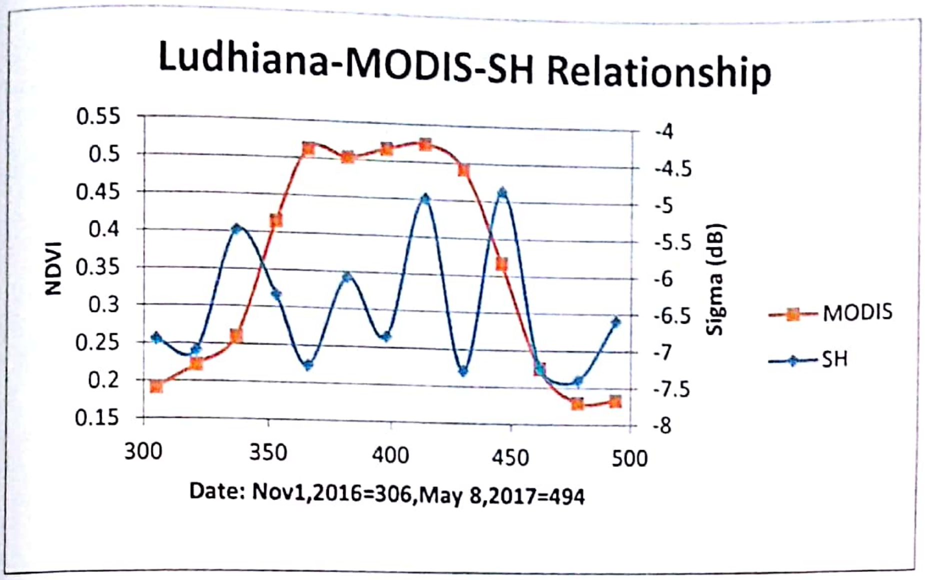
It is possible to conclude that irrigation smoothes out surface which causes dip in NDVI value. The irrigation schedule matches with NDVI graph crests which further strengthens this observation.

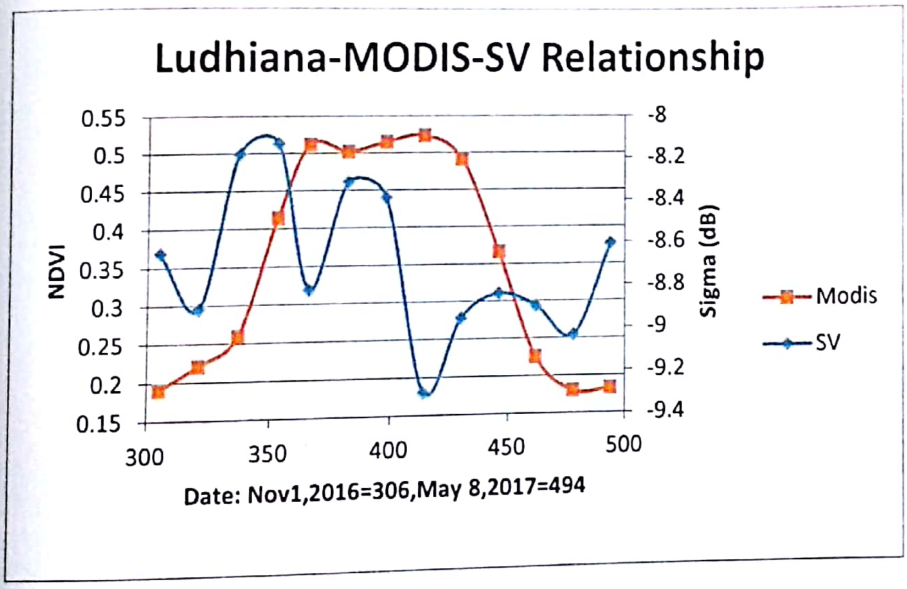
District : Jalandhar



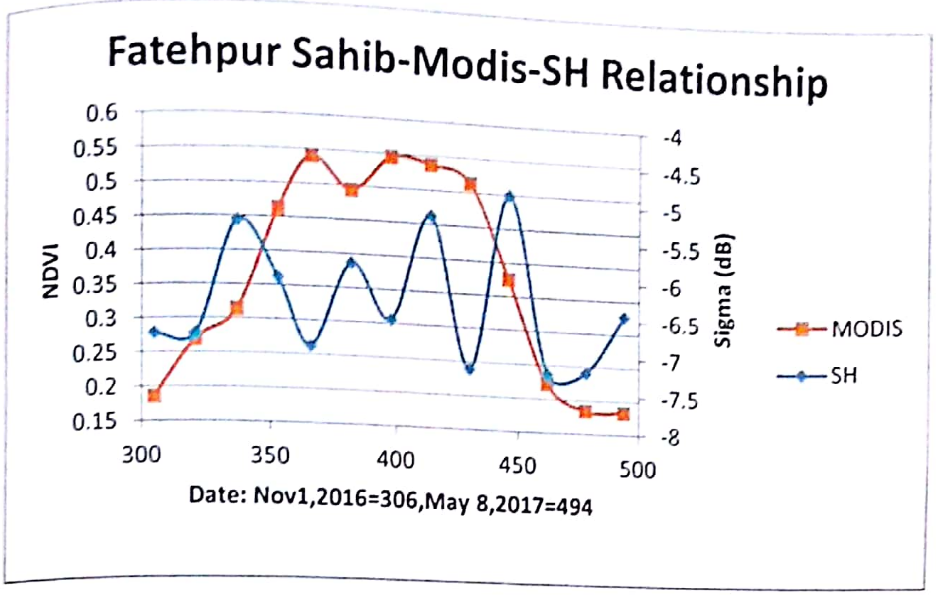


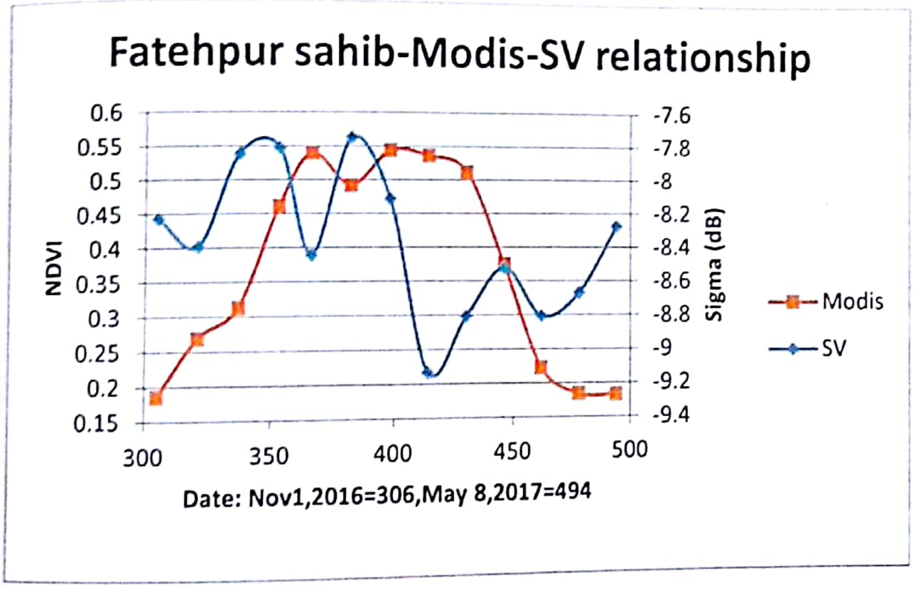
District : Ludhiana





District : Fatehpur Sahib





General Relationship identified:

First peak of Modis NDVI matches with 2nd crest of corresponding SH & SV data.

Since general irrigation schedule is known, we can find first crest of NDVI from SCATSAT data and hence predict sowing date.

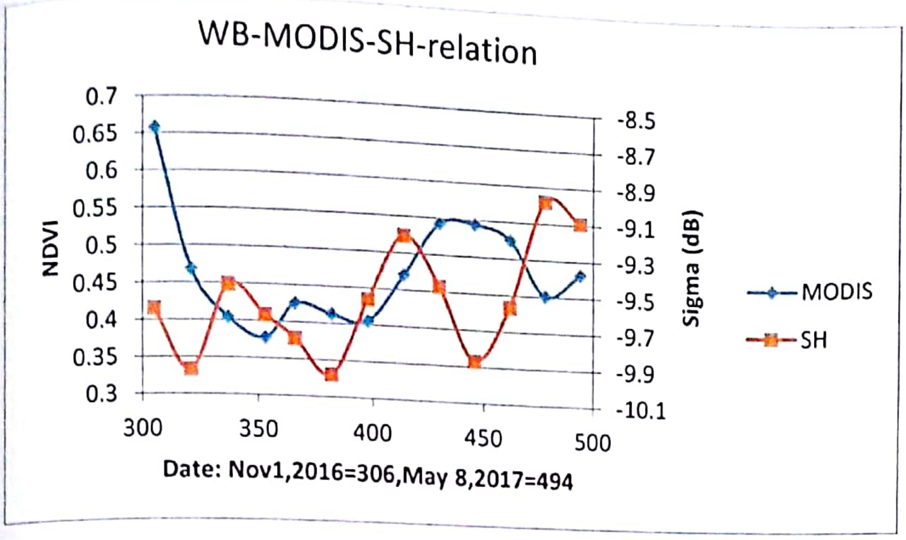
Finding transplanting date:

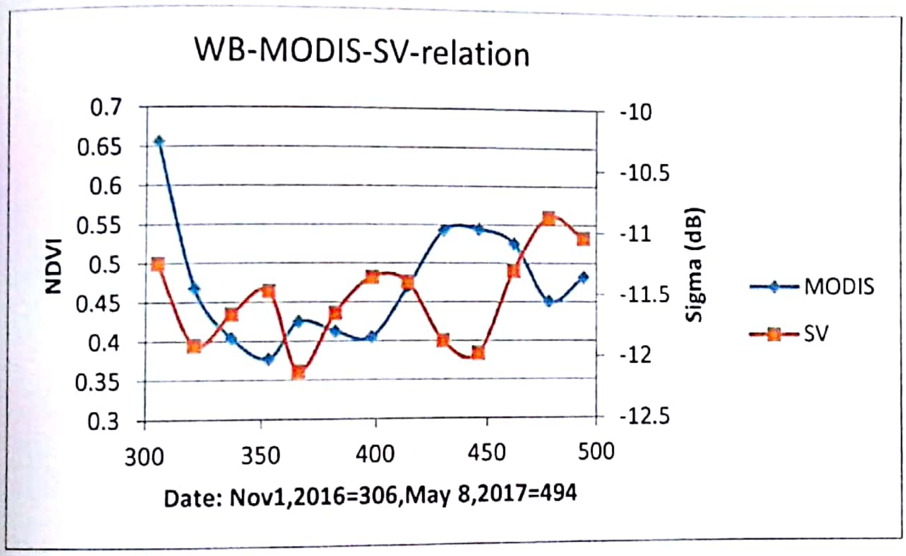
15 days before first positive change (first crest of NDVI).

Rice:

State: West Bengal

Relationship obtained for West Bengal and its districts:



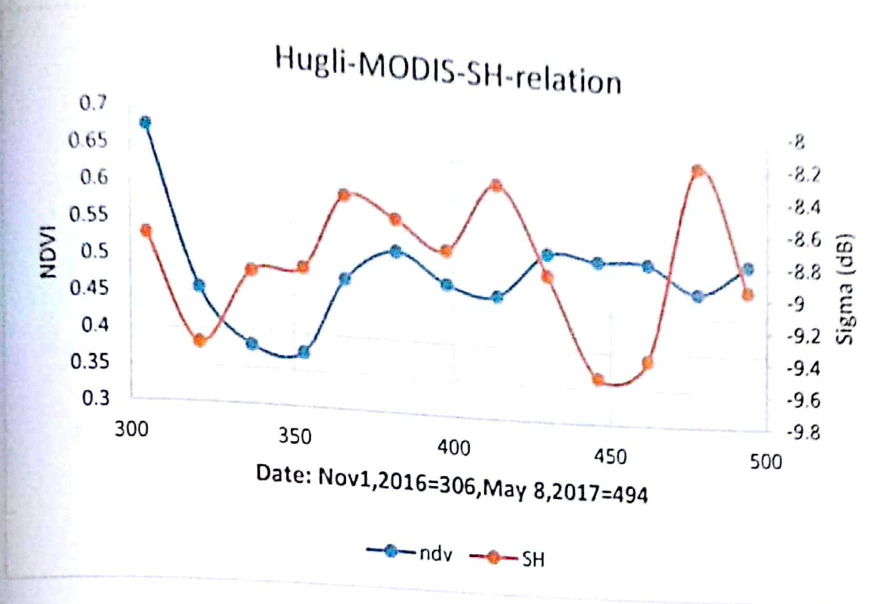


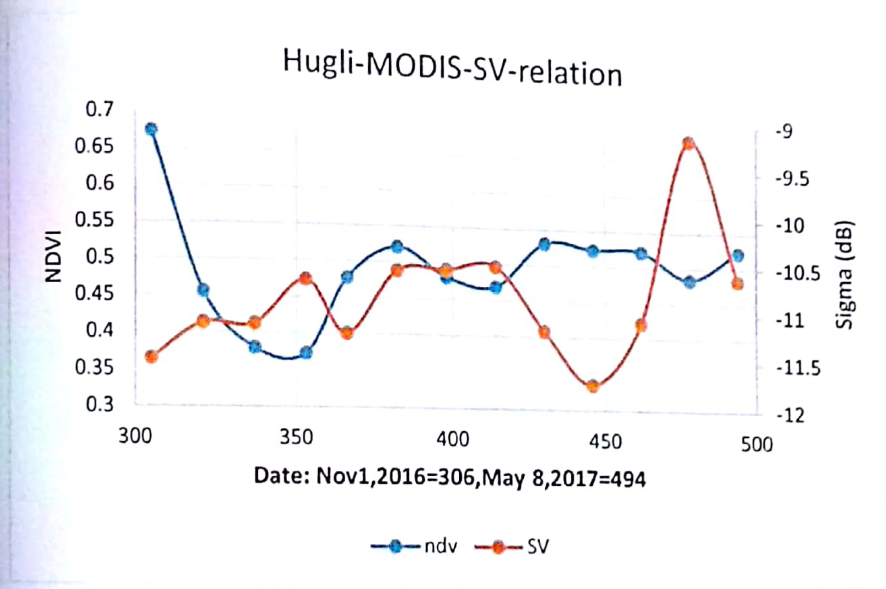
Infletion date: 352

SH peaks date : 337,414,478

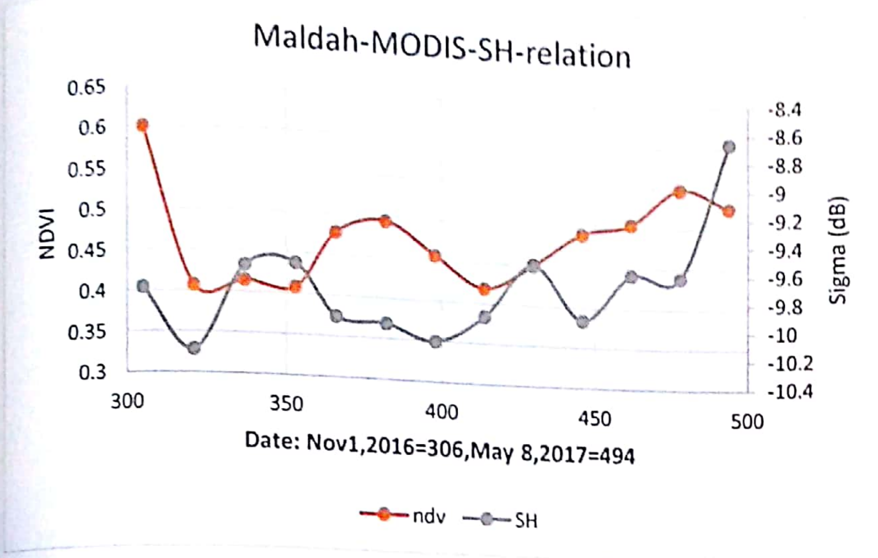
SV peaks date: 352,398,478

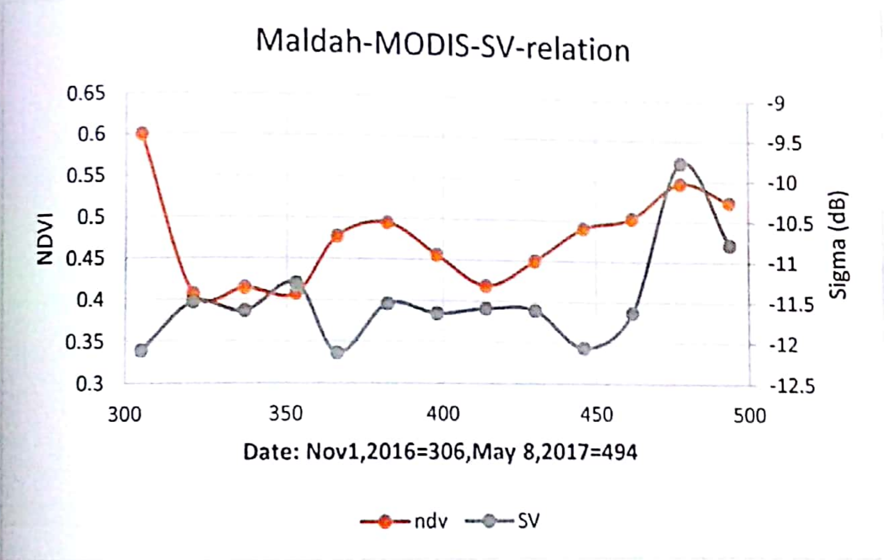
District wise: Hugli



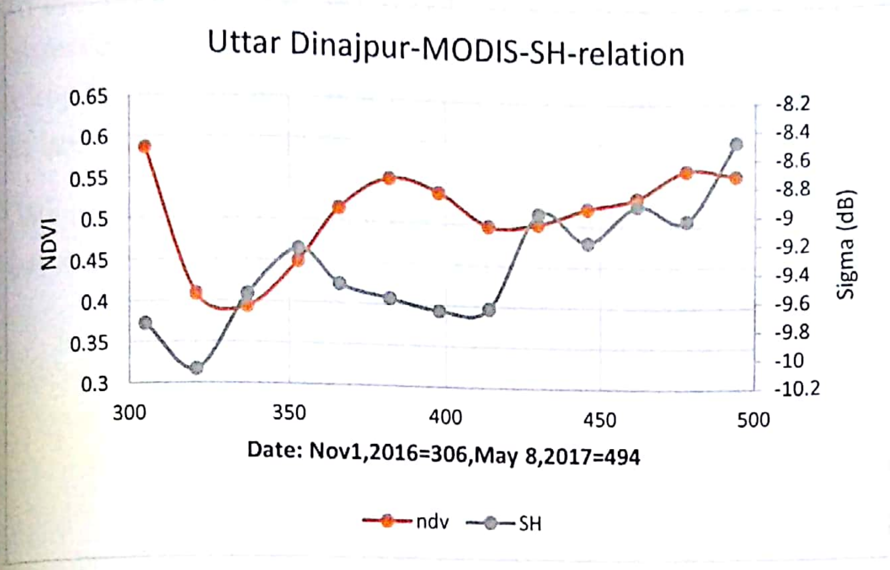


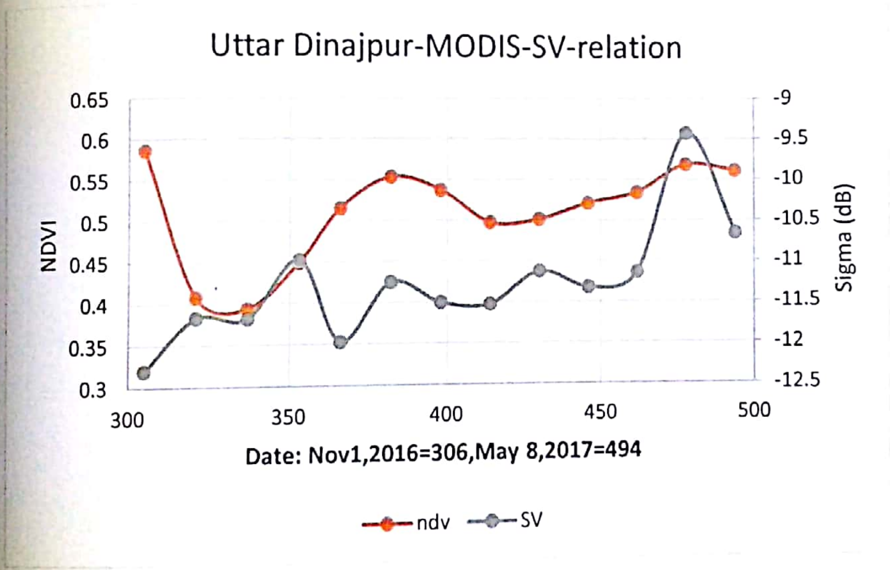
District wise: Maldah





District wise: Uttar Dinajpur





Relationship identified: planting date difference identified. Check with ground truth.

In this study, planting date observed with SCATSAT-1 comes after planting date observed with NDVI. Here the difference between planting date can be considered a key factor in establishing relationship. Planting date difference is almost constant as seen from the graphs.

We can confirm the actual planting date when checking with Ground Truth(GT) values. This part of the study is to be followed later.

5. CONCLUSION

With this study, we've been able to understand the possible reasons why the values obtained with scatterometer are what they are and how they differ. We've been able to classify crops growing areas into different categories. Examining these categories with different explanations of their existence is yet to be followed in future studies.

We've been able to establish & understand the relationship between SCATSAT and MODIS NDVI data in some cases and we've also been able to predict sowing date of crops using these relationships and known factual data.

It can be concluded that identified relationship between MODIS and SCATSAT data can be used to get insights into situations with only SCATSAT-1 data that'd generally require NDVI values to be presented.

6. FUTURE WORK

We can extend this study to identify other stages of crop growth like panicle initiation, maximum tillering, ripening etc.

In case of rice crop, the relationship identified is the difference observed in planting date between two scatterometers. The actual value of planting date is to be confirmed with Ground Truth (GT) value. Thus this part of work is yet to be followed in future.

We can predict optimal time for sowing and ripening and after combining it with weather data to increase accuracy, we can provide this information to farmers for future planning.

Further studies are needed to verify the results. A lot of progress is yet to be made in the study horizon that can predict & conclude results with certainty.

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