PLANT DISEASE AND PEST MONITORING USING GIS

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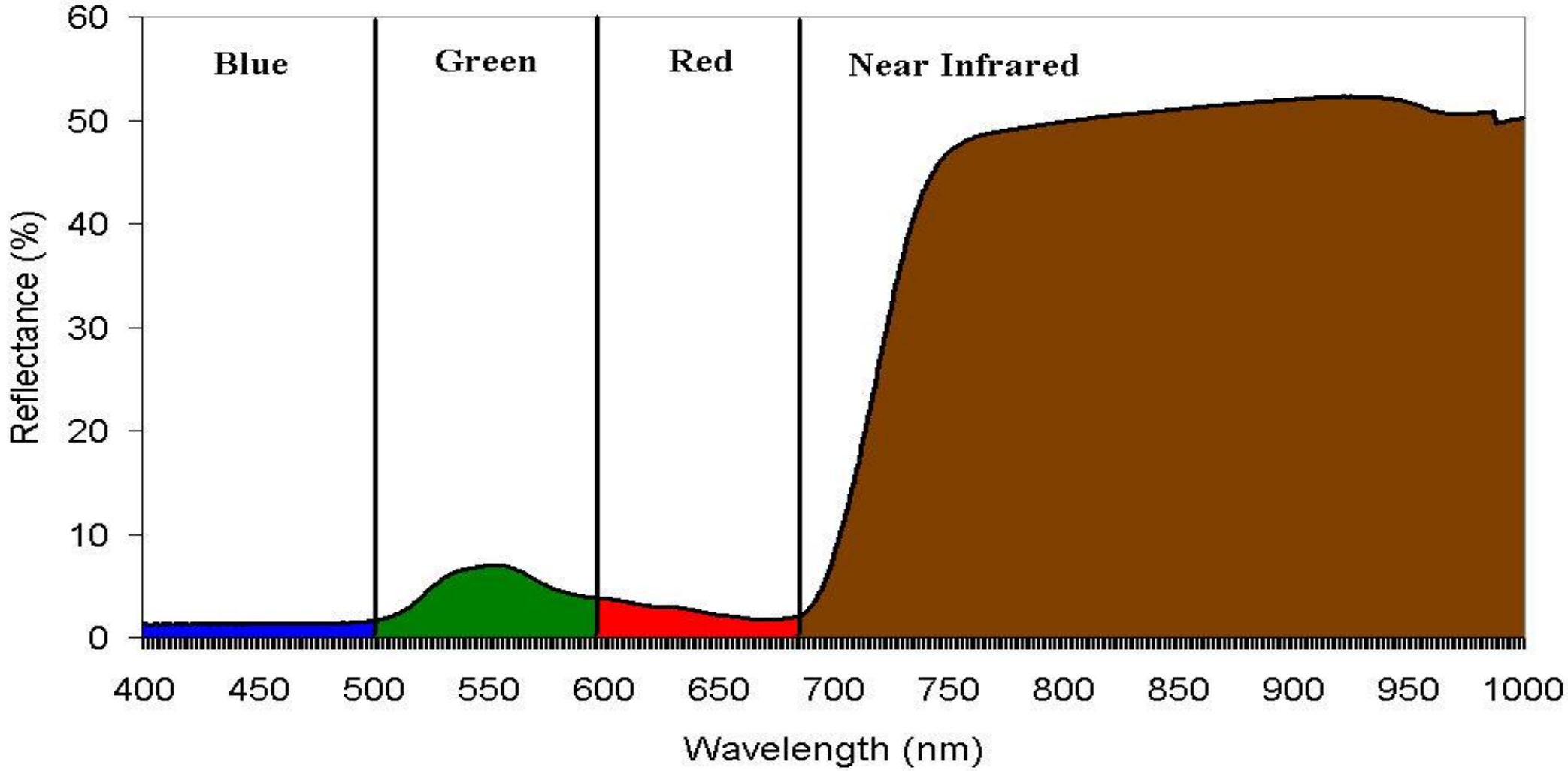
Introduction

- **Farm information can be organized in spatial databases because agricultural systems are inherently spatial**
- **Agricultural systems create spatial heterogeneity and as a result, patchiness is the rule in the occurrence and distribution of plant pathogens and disease**
- **Plant disease management practices can be improved by putting epidemiological information in the same format as other farm information using a geographic information system (GIS)**
- **GIS can be adapted to any size operation ,and data can be incorporated at any scale from a single field to an agricultural region.**
- **Geo statistics tools can be used for the analysis of spatially distributed variables and helps in the predictions of areas not covered by sampling**

Leaf Reflectance Patterns Of Electromagnetic Radiation

- Plants have specific ways to reflect electromagnetic radiation
- Reflectance of vegetation is very low in the blue and red regions of the electromagnetic spectrum, slightly higher in the green region and high in the near infra-red.
- Remote sensing can take advantage of the particular manner that vegetation reflects the incident electromagnetic energy and obtain information about the Vegetation Spectral Signature
- In addition to chlorophyll, the leaf tissue contains other pigments, such as carotenoids, anthocyanins and others, which are also responsible for the absorption of light.
- These pigments absorb, most of the visible electromagnetic energy, especially in the blue and red region
- Absorption in the green regions is slightly weaker, which causes vegetation to appear green to our eyes.

- Near infrared (NIR) energy is not affected by those pigments and almost completely penetrates the pallisade parenchyma
- Presence of air spaces in the parenchyma causes the refraction of the NIR energy in various directions
- Approximately half the energy exit the leaf from the lower epidermis and the other half from the top epidermis, towards the sky
- Remote sensors that record the reflected energy in the visible and near-infrared regions of the spectrum, will record a very weak signal in the blue and red regions, slightly stronger in the green and very strong in the near-infrared.
- The combination of low visible reflectance and high near-infrared reflectance is unique for most vegetation types and that is why it is known as the vegetation spectral signature


Blue
Green
Red
Near Infrared
Reflectance (%)
60
50
40
30
20
10
0
400
450
500
550
600
650
700
750
800
850
900
950
1000
Wavelength (nm)

Plant stress

- The normal growth process of a plant can be disrupted when it goes through a stress period.
- Stress, can be due to nutrient deficiency,pest and diease attack, drought etc
- When a plant is stressed, it usually expresses certain visible symptoms
- Stress symptoms may appear in all the plants of the field or in some portions of the field, depending on the cause

Loss of chlorophyll

Fungal attack

Some sections of the soybean leaves have been infected by the fungus (soybean rust) and have changed colour from green to yellow, because chlorophyll has been destroyed. The fungus attacks the cells by penetrating the walls and using their contents and nutrients to feed itself and develop

Different fungi show different symptoms on the plant leaves. In the picture above, the fungus *Cercospora* has infected parts of the leaf and the infection has begun spreading outwards. As the infection spreads, the cells initially lose their chlorophyll and then dry out and die (brown patches).

Nutrient deficiencies

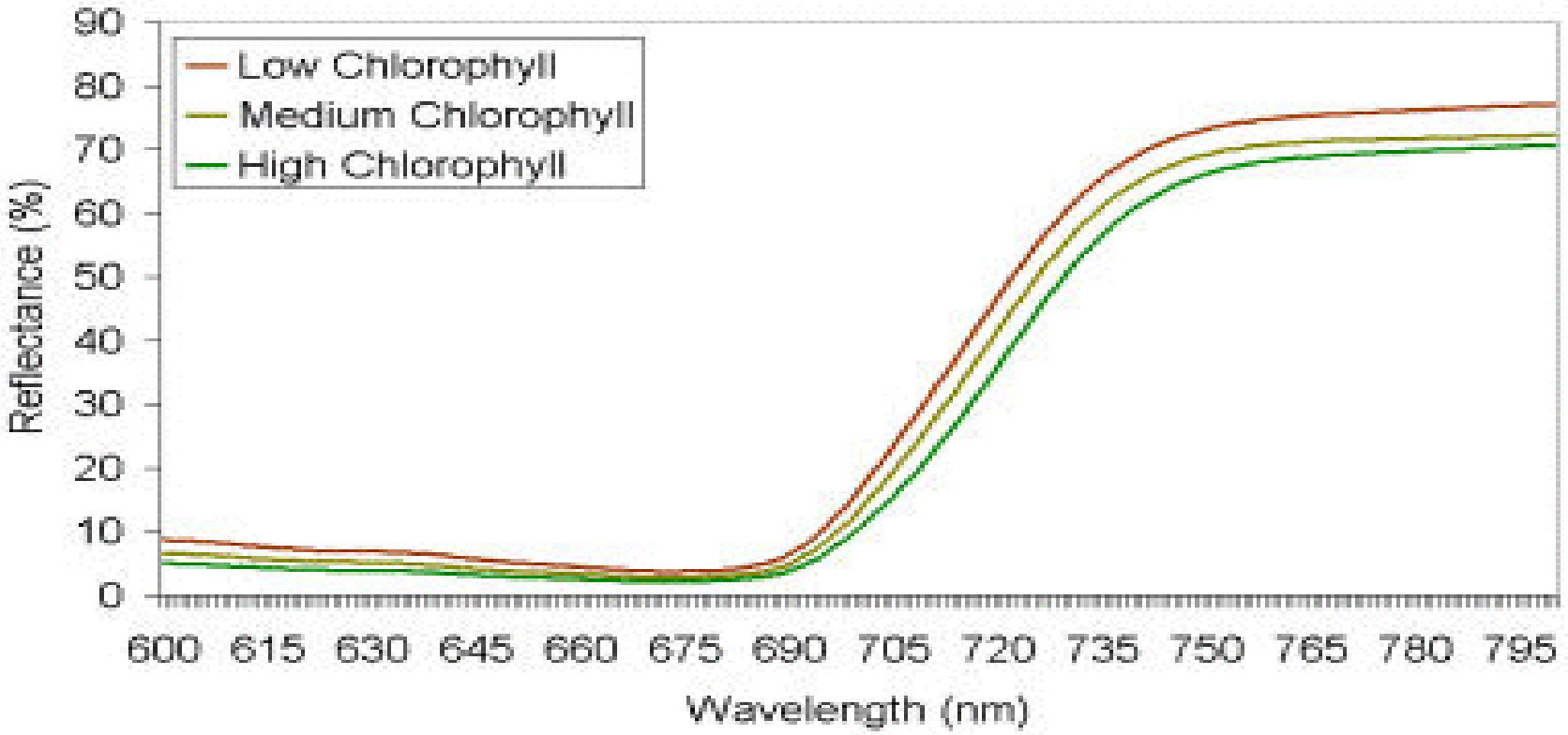
- Deficiency of nutrients is expressed as specific symptoms
- Nitrogen deficiency for example, first causes the yellowing of the leaf area around the veins and progressively the yellow area extends to the rest of the leaf
- Deficiency symptoms are first observed in the older, lower leaves because of greater mobility of nitrogen within the plants
- Each nutrient develops characteristic deficiency symptoms which are expressed by plants

Nitrogen deficiency seen in the older leaves

The Red Edge

- The red and near-infrared regions are adjacent (red is approximately between 600 and 700 nm and near-infrared begins at around 700 and stretches to about 1200 nm)
- Low vegetation reflectance in the red regions is immediately followed by a sharp increase to the high reflectance in the near-infrared.
- This steep increase in reflectance in the 690-730 nm region is known as the red edge

Red edge shift, due to changes in chlorophyll concentration



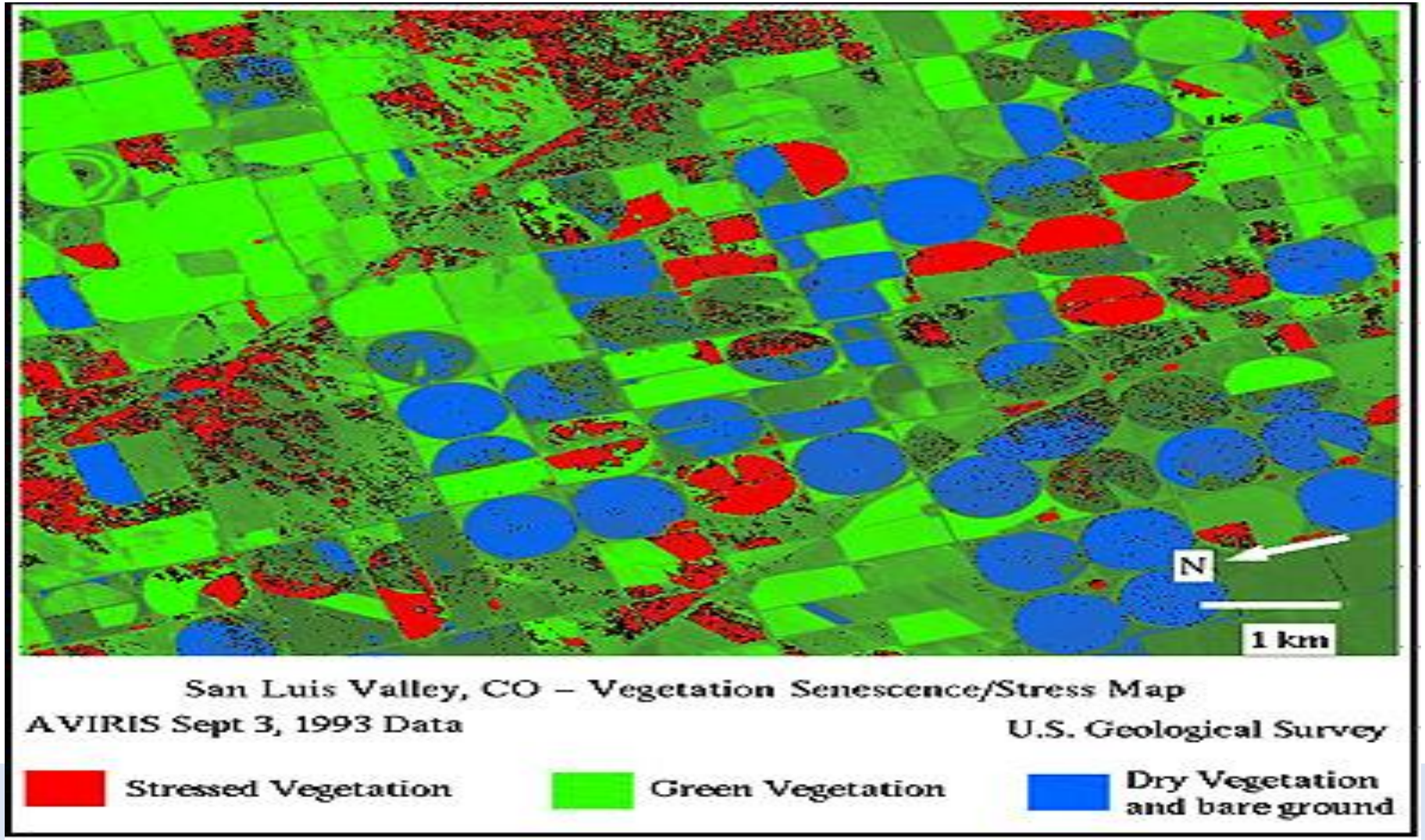
- High chlorlophyll increases absorption in the red region and pushes the red edge to longer wavelengths.
- In the figure above, we can see the reflectance of three similar plant canopies.
- The difference between the three is in the chlorophyll concentration.
- The red, yellow and green lines are from plants with low, medium and high chlorophyll concentrations,
- As chlorophyll concentration increases, the absorbency in the red region also increases, resulting in lower reflectance
- . In addition the absorption well (the area where the absorbency is noted) increases in width
- This causes the red edge to move towards longer wavelengths (towards the near-infrared) and its slope to become less steep.

Evolution of vegetation indices

- Most vegetation indices, take advantage of the difference in reflectance between the visible and the near-infrared region.
- Chlorophyll primarily found in plants and has a unique absorption in the red region
- This region is often selected, instead of using the visible region as a whole.
- This first index used the NIR/Red ratio and this vegetation index help to identify plants under stress
- The vegetation index give us an indication on the amount of chlorophyll present in the plants.

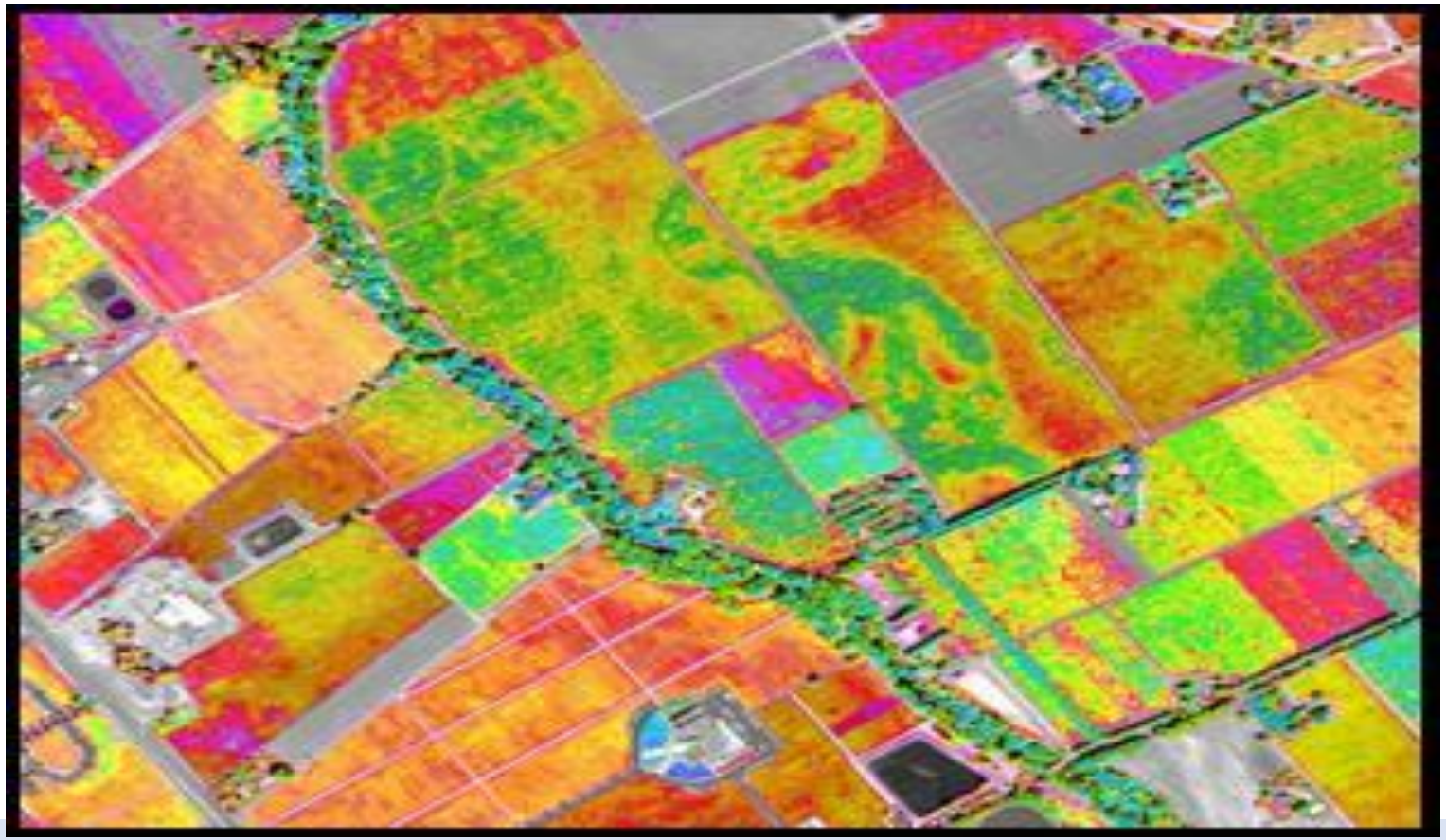
Image, used data captured by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) sensor, which was mounted on an aircraft.

Classified image above below the fields that appear blue are without vegetation (bare soil) Green patches are covered with vegetation



Classification product of a QuickBird satellite image, using vegetation indices. Green colour represents plants with good health.As the colour moves from green to yellow and then to red, the plant health status is reduced.Gray areas represent barren fields. Depending on the patterns in the spread of the stress we can assess the cause of the stress

Variations of crop health within the fields, using Quick Bird data.
Source: Satellite Imaging Corporation



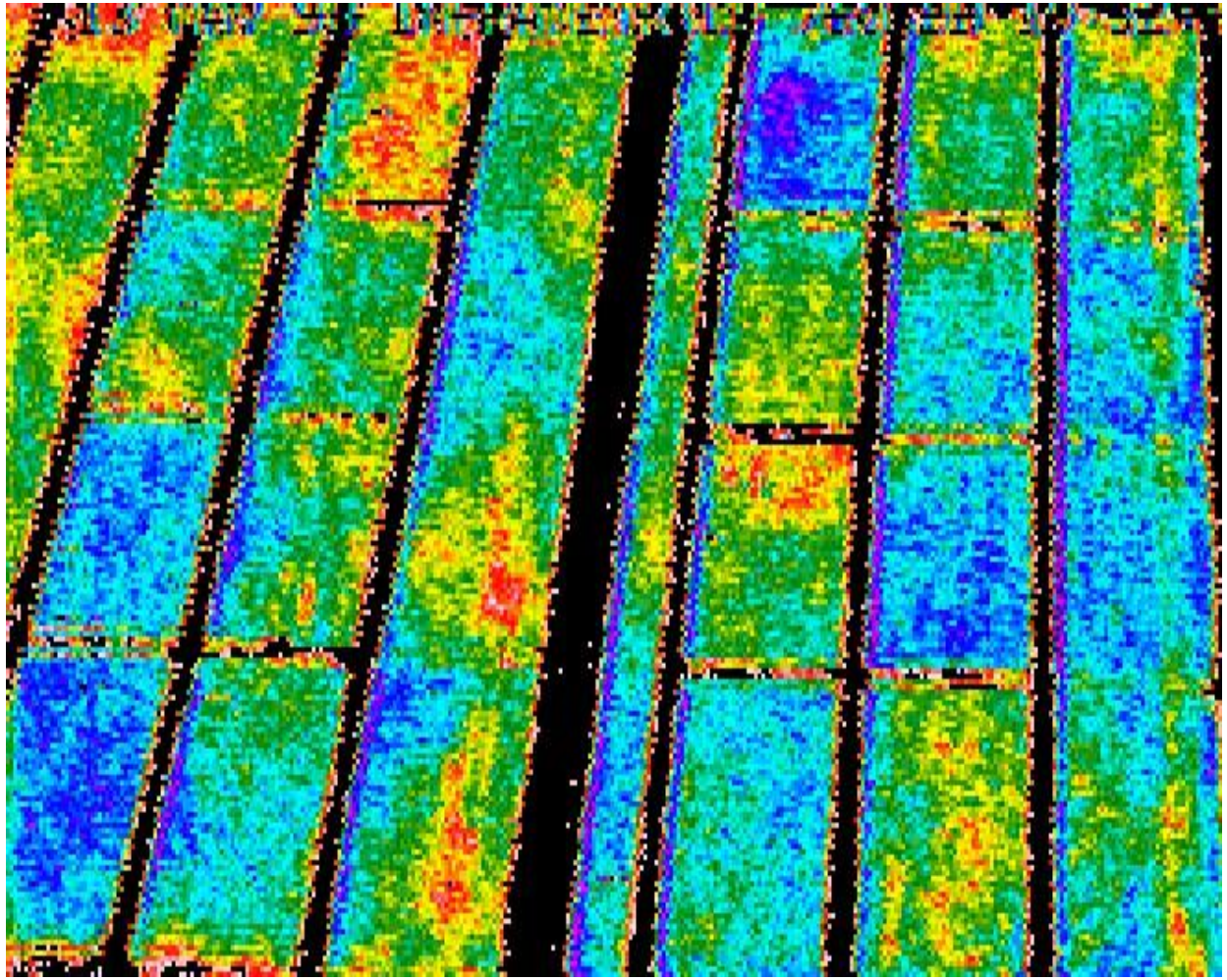
Stomata of the plant

Estimating water stress in plants

- Like many organisms, plants require water for many biochemical processes and is the basis for survival
- Water is also the "means of transportation" for nutrients from the soil to every part of the plant.
- Water enters the plant through the roots, travels through the main stem and the branches, eventually reaching the leaves.
- From there, through the leaf pores known as stomata, it is released into the atmosphere.

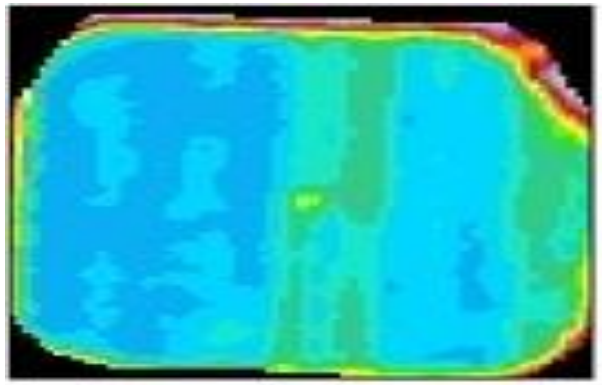
  as transpiration.
- All the biological processes taking place within a plant, produce heat.
- The transpiring water, captures that heat and removes it from the plant when it transpires through the leaves
- When there is not enough water and the plant is under stress, it cannot lose heat through transpiration the plant's temperature increases.
- This increase in temperature can be detected with remote sensing, by using parts of the spectrum that are sensitive to heat.

Estimating water stress in plants

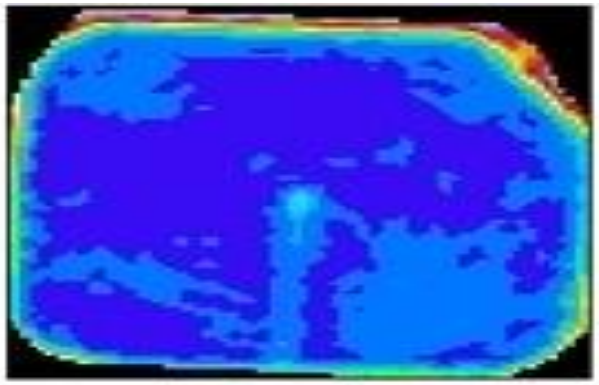


- Image above, shows the variability of water concentration within each field
- Blue pixels represent plants with high water content
- Green shows plants with average water content and red plants shows low water availability.
- This variability is because of the varying soil characteristics and available water capacity
- Partial vegetation cover affects the thermal signal recorded by the sensor indicating higher soil temperature
- Higher soil temperature is often confused with water stress
- Ideal to correlate leaf area index with water stress to reduce effect of soil influence.

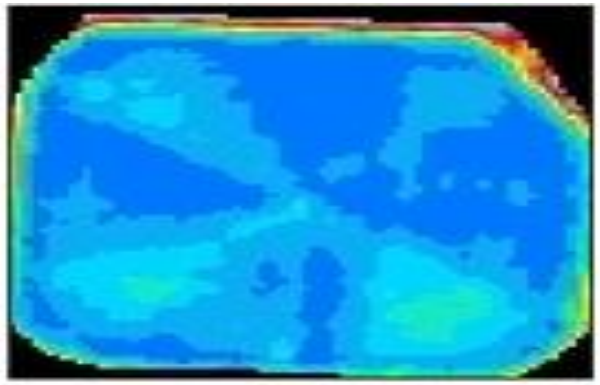
Vegetation response to irrigation and its diminishing effects through time.A pattern is occuring in August and September, where some areas have less water than others. Source: Satellite Imaging Corporation



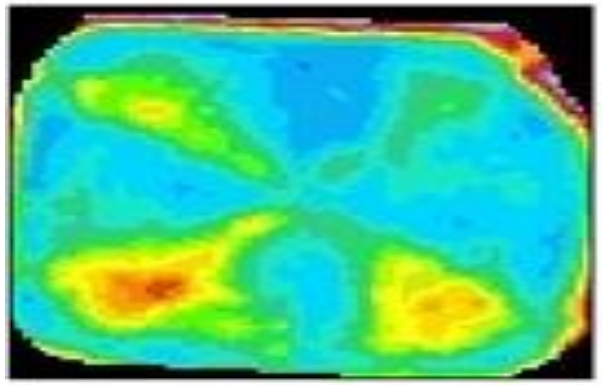
June 24, 2003



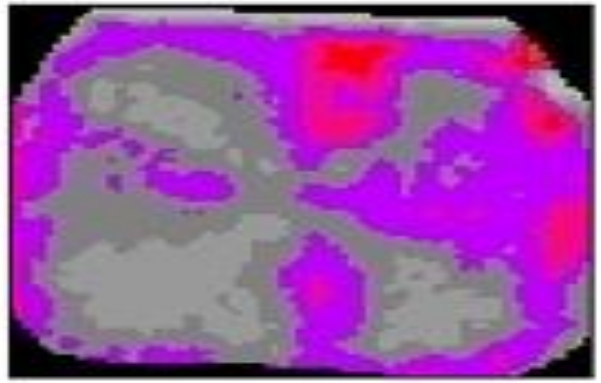
July 19, 2003



August 10, 2003



August 25, 2003



September 20, 2003

In the example above, the effects of irrigation on the amount of water within the plants can be seen. Irrigation has taken place between June 24 and July 19, producing high water content in the second image. Gradually, the amount of water is reduced as we move from summer to autumn.

Combating disease and pests

- **Combining agricultural knowledge with remotely sensed data, it is possible to have early warning and prevent a pest or a disease from affecting the crops, by taking appropriate action at an early stage.**
- **pesticides need only be applied at the highlighted areas, reducing the cost of the treatment and reducing environmental hazards**
- **In addition to loss of chlorophyll, pest and diseases can cause the destruction of whole leaves.**
- **This leads to a reduction in the total leaf area and reduction of the plant's capacity for photosynthesis**
- **Estimating the Leaf Area Index (LAI) of a group of plants helps in identification an insect attack at an early stage and warn the farmers to take the appropriate measures.**

The above multispectral image shows cotton plants that because of favourable conditions, are growing faster than others. These plants (appearing in red) are the most probable targets for an attack of

A moth larvae eating a leaf. Damage can be detected, by RS by estimating LAI

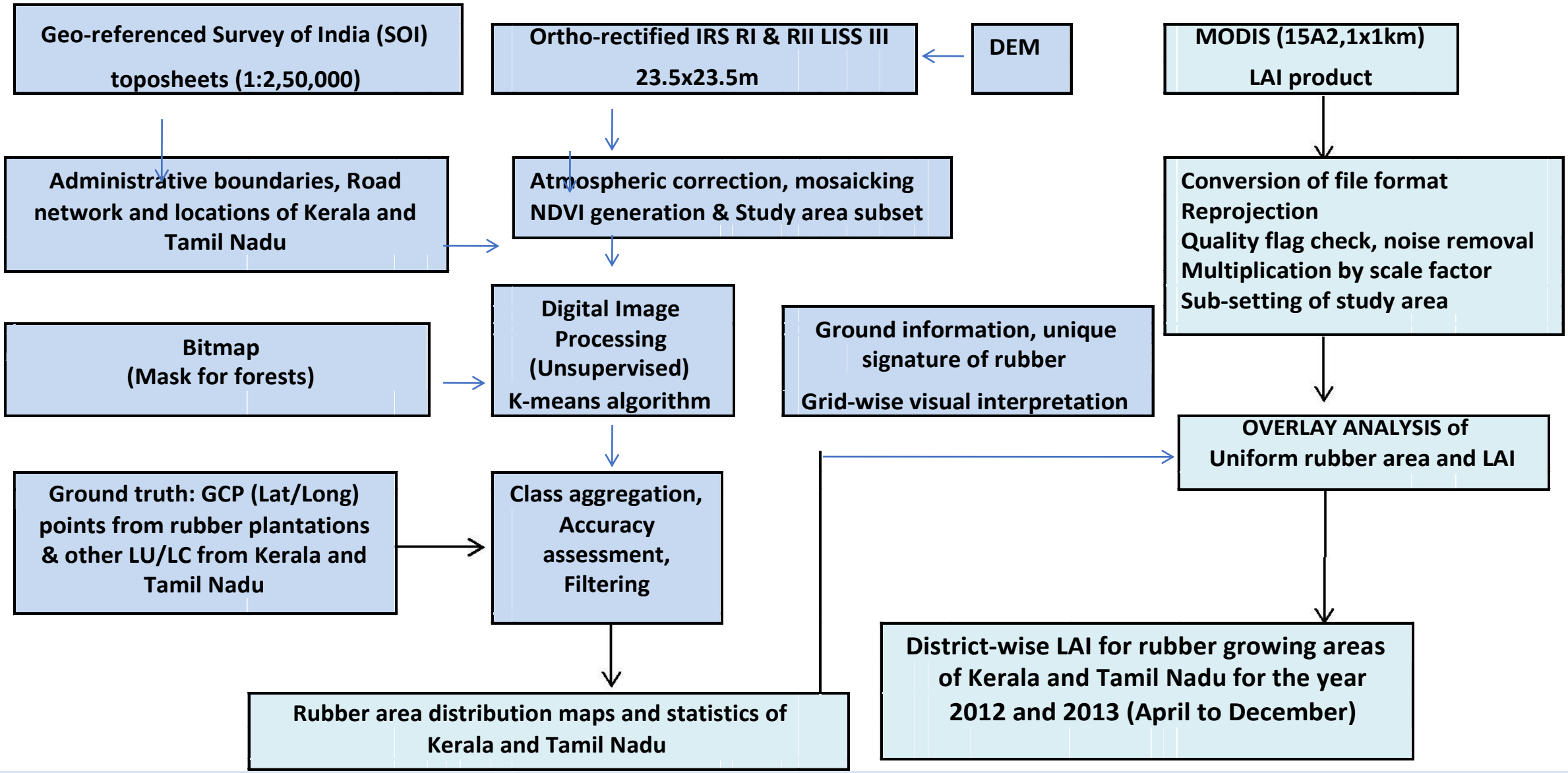
GIS as a tool for real time monitoring of leaf retention in natural rubber plantations affected by abnormal leaf fall disease – a case study

Methodology

- LAI, ratio of leaf area to land area was estimated using data from MODIS Terra satellites
- Monthly composite 1km LAI tile data (MOD15A2) covering the study area (Kanyakumari district of Tamil Nadu in the south to Kasargod district of Kerala in the north) for the period April to December 2012 and 2013 were downloaded from the USGS site
- MODIS Hierarchical Data Format (HDF) was converted using MODIS tool
- The study area was clipped and scale factor was applied to MODIS data sets for generating LAI values
- Rubber area distribution map developed earlier using satellite imageries (RRII, 2014) was overlaid over the LAI raster images and LAI quality parameters of rubber growing areas were extracted
- District-wise LAI images were generated and monthly district mean LAI was calculated.

Abnormal leaf disease of Rubber (Incidence during june/july)

Estimation of leaf area in Rubber



Results

- LAI during April/ May coincides with the phenological stage of mature refoliated leaves (maximum foliage retention) and normally, June/July coincides with peak incidence of abnormal leaf fall disease (least foliage retention).
- A weighted mean LAI for the entire period of April to December was calculated for 2012 and 2013.
- Multiplying the mean LAI for each district for the year with the per cent of total area under rubber in the respective district
- This ensured that LAI for each district had different weightage according to the extent of rubber area
- Leaf retention is absolutely essential for latex production
- Loss in area-weighted LAI is reflected as lost yield which we expect could be in the range of 10-15 per cent reduction in yield in 2013 compared to 2012

Limitations and scope of study

- **Coarse spatial resolution (1Km) of MODIS LAI data**
- **More spatial accuracy can be achieved through MODIS LAI 250m product.**
- **In-situ measurements of LAI through out the year would help to relate satellite based LAI- NDVI and phenological cycles of rubber plantations and yield.**
- **Potential of MODIS terra satellite data for monitoring leaf retention of rubber plantations by estimating LAI in different seasons has been proved**


Thank You