DEFINITION AND USES OF REMOTE SENSING AND CROP WEATHER MODELING – CLIMATE CHANGE AND VARIABILITY – EL- NINO, LA- NINA

Definition: Remote sensing is defined as the art and science of gathering information about objects or areas from a distance without having physical contact with objects area being investigated.

Uses: Remote sensing techniques are used in agricultural and allied fields.

1. Collection of basic data for monitoring of crop growth
2. Estimating the cropped area
3. Forecasting the crop production
4. Mapping of wastelands
5. Drought monitoring and its assessment
6. Flood mapping and damage assessment
7. Land use/cover mapping and area under forest coverage
8. Soil mapping
9. Assessing soil moisture condition, irrigation, drainage
10. Assessing outbreak of pest and disease
11. Ground water exploration

Remote Sensing platforms:

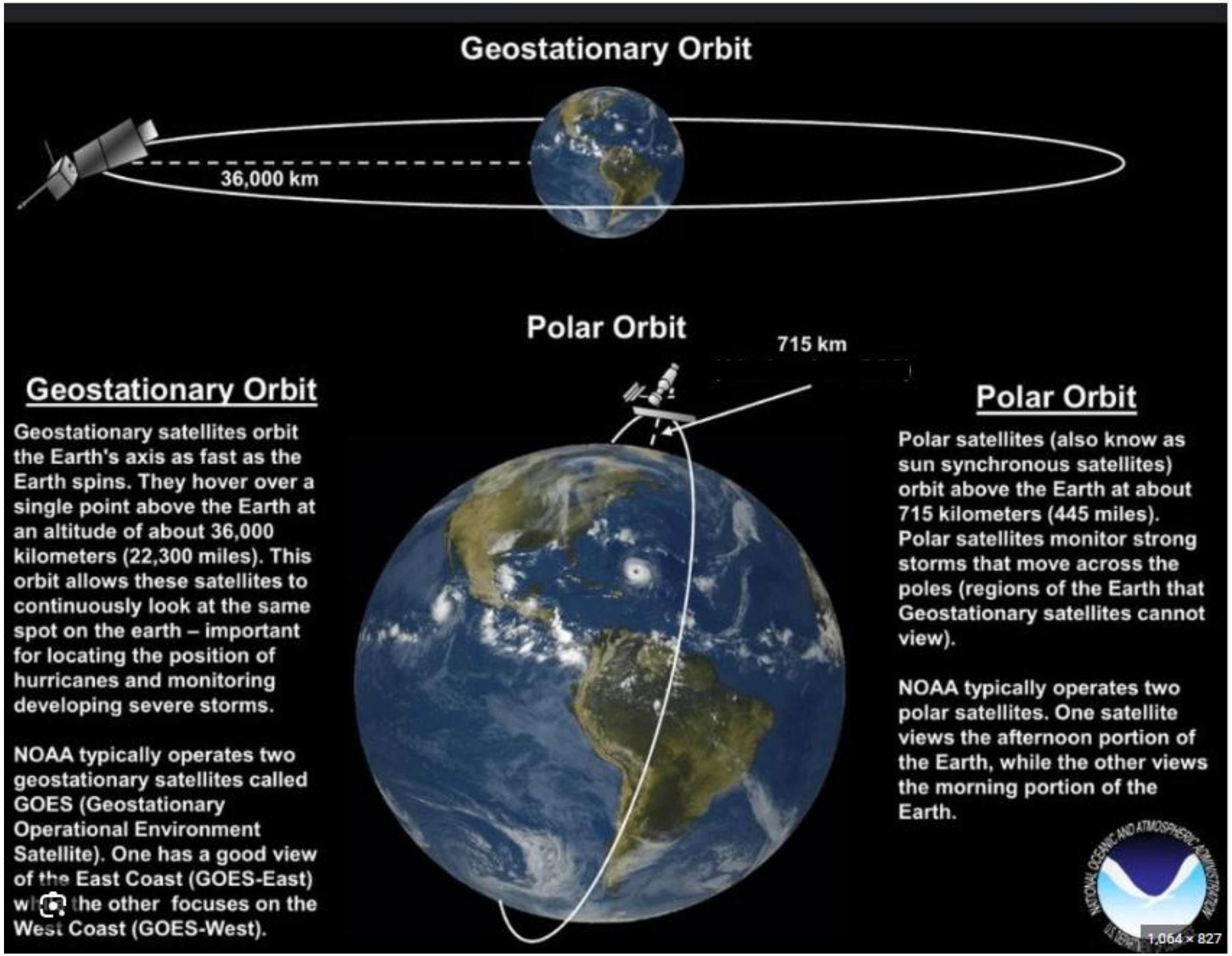
Three platforms are generally used for remote sensing techniques. They are ground based, air based and satellite based. Infrared thermometer, Spectral radiometer, Pilot-Balloons and Radars are some of the ground based remote sensing tools while aircrafts air based remote sensing tools. Since the ground based and air based platforms are very costly and have limited use, space based satellite technology has become handy for wider application of remote sensing techniques. The digital image processing, using powerful computers, is the key tool for analyzing and interpretation of remotely sensed data. The advantages of satellite remote sensing are:

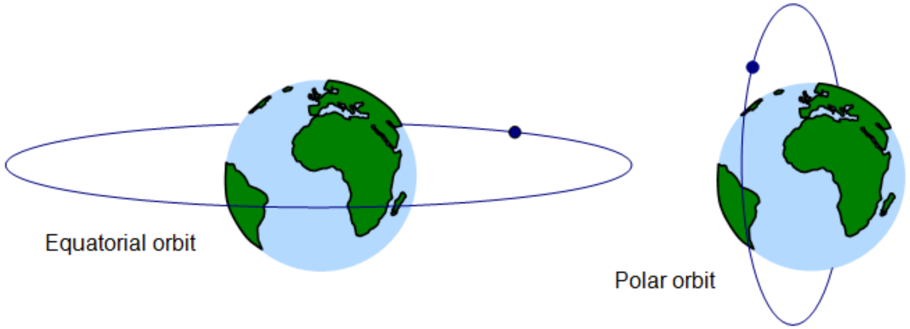
- Synoptic view – Wide area can be covered by a single image/photo (One scene of Indian Remote Sensing Satellite IRS series cover about 148 x 178 sq.km area).
- Receptivity – Can get the data of any area repeatedly (IRS series cover the same area every 16-22 days).

Coverage – Inaccessible areas like mountains, swampy areas and thick forests are easily covered.

Polar orbiting satellites: These satellites operate at an altitude between 550 and 1,600 km along an inclined circular plane over the poles. These satellites are used for remote sensing purposes. LANDSAT (USA), SPOT (FRANCE), and IRS (INDIA) are some of the Remote Sensing Satellites.

Geostationary satellite: These have orbits around the equator at an altitude of 36,000 km and move with the same speed as the earth so as to view the same area on the earth continuously. They are used for telecommunication and weather forecasting purposes. INSAT series are launched from India for the above purposes. All these satellites have sensors on board operating in the visible and near infrared regions of the electromagnetic spectrum. INSAT-3A was launched on 10th April, 2003.


Geostationary Orbit
36,000 km
Polar Orbit
715 km
Geostationary Orbit
Geostationary satellites orbit the Earth's axis as fast as the Earth spins. They hover over a single point above the Earth at an altitude of about 36,000 kilometers (22,300 miles). This orbit allows these satellites to continuously look at the same spot on the earth – important for locating the position of hurricanes and monitoring developing severe storms.
NOAA typically operates two geostationary satellites called GOES (Geostationary Operational Environment Satellite). One has a good view of the East Coast (GOES-East) wh the other focuses on the West Coast (GOES-West).
Polar Orbit
Polar satellites (also know as sun synchronous satellites) orbit above the Earth at about 715 kilometers (445 miles). Polar satellites monitor strong storms that move across the poles (regions of the Earth that Geostationary satellites cannot view).
NOAA typically operates two polar satellites. One satellite views the afternoon portion of the Earth, while the other views the morning portion of the Earth.

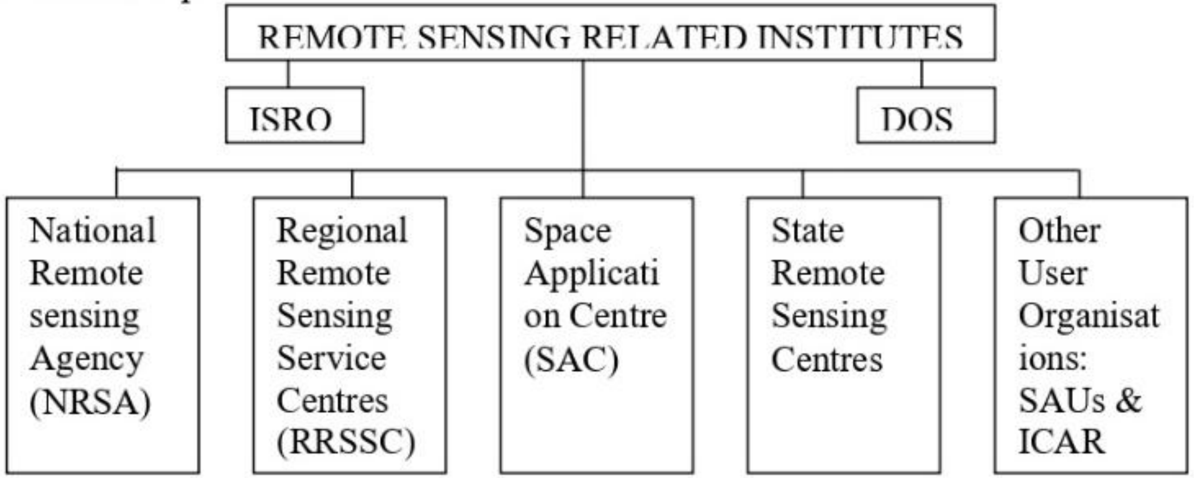

Equatorial orbit
Polar orbit

Role of Remote Sensing in agriculture

Agricultural resources are important renewable dynamic natural resources. In India, agriculture sector alone sustains the livelihood of around 70 percent of the population and contributes nearly 35 percent of the net national product. Increasing agricultural productivity has been the main concern since scope for increasing area under agriculture is rather limited. This demands judicious and optimal management of both land and water resources. Hence, comprehensive and reliable information on land use/cover, forest area, soils, geological information, extent of wastelands, agricultural crops, water resources both surface and underground and hazards/natural calamities like drought and floods is required. Season-wise information on crops, their acreage, vigour and production enables the country to adopt suitable measures to meet shortages, if any, and implement proper support and procurement policies. Remote Sensing systems, having capability of providing regular, synoptic, multi-temporal and multi-spectral coverage of the country, are playing an important role in providing such information. A large number of experiments have been carried out in developing techniques for extracting agriculture related information from ground borne, air borne and space borne data.

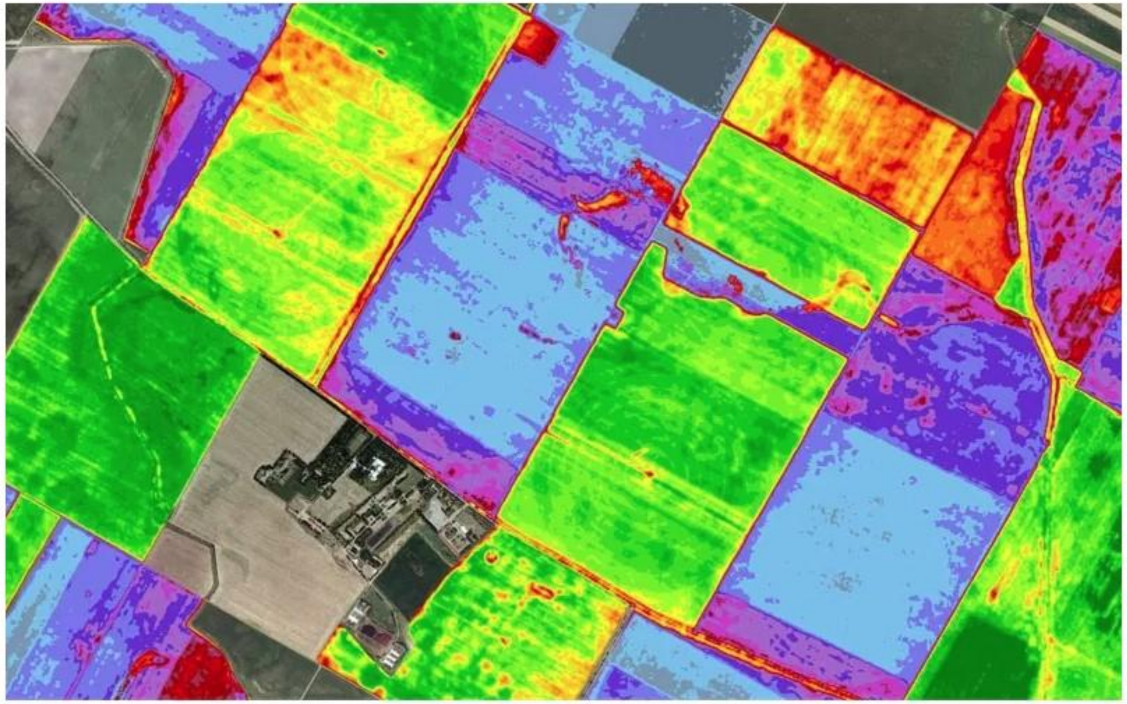
Indian Remote Sensing programme:

India, with the experience gained from its experimental remote sensing satellite missions BHASKARA-I and II, has now established satellite based operational remote sensing system in the country with the launch of Indian Remote Sensing Satellite IRS-IA in 1988, followed by IRS-IB (1992), IRS-IC (1995) and IRS-ID (1997). The Department of Space (DOS) / Indian Space Research Organisation (ISRO) as the nodal agency for establishing an operation remote sensing system in the country initiated efforts in the early 1970s for assessing the potentials of remotely sensed data through several means. In order to meet the user requirement of remote sensing data analysis and interpretation, ISRO/DOS has set up a system to launch remote sensing satellites once in three or four years to maintain the continuity in data collection. The remote sensing and some of its related institutes are depicted.



Applications of Remote Sensing In Agriculture

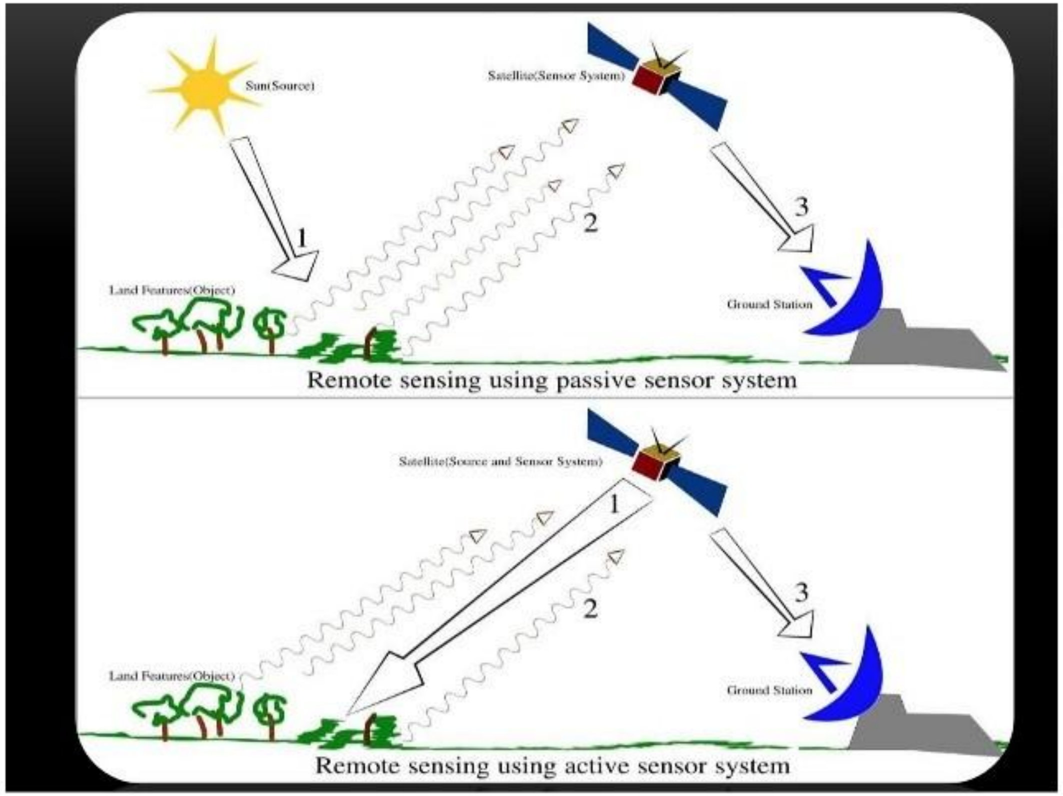
Agriculture provides raw materials, fuel, fibers, and food (of course!) to humanity. This role needs to be fulfilled within climate change and environmental sustainability, combined with the expanding population while maintaining agricultural activities' viability to sustain livelihoods. The application of remote sensing in agriculture can help the evolution of agricultural practices face different types of challenges by providing information related to crop status at different scales all through the season.



Typical aerial view of a farm using remote sensing (Sentinel-hub) | Source: https://i0.wp.com/www.geoawesomeness.com/wp-content/uploads/2017/02/SentinelPrecisionFarming.jpg?w=800&ssl=1

Working of Remote Sensing In Agriculture

Remote sensing and agriculture go hand-in-hand. The basic working of this technology with UAVs, satellites, and other platforms is almost the same. Energy, in the form of light, will travel from the sun to the Earth. Light waves travel virtually like ocean waves – the distance between the peak of one wave to the peak of the next is known as wavelength. The energy emitted from the sun is known as electromagnetic energy and is part of the electromagnetic spectrum. The wavelengths that are used for agricultural applications cover a small amount of the electromagnetic spectrum.



When electromagnetic energy hits the plants during hyperspectral remote sensing in agriculture, one of three things can occur. The energy will be reflected, absorbed, or transmitted, depending on the wavelength of the energy and the characteristics of the plant itself. The reflected, absorbed, and transmitted energy can be detected by remote sensing technology.

The relationship between the three occurrences determines the spectral signature of the plants. This signature is unique to different plant species. Remote sensing farming helps identify stressed areas by determining the spectral signatures of plants that are healthy.

What Are Some Advantages of Using Remote Sensing In Agriculture?

Agriculture is one of the most significant land-use activities around the world. Apart from changing the land cover, agriculture also profoundly impacts the sustainable development of the social economy, carbon cycle, climate change, ecosystem services, food security, etc. There are types of remote sensing in agriculture. The location, area, status, and conversion information of farmlands are vital if you want to understand how human activities will affect the lithosphere, hydrosphere, and biosphere. Additionally, you can also formulate sustainable agricultural development policies and study the simulation of the carbon-nitrogen cycle. Hence, understanding remote sensing and its application in agriculture are vital.

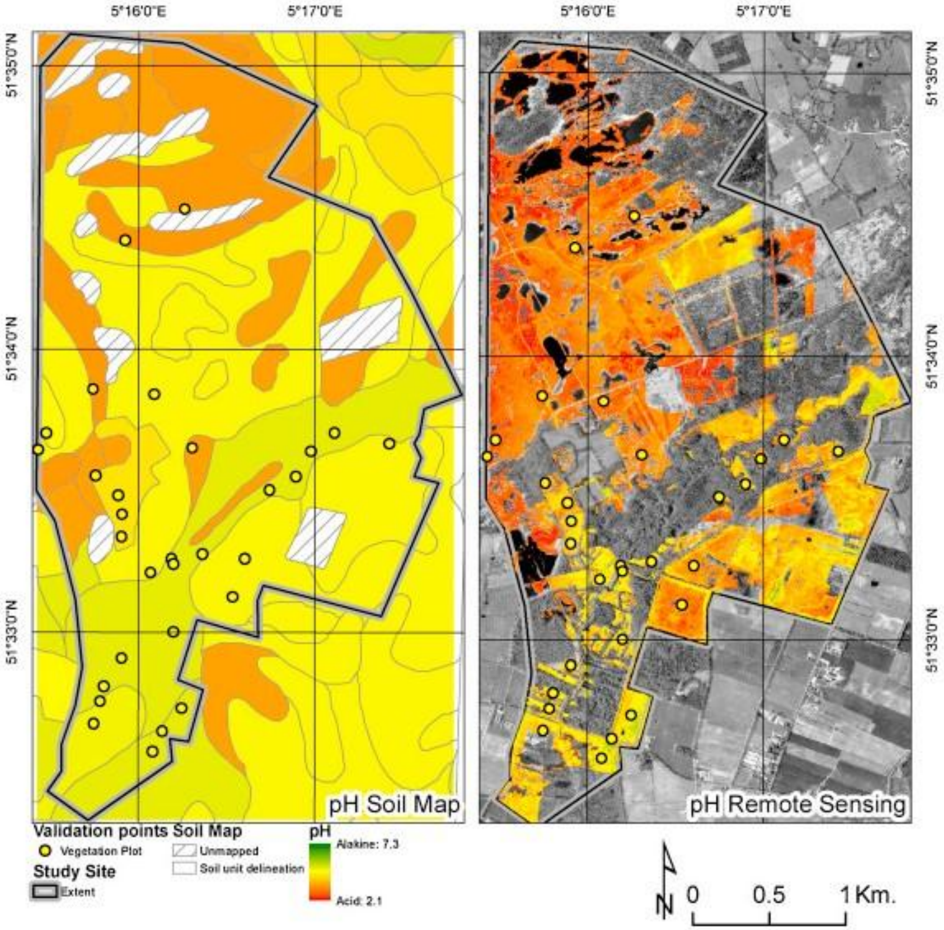
Applications of Remote Sensing In Agriculture

Remote sensing technology has found numerous applications in fields like forestry, geology, surveying, and photography. However, the use of remote sensing in agriculture is where it has been found most useful. Some of the many applications of agriculture and remote sensing include the following.

Observing and Monitoring Crops

A critical role of remote sensing in agriculture is monitoring the health of crops. Optical (VIR) sensing allows one to see beyond visible wavelengths, like infrared; in this case, the wavelengths are very sensitive to crop vigor, damage, and stress. Recent advances in this technology have allowed farmers to observe their fields and make timely crop management decisions. Crop identification using remote sensing also helps identify crops affected by conditions related to weather, pests, etc.

Observing Soil Conditions



For precision agriculture, monitoring the soil is essential. Some critical soil parameters to optimize crop management include soil organic matter (SOM), soil texture, soil pH level, moisture content, etc. Remote sensing technology in agriculture will also provide canopy health, growth stage, yield, biomass, and vegetative density. If you want to investigate the crop growth pattern changes, you need to emphasize the link between crop performance and soil conditions.

Monitoring Water Conditions

Due to population growth and food demand, it is expected that irrigated lands will double by 2050. It will decrease water availability, contribute to climate change, and cause other environmental changes. Hence, monitoring and assessing agricultural water resources are critical to achieving sustainable food security and development. Remote sensing in precision farming has successfully provided accurate and timely information like water bodies, irrigated cropland, crop and soil water status, and various scales.

Predicting Weather Conditions

Climate and weather data systems are essential if you want to make crop management decisions and schedule irrigation. Additionally, this data can also help you prepare against natural disasters. This application of remote sensing in precision farming has provided spatial coverage to predict upcoming weather conditions successfully. With this data's help, you will be provided better predictions of crop needs and help cut down unwanted costs.

For Precision Farming

The introduction of new farming techniques in the last few decades has helped agriculture keep pace with the increasing population's food demand. Precision farming and crop mapping using remote sensing aim to increase the yield of the crops and minimize strain on the natural environment. Modern technologies like AI or the Internet of Things have proved to be useful in this aspect. Remote sensing uses in agriculture have also been used to increase the productivity of the crops.

Finally, monitoring and Predicting Climate Changes

The remote sensing concept and application in agriculture has provided a lot of advances when it comes to an understanding of climatic changes by quantifying the temporal states of the oceans, land, and atmosphere. While technologies could detect weather and climatic changes, there were not as precise as this one. When it comes to farming and agriculture, weather plays an important role and will determine the yield results. Hence, this technology has proved to be a valuable tool for making accurate climate change predictions.

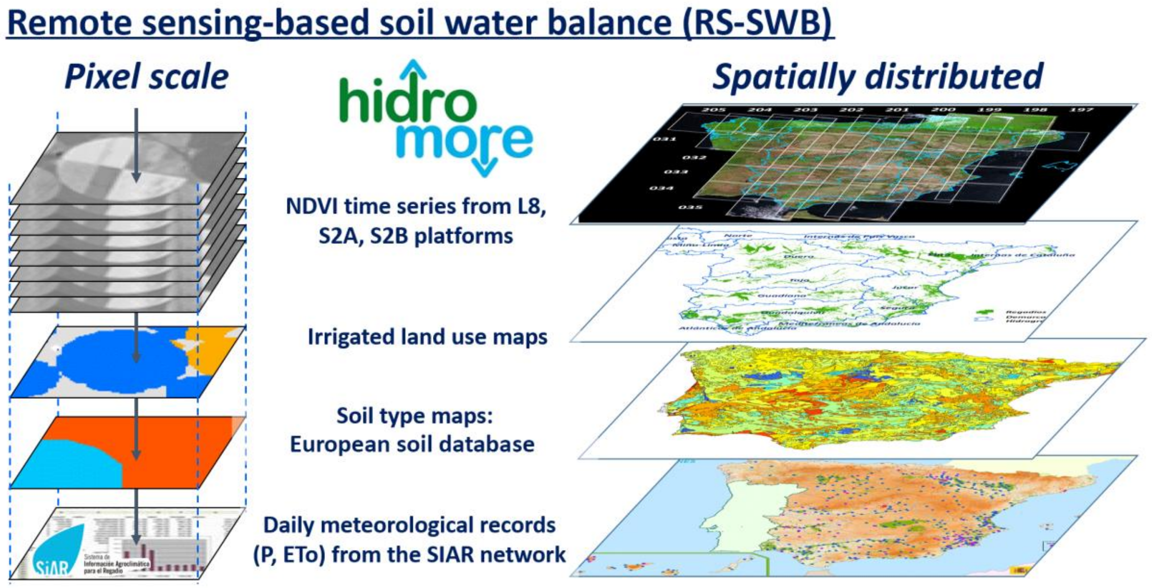
Earth observation data can be used to monitor the cropping area. RISAT -1SAR satellite data is used for rice production, R2 LISS III satellite data used for sugarcane production. For wheat production R2AWiFS satellite data used. For crop production, the ministry of agriculture and corporation from the government of India running the projects named as Crop Acreage and Production Estimation. Based on the weather and remote sensing data CAPE project provides crop production.

D. Irrigation monitoring and management

Remote sensing satellite data are the essential one to monitor the problems of the irrigated area. Multi-temporal imagery and ancillary data are useful methods to improve the identification of irrigated area using remotely sensed satellite data [4]. Multi –temporal imagery and ancillary data are included climate, soil. The distribution of the irrigation is entirely based on climate changes, it determines crop demand and crop schedules. To avoid the irrigation ground water is considered as a better source.

Table 2. Satellites used for irrigation study

Satellites / Sensors	Frequency of uses in irrigation
Landsat	high
SPOT	medium
LISS	Low
AVHRR	medium
MERIS	low
MODIS	medium
RapidEYE	low



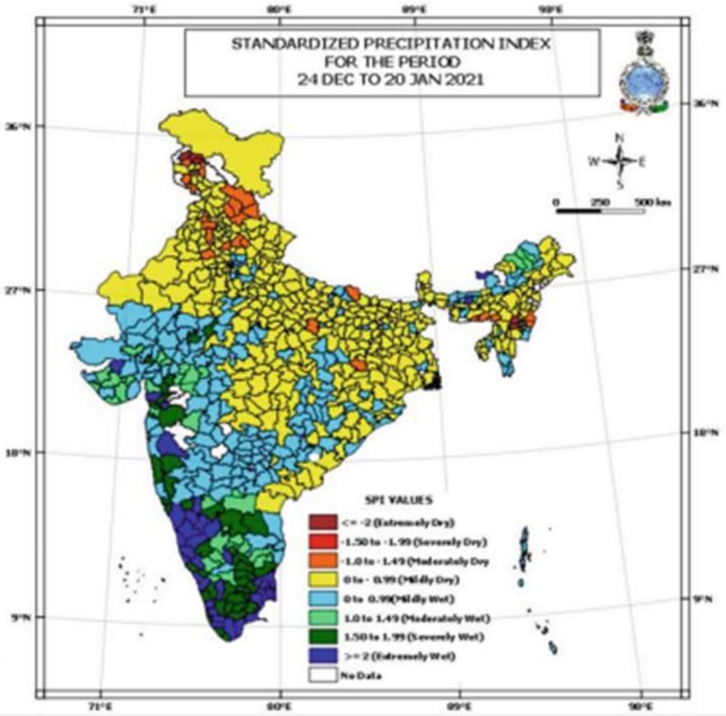
E. Soil Mapping

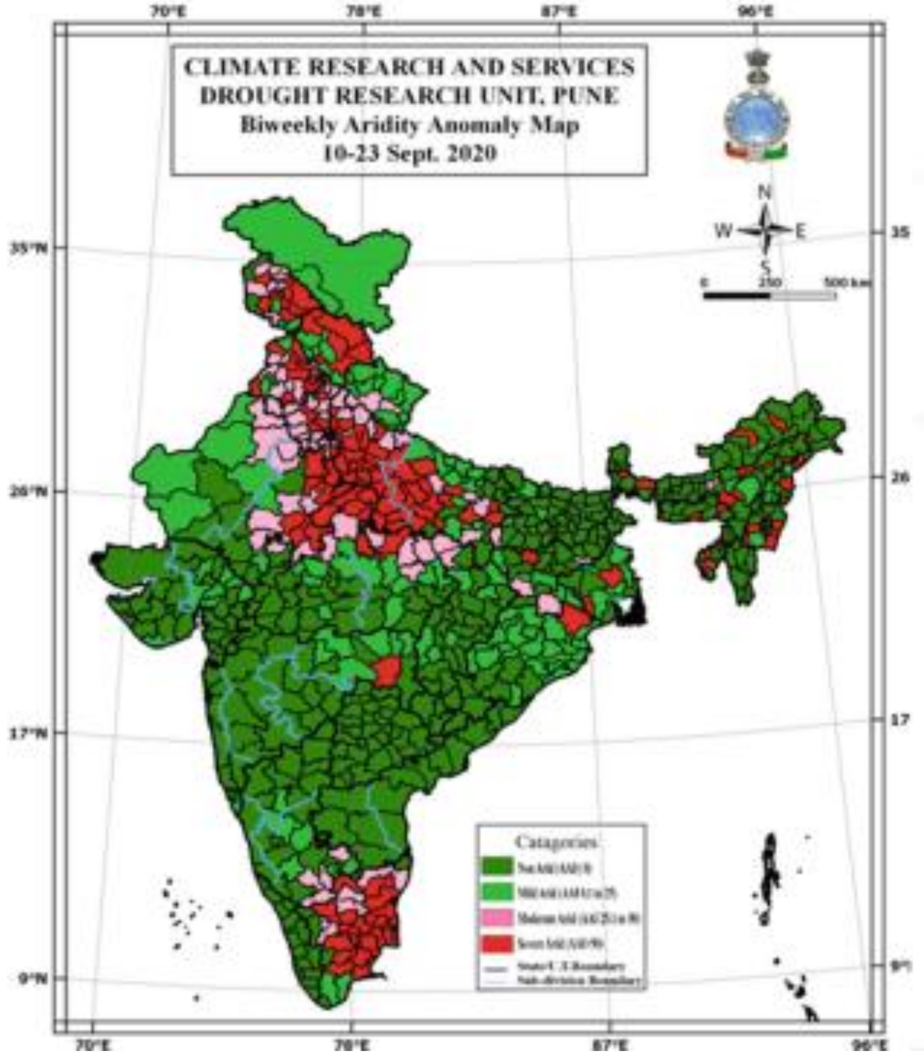
The soil is a fundamental and essential resource of growing plants. Mostly hundred percent of food production is based on the soil. Different types of soils are available here. Characteristics and elements like land type, land cover, vegetation type are mapping with the help of remote sensing data. In remote sensing thermal infrared used to identify and estimate salinity and moisture. Mapping of minerals in soil is made by hyper spectral remote sensing method. The efficient method to the mapping of soil moisture is microwave [5]. The common microwave configuration is SAR (Synthetic Aperture Radar).

Soil mapping depends upon the spectral reflectance of soil characteristics like colour, texture, structure, mineralogy, organic matter, free carbonates, salinity, moisture etc. Satellite sensors used for soil mapping includes IRS WiFS, IRS-LISS-II, IRS-LISS-III, IRS PAN [6].

F. Droughts Assessment and Monitoring

In many aspects, droughts differ than the other natural hazards. Agriculture droughts provide crop stress and wilting, it could not support crop growth and maturity due to inadequate rainfall and soil moisture. A mechanism for rainfall prediction and drought early warning gives solution for drought management problem [6]. The satellites/sensors include Resourcesat1, Resourcesat2, AVHRR, MODIS are carried out the problems of drought assessment and monitoring system.





Satellite or mission which has launched and used for drought assessment and monitoring system is depicted in the below table 3.

Table 3. Current and future satellite missions of drought monitoring and assessment.

Launched year	Satellite/mission
2000-2005	CALIPSO, CloudSAT,EOS-Aura,NOAA-N
2005-2010	GOES-N-P, SMOS
2010-2015	GPM,LDCM,ALOS 2, SMAP
2015-2020	ICESat-2, LDCM, GRACE-FO,GOES-R, SWOT, NPOESS.

Table 6. Crop pest and Disease monitoring by remote sensing

Name of Sensor	Definition
MSI	Moisture Stress Index
DSWI	Disease Water Stress Index
RVSI	Red-edge Vegetation Stress Index
WI	Water Index
SIWSI	Shortwave Infrared Water Stress Index
MCARI	Modified Chlorophyll Absorption in Reflectance Index

Table 7. Agriculture satellite with technical details

Name of Satellite	Date of Launch	Sensors	Cost incurred (in crores)	Operator	Objectives
Resourcesat-2A (PSLV – C36)	07.12. 2016	VNIR, SWIR	106.11	ISRO	Provide multispectral images for natural resources, crop production, water resources, and disaster management.
INSAT-3DR	08.09.2016	DRT, SAS&R	116.38	INSAT	Designed for improved weather forecasting, enhanced meteorological observations and disaster warning.
Lansat 8	11.02.2013	OLI, TIRS	85.5	NASA/USGS	Designed for water resources and coastal zone investigation
GPM	27.02.2014	DPR, GMI	97.8	JAXA/NASA	Designed for environmental research
ICESat-2	15.09.2018	ATLAS	9.66 USD	NASA	Examine ocean exchanges of energy, mass and moisture, quantify recent sea level change and the linkages to climate conditions.
NOAA – 19	06.02.2009	AVHRR	11 USD	NOAA	Designed for weather prediction
Kalpana-1	12.09.2002	VHRR, DRT	71.30	ISRO	Provide meteorological data for weather forecasting services.

Spectral Bands of Landsat 8

Band No.	Band name	Spectral ranges (μm)	Spatial resolution (m)	Applications
1	Deep blue	0.43–0.45	30	Coastal and aerosol studies
2	Blue	0.45–0.51	30	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
3	Green	0.53–0.59	30	Assessment of vegetation vigor
4	Red	0.64–0.67	30	Chlorophyll absorption for vegetation discrimination
5	Near infrared (NIR)	0.85–0.88	30	Emphasizes biomass content and waterbodies/shorelines
6	Short-wave infrared 1 (SWIR_1)	1.57–1.65	30	Discriminates moisture content of soil and vegetation; thin cloud penetration
7	Short-wave infrared 2 (SWIR_2)	2.11–2.29	30	Improved discrimination of moisture content of soil and vegetation; thin cloud penetration
8	Panchromatic	0.50–0.68	15	Sharper image definition for visual interpretation
9	Cirrus	1.36–1.38	30	Improved detection of cirrus cloud contamination
10	Thermal infrared 1 (TIR_1)	10.60–11.19	100*	Thermal mapping and estimated soil moisture
11	Thermal infrared 2 (TIR_2)	11.50–12.51	100*	Improved thermal mapping and estimated soil moisture
BQA	Quality assessment			Quality assessments for every pixel in the scene

*TIRS bands are acquired at 100 m resolution, but are resampled to 30 m in the delivered data product.[29,30]

Spectral Bands of Sentenel-2

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	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

Moisture Stress Index (MSI)

It uses the NIR and SWIR channels to measure healthy moisture, pixel by pixel with a simple algorithm. The MSI is a reflectance measurement, sensitive to increases in leaf water content. Applications of the MSI include canopy stress analysis, productivity prediction and modelling, fire hazard condition analysis, and studies of ecosystem physiology. The values of this index range from 0 to more than 3.

Disease Water stress index (DSWI)

Disease Water Stress Index (DWSI) is expressed as the ratio of reflectance of those spectral bands that are very sensitive to changes in leaf pigments, internal leaf structure and moisture content

Red Edge Normalized Difference Vegetation Index (RENDVI)

It capitalizes on the sensitivity of the vegetation red edge to small changes in canopy foliage content, gap fraction, and senescence. The value of this index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.9. "**Red Edge** is the region of the spectrum where spectral reflectance of green **vegetation** changes rapidly.

Water Index (NDWI)

The NDWI is a remote sensing based indicator sensitive to the change in the water content of leaves (Gao, 1996). NDWI is computed using the near infrared (NIR – MODIS band 2) and the short wave infrared (SWIR – MODIS band 6) reflectance’s.

Shortwave Infrared Water Stress Index (SIWSI)

This index gives the changes in water content in plant tissues have a large effect on the leaf reflectance in several regions of the 0.4 –2.5 Am spectrum. It is well known that a large absorption by leaf water occurs in these wavelengths and therefore shortwave infrared reflectance (SWIR) reflectance is negatively related to leaf water content

Modified Chlorophyl Absorption in Reflectance Index (MCARI)

MCARI gives a measure of the depth of chlorophyll absorption and is very sensitive to variations in chlorophyll concentrations as well as variations in Leaf Area Index (LAI).

The MCARI results from the following equation: Index = ((VNIR - Red)-0.2*(VNIR - Green))*(VNIR / Red) using Sentinel-2 Band 5 (VNIR), Band 4 (Red) and Band 3 (Green).

Crop weather modeling

Crop model: It is a representation of a crop through mathematical equations explaining the crops interaction with both above ground and below ground environment.

The increase in dry matter of the crop is referred to as growth. The rate of growth of a healthy crop depends on the rate at which radiation is intercepted by foliage and / or on the rate at which water and nutrients are captured by root systems and therefore on the distribution of water and nutrients in the soil profile. The crop development is described in terms of various phenophases through which the crop completes its lifecycle. That is the progress of the crop from seeding or primordial initiation to maturity. Finally the yield of crop stand is expresses as a product of three components, viz., the period over which dry matter is accumulated (the length of the growing period), the mean rate at which dry matter is accumulated and the fraction of dry matter treated as yield when the crop is harvested.

It is understood that the crop growth, development and yield depend upon the mean daily temperature (DTT), the length of the day and the amount of solar radiation (PAR) received by the crop.

$$\text{DTT} = \frac{\text{Max daily temperature} + \text{Min daily temperature}}{2} - \text{base temperature}$$

Where, DTT = Daily thermal time accumulation.

The time needed for the crop to reach a development stage depends upon temperature measured above a base value (DTT) and for photo periodically sensitive phases such as flowering, the

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day length above a fixed base. In the absence of stress, the harvest index does not vary much from year to year for a specified cultivar / variety. Therefore, crop weather modeling is based on the principles that govern the development of crop and its growing period based on temperature and / or day length. They are used to quantify the rate of crop growth in terms of radiation interception, water use and nutrient supply which moderate harvest index when the crops experience stress condition.

The basic information required to be generated for crop weather modeling includes.

a) Crop phonology in relation to the temperature and day length
b) Water use by the crop during different phenophases of crop growth
c) The relationship between radiation interception, crop water use and total dry matter production
d) Partitioning of dry matter into various plant components as influenced by water and nutrient availability, and
e) The effect of weather parameters on biotic interference to crop growth.

Types of models

a) Statistical models

These models express the relationship between the yield or yield components and the weather parameters. The relationships are measured in a system using statistical techniques. Simple regression techniques explaining weather crop relationships are also considered as models.

b) Mechanistic model

These models explain not only the relationships between the weather parameters and the yield, but explain the relationship of influencing dependent variables.

c) Deterministic models

These models estimate the exact value of the yield or dependent variable. These models also have defined co-efficient.

d) Stochastic models

A probability element is attached to each output. For each set of inputs different outputs are given along with probabilities. These models define the yield or state of dependent variable at a given rate.

e) Dynamic models

Time is included as a variable. Both dependent and independent variables are having values which remain constant over a given period of time. Over a period of time these variables are changing due to change in rate of increment.

f) Static models

Time is not included as a variable. The dependent and independent variables having values remain constant over a given period of time.

g) Simulation models

Computer models in general, are a mathematical representation of a real world system. One of the main goals of crop simulation models is to estimate agricultural production as a function of weather and soil conditions as well as crop management. These models use one or more sets of differential equations over time, normally from planting until harvest maturity or final harvest.

h) Descriptive models

A descriptive model defines the behaviour of a system in a simple manner. The model reflects little or none of the mechanisms that are the causes of phenomena but consists of one or more mathematical equations. An example of such an equation is the one derived from successively measured weights quickly the weight of the crop where no observation was made.

i) Explanatory models

This model consists of quantitative description of the mechanisms and process that cause the behaviour of the system. To create this model, a system is analyzed and its process and mechanisms are quantified separately. The model is built by integrating these descriptions for the entire system. It contains descriptions of distinct processes such as leaf area expansion, tiller production etc. Crop growth is a consequence of these processes.

Dynamic simulation models

Categories	Types
Based on phases of development	Preliminary models Comprehensive models Summary models
Based on Input-Output relationships	Deterministic models Stochastic models
Based on the purpose	Statistical models Mechanistic models Static models Descriptive models Explanatory models Dynamic models Simulation models Optimizing models

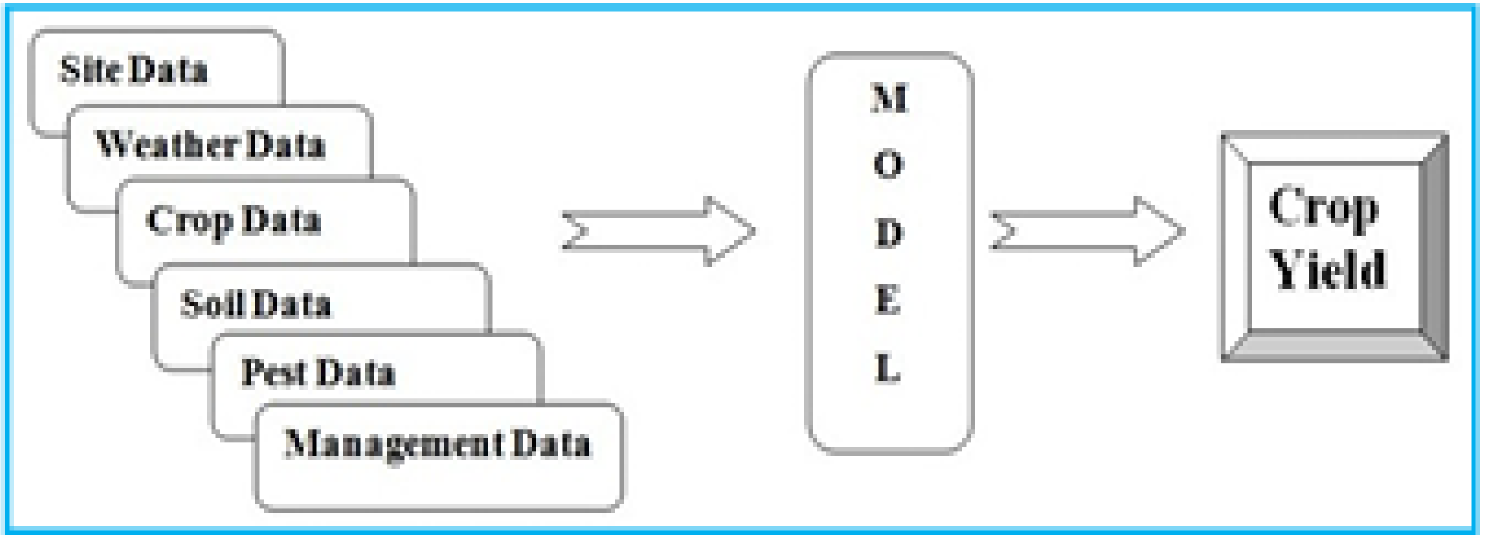

Fig. 1. Inputs and system approach of crop growth models

Various input data required to run crop growth model

Site data	Weather data	Crop data	Soil data	Management data	Pest data
	T-max	Crop & variety	Soil thickness	Tillage	Pest name
Country	T-min	Planting date	Soil pH & E C	Seed rate & depth	Pest types
Station	RH	Crop phenology	N P K & O C status	Irrigation	Insect
Longitude	Rainfall	Root depth	Soil texture, structure	Fertilizer	Diseases
Latitude	Radiation	Crop height	Soil moisture	Residue	Others
Altitude	Wind speed	Critical depletion	F C & W P	Pesticide	Mode of attack
		LAI & Test wt.	Bulk density	Harvesting	Pest population