PROBLEM SOILS

Physical problems

An optimum physical environment of soils is essential for better growth of plants, consequently for better yields. Based on soils physical properties viz., infiltration, bulk density, hydraulic conductivity, porosity (capillary and non capillary, aggregates etc soil physical constraints are identified as below.

1. Slow permeable soils
2. Excessively permeable soils
3. Subsoil hardening
4. Surface crusting
5. Fluffy paddy soils
6. Shallow soils

Slow permeable soils

Slow preamble soils are those having infiltration rates less than 6 cm/day due to high clay content of the soil. Due to low infiltration rates, the amount of water entering the soil profile is reduced thus increasing the run-off. Further, it encourages erosion of surface soil leading to nutrient removal in the running water. More ever, due to heavy clay content, the capillary porosity is relatively high resulting in impeded drainaze and reduced soil conditions. This results in increase of some soil elements to the level of toxicity to the plants. It also induced nutrient fixation in the clay complex thereby making the nutrient becoming unavailable to the crop, eventually causing deficiency of nutrients. Such soils are spread over Tamil Nadu in an area of 7,54,631 has, which is 7.5% of total geographical area.

Management

The constraints in such soils can be managed by adopting suitable practices like

1. Provision of drainage facilities either through open or closed sub surface drains.
2. Forming contour and compartmental bunding to increase the infiltration rates of soils.
3. Application of huge quantities of river sand or red soils of coarser texture to dilute heaviness of the soil.
4. Application of liberal doses of organic manures like Farm Yard Manure, Compost, Green manure, Composted coir pith, sewage waste, press mud etc.
5. Adopting ridges and furrows, raised beds, broad bed and furrow systems.

6. Application of soil conditioners like H-concentrate, Vermiculite, Jalasakti etc to reduce run-off and soil erosion.

Excessively Permeable Soils Excessively permeable soils are those having high amount of sand exceeding 70- percent. Due to this, the soils are inert and unable to retain nutrient and water. These soils being devoid of finer particles and organic matter, the aggregates are weakly formed, the non-capillary pores dominating with very poor soil structure. Due to low retaining capacity of the soils, the fertilizer nutrients are also lost in the drainage water. These soils are spread over 24, 12, and 086 ha in Tamil Nadu (23:97% of total geographic area).

Management

The excessively preamble soils can be managed by adopting the techniques given below.

1. Compacting the field with 400kg stone roller (tar drum filled with 400 kg of sand or stones can also be used) 8-10 times at optimum moisture conditions.
2. Application of clay soil up to a level 100 t ha^{-1} based on the severity of the problem and availability of clay materials.
3. Application of organic materials like farm yard manure, compost, press mud, sugar factory slurry, composted coir pith, sewage sludge etc.
4. Providing asphalt sheet, polythene sheets etc. below the soil surface to reduce the infiltration rate.
5. Crop rotation with green manure crops like Sunhemp, sesbania, daincha, kolinchi etc.

Sub soil hardening /hard pan

The sub soil hard pan in red soils in due to illuviation of clay to the sub soil horizon coupled with cementing action of oxides of Fe, Al and Calcium carbonate, which increases the soils bulk density to more than 1.8 Mg m^{-3}. Further, the hard pan can also develop due to continuous cultivation of crops using heavy develop due to continues cultivation of crops using heavy implements up to certain depth constantly. Besides, the higher exchangeable sodium content in black soils areas also result in compactness. All put together lowered the infiltration and percolation rates, nutrient movement and free air transport within the soils profile. It prevents root proliferation and limits the volume of soils available for nutrients uptake resulting in depleted, less fertile surface soil. Due to this, the contribution of sub soil fertility to crop growth is hampered. The area under this constraint is 10,54, 661 ha in Tamil Nadu (10: 48% TGA).

Management

These soils are managed by adopting following practices

1. Ploughing the soil with chisel plough at 0.5m interval criss cross at 0.5m depth once in 2-3 years.
2. Application of organics to improve the aggregation and soil structure so as to prevent further movement of clay to the lower layers.
3. Deep ploughing of the field during summer season to open up the sub soils.
4. Cultivating deep rooted crops like tapioca, cotton so as to encourage natural breaking of the hard pan.
5. Raising deep rooted semi perennial crops like Mulberry, Jasmine, Match wood tree etc. can also help in opening up the sub surface hard pan.

Surface crusting

Surface crusting is due to presence of colloidal oxides of iron and Aluminium in Alfisols which binds the soil particles under wet regimes. On drying it forms a hard mass on the surface. The ill effects of surface crusting are

1. Prevents germination of seeds
2. Retards/inhibits root growth.
3. Results in poor infiltration.
4. Accelerates surface run off
5. Creates poor aeration in the rhizosphere
6. Affects nodules formation in leguminous crops Area : 4,51,584 ha (4.49% TGA) in Tamil Nadu.

Management

Surface crushing can be managed as below

1. When the soil is at optimum moisture regime, ploughing is to be given.
2. Lime at 2 t ha^{-1} may be uniformly spread and another ploughing given for blending of amendment with the surface soil.

3. Farm yard manure at 10 t ha^{-1} or composted coir pith at 12.5 t ha^{-1} or other organics may be applied to improve the physical properties of the soils, after preparation of land to optimum tilth.
4. Scraping surface soil by tooth harrow will be useful.
5. Bold grained seeds may be used for sowing on the crusted soils.
6. More number of seeds/trill may be adopted for small seeded crops.
7. Sprinkling water at periodical intervals may be done whenever possible.
8. Resistant crops like cowpea can be grown

Fluffy paddy soils

The traditional method of preparing the soil for transplanting rice consists of puddling, which substantially breaks soil aggregates into a uniform structure less mass. Under continuous flooding and submergence of soil for rice cultivation in a cropping sequence of rice-rice-rice, the soil particles and always in a state of flux and the mechanical strength is lost leading to the fluffiness of the soils. Impact of fluffiness is sinking of drought animals and labourers during pudding. This has been thus, an invisible drain of finance for the farmers due to high pulling power needed for the bullocks and slow movement of labourers during the puddling operations. Further fluffiness of the soil lead to very low bulk density and thereby leading to very rapid hydraulic conductivity and in turn the soil does not provide a good anchorage to the roots and the potential yield of crops is adversely affected. About 25, 919 ha (0.26% TGA) in Tamil Nadu have this problem.

Management

Following practices are need to be adopted to overcome this problem.

1. The irrigation should be stopped 10 days before the harvest of rice crop.
2. After the harvest of rice, when the soil is under semi-dry condition, compact the field by passing 400 kg stone roller or an tar drum filled with 400 kg of sand for 8 times.
3. The usual preparatory cultivation is carried out after compaction.

Shallow soils:

The shallow soils are characterized by the presence of the parent root immediately below the soil surface at about 15-20 cm depth. This restricts the root elongation and spreading. Hence, the crops grown in these soils necessarily are shallow noted crops, which can exhaust the soil within 2-3 seasons. Therefore, frequent renewal of soil fertility is a must in these soils. These soils can be managed by growing crops which can withstand the hard rooky sub soils like mango, ber, fig, country, goose berry, west, Indian cherry, Anona, Cashew, and Tamarind etc. These soils spread over an area of 1, 16,509 ha in Tamil Nadu which is 1-16 per cent of total geographical area.

Problem Soils

ACID SOILS

Acid soils are those having high degree of adsorbed Aluminium and Hydrogen.

Soil acidity of two types Those are

1. Research acidity/Exchange acidity/potential acidity/salt replaceable acidity
2. Active acidity

Reserve acidity:

Refers to acidity at exchange complex i.e. Concentration of Hydrogen and Aluminium at the exchange complex.

Soil solid (Reserve acidity) | Soil solution (Active acidity)

Reserve acidity and activity are in equilibrium i.e. If H^+ concentration in soil solution decreased. H^+ from soil solution. If H^+ in soil solution increased, some H^+ moves to soil solid. The potential acidity is always high even more than 100 times than active acidity in soils.

Role of Al^3 in soil acidity

H^+ directly contributes to soil acidity, while Al^{3+} on hydration releases free H^+ free H^+ ion and thereby increase soil acidity.

Strongly acid soils (pH < 5.0)

$Al_{3+} + H_2O \rightarrow Al(OH)^{2+} + \boxed{H^+}$

Moderately acid soils (pH 5.0-6.5)

$Al(OH)^{2+} + H_2O \rightarrow Al(OH)_2^{+} + \boxed{H^+}$

$Al(OH)^{2+} + H_2O \rightarrow Al(OH)_3^{+} + \boxed{H^+}$

Genesis of acid soils

Following are the factors responsible for formation/ genesis of acid soils.

1) Parents Materials:

Soil formed from acid parent root are usually acidic in nature is : granite, Rhyolite etc.

2) High rainfall

It is an important phenomenon in the genesis of acid soils. High rainfall leaches the bases from the soil and becomes reason for accumulation of H^+ ion at exchange complex. Bases like Ca, Mg, K, Na et are removed from the soil by the water in high rainfall areas.

3) Organic Matter

Decomposition of organic matter released weak organic acids (Carbanic acid → $CO_2 + H_2O \rightarrow H_2CO_3$), strong organic acids. These organic acids particularly carbonic acid solublses bases which subject to leaching. Further decomposition of nitrogen containing materials release nitric acid and sulphur compounds release sulphonic acid. These inorganic acids also contributes to soil acidity.

4) Acid Forming Fertilizer

Application of acid forming fertilizers like elemental sulphur, Ammonium sulphate, Ammonium chloride etc continuously over a period to soils become a reason for the acid soil formation. Ammonical fertilizers on odixation release free hydrogen ion

$$NH_4^+ + 2O2 \rightarrow \boxed{2H^+} + NO_3^- + H_2O$$

5) Industrial Effluents

Oxides of nitrogen and sulphur are let out of te industries which are combine with rain water to form acids. These acids reach the ground and polluter the soil.

$2S + 3O_2 + 2\ H_2O \rightarrow 2\ H_2SO_4$

Effect of acidity

1. Excess hydrogen in soil solution result in injury to the growing plants.
2. In acid soils (low pH) Fe, Al and Mn are solubilised and available excessively. This causes toxicity effect on the growing plants.
3. Growth of microorganisms is restricted in acid soils particularly bacteria multiplication reduced.
4. Nutrients availability in acid soils are reduced Calcium, Magnesium are in low levels because acid soil do not have bases. Further poor decomposition of organic matter due to low microbes in acid soils leads to low availability of nitrogen and sulphur. Phosphorus is converted into Al and Fe phosphates which are insoluble hence P is deficient in acid soils. Molybdenum is another element available in low level in acid soils.

Reclamation

Acids soils can be reclaimed to normal soil by introducing suitable base cation and thereby removing excess H^+ and Al^{3+} at exchange complex. The commonly used living materials (supply Ca to remove $H^+ + Al^{3+}$) to reclaim acid soils are

a) Quick / Burnt / Oxide of lime (CaO)
b) Hydrated lime ($Ca\ COH)_2$)
c) Lime / Calcite ($CaCO_3$)
d) Dolomite [$Ca\ Mg\ (CO_3)_2$]
e) Marl/Oyster shells/ Basic slay etc)

Among the above calcite (Lime-$CaCo_3$) and Dolomite [$Ca\ Mg\ (CO_3)_2$] are mostly used and for reclamation of acid soils.

Lime requirement

The quantity of lime required to reclaim acid soils is worked out by following standard procedures in the laboratory (Schoomaker method (Details refer practicals) Hutchinson and Macleamn method) etc.

Lime requirement of an acid soil depends on the following

1) **Change in pH required**: Lower the pH more lime required.

2) **Buffering capacity of soils:** Higher clay and organic matter in soils more will be buffering capacity of soil and more lime is required for reclamation.
3) **Finess of liming material:** Finer lime materials quickly solubilization and react hence less lime requirement.
4) **Texture of soil:** Fine textured soils require more time than coarse textured soils for reclamation.'
5) **Organic matter:** Higher organic matter in soils more will be buffering capacity hence higher the time requirement for reclamation.

Reactions

All liming materials on addition to soil first they converted into calcium bicarbonate in the presence of CO_2 due to high partial pressure of CO_2 which is hundred times more than atmosphere. Secondly they involve in exchange reaction and replaces H^+ from soil colloids.

$CaO + H_2O + 2CO_2 \rightarrow Ca(HCO_3)_2$

$Ca(OH)_2 + 2CO_2 \rightarrow Ca(HCO_3)_2$

$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$

$^{H}\boxed{\text{Micelle}}^{H} + Ca(OH)_2 \qquad \boxed{\text{Micelle}}^{Ca} + 2H_2O$

$^{H}\text{Micelle}^{H} + Ca(HCO_3)_2 \qquad \text{Micelle}^{Ca} + 2H_2O + 2CO_2$

$^{H}\text{Micelle}^{H} + CaCO_3 \qquad \text{Micelle}^{Ca} + 2H_2O + CO_2$

Finess of lime:

Lime material at least 50 per cent should pass through 60 mesh sieve and coarser particles less effective than finer particles.

Acid soils in India distributed mostly in North eastern states and hilly area of other state. A special cid soil is seen in Kerala which is acid sulphate soils having low pH i.e. < 3.5 and high amount of sulphates.

Saline – Sodic soils

There are four major tracts where salt affected soils are commonly met within India. These are

(i) The Semi-arid Indo-Gangetic alluvial tracts (mainly in Punjab, Haryana, Uttar Pradesh and a part of Bihar)

(ii) The arid tracts of Rajasthan and Gujarat.

(iii) The arid and semi arid tracts of southern states, particularly of the irrigated rigor (Vertisol) soils.

(iv) The coastal alluvium

It is estimated that about 7 million hectares of land have been affected by salinity/ Sodicity conditions in India.

Classification of saline sodic soils

Based pH, electrical conductivity (EC) and Exchangeable sodium percentage ($ESP = \frac{\text{Exchangeable Na}}{\text{CEC}} \times 100$) saline –sodic soils are classified as follows.

	EC (dsm^1)	ESP	pH
Saline	> 4.0	< 15	< 8.5
Sodic	< 4.0	> 15	> 8.5
Saline – sodic	> 4.0	>15	< 8.5 or > 8.5

Saline soils / white/ alkali/ solonchak

Soils with high amount of soluble salts having EC > 4.0 dsm^{-1} and white encrustations are seen on the surface. Hence it is called as white alkali.

Brown alkali

Saline soils with high proportion of nitrate salts.

Sodic soils: Two types

1. Black alkali/ solonetz

These soils have PH> 8.5 and ESP > 15 and with precipitated $CaCO_3$. Dispersed clay with decomposed organic mater (humus) give black Colour to these soils and hence these soils are called as black alkali / solonetz (Russian term)

2. Degraded sodic / degraded alkali / solodi soils

These soils have exchangeable sodium percentage > 15. But the PH of surface horizon acidic in nature and there is no precipitate $CaCO_3$. However, the sub surface horizon may have PH>8.5. In the assume of $CaCO_3$ and soluble salts the sodic clay with water degrades and Hydrogen clay is formed in the surface. This process is known as solodization,

^{Na} [Micelle] + H_2O → ^{H} [Micelle] + Na OH

and the soil is called as solodi in Russian terminology.

Genesis of saline – sodic soils

1. Parent material

Soils formed from rocks having high proportion of bases are become salinc / sodic in nature.

E.g.: Basalt, Sand stone.

2. Low rainfall

One of the important reason for the development of saline-sodic soils. Insufficient water to remove bases from soil horizon leach to accumulation of salts in soil. This is more common in semi arid and arid regions where the rainfall is usually low.

3. High Evaporation

High evaporation is a common feature in semi arid and arid regions. Because of high evaporation more capillary movement of water from sub surface to surface. on teaching the surface water along evaporates to atmosphere leaving the salt to accumulate in the surface of soils.

4. Poor drainage

Water logged salinity / sodicity is a common seen in low lying area of islands particularly in high clay soils. Improper drainage leads to accumulation of salts at surface horizon and becomes reason for entry of sodium in clay complex.

5. Poor quality irrigation waters

Continuous use of poor quality saline / sodic water for cultivation accumulates salts / sodium in the soils.

6. High water table

High water table at alluvial plains and other areas leads to improper drainage which leads to accumulation of salts in soils.

7. Sea water intrusion

In coastal regions sea water intrudes into land and pollutes the soil as well as ground water of that locality.

8. Base forming fertilizers

Continuous application of base forming fertilizers for cultivation is also causes soil salinity / sodicity. Eg. $NaNO_3$

Saline soils

Soils having higher proportion of soluble salts affect adversely the growth of plants. The salt level in saline soils exceeds a limit of 4.0 dSm^{-1}. Mostly these soils are dominant with chloride and sulphate salts. These salts are neutral salts and hence the pH of these soils may not round 8.5. Saline soils are formed through a soil forming process called **salinization** in semi arid and arid zones. Salinization refers to accumulation of soluble salts in the soil surface horizons.

Effects of soil salinity

The characteristics feature of saline soil in white encrustation on surface of soils due to evaporation of water to atmosphere leaving the salts on surface of soils presence of salts leach to alteration of osmotic potential of the soil solution. Consequently water intake by plants restricted and there by nutrients uptake by plants are also reduced. In these soils due to high salt levels microbial activity is reduced. Redirect microbial activity result in slow decomposition or organic matter. Slow decomposition leads to slow nutrient availability particularly nitrogen and sulphur. Due to osmotic potential alteration water from plants cells moves to soil and plants are affected due to dehydration. As a result drying of leaves and finally death of plants common seen in saline soils. Apart from above effects specific ion effects on plants are also seen due to toxicity of ions like chloride, sulphate etc.

Reclamation

All saline soils can be reclaimed easily of good quality water is available. Since the salts in this soils are soluble in nature using quality water they can be solubilized and leached off from the field. In the absence of good quality water in becomes necessary to manage saline soils for better growth of plants.

Management of saline soils

1. Crop management

Growing crops that are tolerate high level soil salinity e.g.: Cotton, Ragi, Barley, sugar beat, Beet root, curry leaf, Bermuda grass, saline grass, spinach etc. Crops that are tolerant to soil salinity at medium level are paddy, wheat, onion, maize, sunflower, castor, grape, pomegranate, tomato, cabbage and potato. Crops that are tolerant to low level of soil salinity are garden beans, Reddish, lime etc. Black gram, green gram are sensitive to soil salinity. Crops are to be chosen based on the soil salinity level.

2. Soil / cultural management

Growing crops in raised beds will reduce accumulation of salt a around root zone. Planting seedlings / sowing seeds on slopry ridges slecreases accumulation salts around root zone. Mulching soil prevents evaporation which reduces accumulation of salts due to capillary rise of water ate surface of soils. Providing drainage in water lugged areas also helps to reduce salt accumulation.

3. Fertilizer Management

Addition of extra dose of nitrogen to the tune of 20 – 25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (sun hemp, Daincha , Kolingi) and / or green leaf manuring also counteracts the effects of salinity.

4. Irrigation management

Proportional mixing of good quality (if available) water with salin water and then using for irrigation reduces effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip and sparkler irrigation systems aim are reduced use of water which is favorable for growth of plant since slat accumulation also reduced with low usage of water.

All the above four management practices suitably integrated to reduce the soil salinity which in favorable for better growth of plants and ultimately for better yields management of saline soils becomes essentials and unavoidable particularly in areas where both soil as well as irrigation water are saline in nature.

Problem soils

Sodic soils

Sodic soils are having high proportion of sodium at exchange complex. The sodium ion at exchange complex usually exceeds 15 percentage in this soils. These soils also have high proportion of carbonates and bicarbonates and hence the pH always more than 8.5. precipitated $CaCO_3$ present in this soil insoluble in nature. One contrary degraded sodic soils have low pH at surface but exchangeable sodium percentage is more than 15. these soils do not have precipitated $CaCO_3$. Sodic soils are formed due to the soil forming process of alkalization (accumulation sodium in soils) which solodi solids / degraded alkali (sodic) formed by the process called solidization.

Effect of soil sodicity

Since these soils have high amount of CO_3 and HCO_3 and high pH. Carbonate, bicarbonate and OH (hydroxy) ion injuries on plants are observed. High sodium in clay becomes reason for dispersed nature of clay under wet moisture regions. Dispersed nature of clay leads to soapy feeling of soils, stagnation of water, poor infiltration/ percolation and poor aeration. During dry periods these soils become hard mass. These soils have poor workability both under wet and dry seasons, further hazardous effects of Na on plants are also seem. Sodium carbonate with water releases Na^+, HCO^-_3 and OH^- ions which are harmful to growing plants in these soils.

$$2\,Na^+ + CO_3^{2+} + H_2O \rightarrow 2\,Na^+ + HCO_3^- + OH^-$$

Higher pH also unfavorable for the growth of microorganisms. Low microbial activity causes slow decomposition of organic matter and hence nutrient availability is also affected specifically nitrogen, sulphur etc. Since these soils enriched with high Na at exchange complex Ca and Mg availability are also less. High pH becomes the reason for non availability of Fe and Zn, particularly Zn availability is less and deficiency of Zn is N common in this soils. Phosphorus availability is also less due to conversion phosphors into insoluble calcium and Magnesium phosphates. All the above effects on plants result in drying of plants in patches in a field. Under extreme conditions no plants are sum in these soils.

Reclamation

Physical

This is not actually removes sodium from exchange complex but improve physical condition of soil through improvement in infiltration and aeration.

a. Deep ploughing is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also help in improvement of aeration.

b. Providing drainage is also practiced to improve aeration and to remove further accumulation of salts at not gone.

c. Sand filling which reduces heaviness of the soil and increases capillary movements of water.
d. Profile inversion – Inverting the soil benefits in improvement of physical condition of soil as that of deep ploughing.

Biological

Biological reclamation aims at improvement in physical condition of soils through addition of organic matter and to some extent solubilized native Ca for reclamation. Biological reclamation is also not a complete reclamation which not reduces sodium from soil below 15 percentages.

a. Addition of organic matter (Farm yard manure, press mud, Green manures, Green leaf manures) improves general physical condition of these soils. Further decomposition of organic matter releases organic acids and inorganic acids which are contracts the ill effects of high pH of soils.
b. Growing grasses like Cynodon dactylon, Brachiaria mulica, Chlon’s gayana, pai korai etc which are become sodium from the soils. But the removal is slow process.
c. Afforestation i.e growing trees which are also behaves as grasses and add organic matter through leaf fall.

    E.g. AZadirachta indica, prosopis juliglora, Tamarix, rticulata, Albizia procera, Zizyphus sp., Acaciasp., Cassia sp. etc.

Chemical Reclamation

This aims at removal of sodium from exchange complex by introducing calcium.

Materials

Gypsum, Calcium Chloride, Calcium Carbonates, phosphor gypsum etc are used for reclamation which are directly supply calcium as they have calcium in their composition. Among them gypsum is most commonly used. $CaCO_3$ is insoluble in nature which of no use in sodic soils (have already precipitated $CaCO_3$) but can be used in degraded sodic soils (do not have precipitated $CaCO_3$) since pH of this soils are low and favoring solubilization of $CaCO_3$.

Some of indirect suppliers of Ca Viz. Elemental sulphur, sulphuric acid, Iron sulphate are also used for sodic soils. These materials on application solubilized precipitated

$CaCO_3$ in sodic soils and releases Ca for reclamation (for exchange reaction). Since degraded sodic soils do not have precipitated $CaCO_3$, use of this materials is not beneficiate. Lime sulphur supply Ca both directly as well as indirectly.

Reactions: (Direct sources)

^{Na} Micelle ^{Na} + $CaSO_4$ Micelle ^{Ca} + Na_2SO_4 **(leachable)**

^{Na} Micelle ^{Na} + $CaCl_2$ Micelle ^{Ca} + 2NaCl **(leachable)**

Indirect sources

Sulphur and iron sulphate are converted into sulphuric acid which dissolvers native $CaCO_3$. Thus Ca is made available for exchange reactions.

Management of Sodic soils

Reclamation of sodic soils requires good quality water to leach the sodium salts that are released during reclamation process. In the absence of good quality water these soils can be managed by following physical and biological methods as explained above which are nto true reclamation though they are called as reclamation. In addition to physical and biological methods, choosing crops suitable to sodic soil also benefits.

Crops tolerant to high sodicity are paddy (Py 1, CO 43,Paiyur 1, TRY 1 and TRY 2 etc) and ragi (CO 11, CO 12 and CO 13). Crop tolerant to medium sodicity are sorghum (CO 24 and CO 25) sugarcane (COC 771), Cumbu CO 6, X 5), Cotton MCU 7, MCU 10), Wheat, sunflower, subabol, Lucerne, varagu, guava, etc. Crops sensitive to sodicity are beans, green gram, black gram etc.

Quality of irrigation waters

Quality irrigation water is an essential resource for better growth of plants and to get better yields. Poor quality water often results in water losing salinity and sodicity problems in soils. Following are the characteristics on which irrigation water quality is judged.

1. Presence of total soluble salts in irrigation waters.
2. Proportion of carbonates and bicarbonates in relation to calcium and Magnesium in irrigation waters.
3. Proportion of sodium in relation to other cations in irrigation waters.
4. Concentration of specific ions in irrigation waters.

Several parameters are employed to judge the quality of irrigation waters. No parameter in complete in judging the quality of irrigation waters. Further the quality of water, should be judged by considering the crop and soil factors. Any judgement without considering the above factors may not be useful. Following are the parameters commonly adopted in judging the quality of irrigation waters.

1. Electrical conductivity

It is a measure of total soluble salts in waters. Based on EC following classification of waters are made as given by USDA.

Low saline → 0.250 dSm^{-1} : Good } can be used for irrigation

Medium saline → 0.250 to 0.750 dSm^{-1} : Fair }

High saline → 0.750 to 2.250 dsm^{-1} : Poor

Very high saline → 2.250 dSm^{-1} : Very poor

Soil testing laboratory of Tamil Nadu classification

1 dsm^{-1} Good - suitable

1-3 dsm^{-1} Critical - suitable on proper management

3 dsm^{-1} Injurious - not suitable

Potential salinity

This refers to judging quality of irrigation waters considering chloride and sulphate ion concentration in waters.

Potential salinity (PS) = $\frac{1}{2} SO^{2-}{}_4 + Cl^-$

It PS between 5 and 20 meq/l – can be used only in sandy soils

It PS between 3 and 15 meq/l – can be used in medium textured soils.

It PS between 1-3 meq /l - can be used in fine textured soils.

Purils salt Index (PSI)

This explains the relationship between sodium and calcium concentration in waters.

PSI = (Total Na^+ - 24.5) - (Total Ca^{2+} - CA as $CaCO^3$) x 4.85

If negative : Good quality water.

Positive : Poor quality water.

Sodium Adsorption Ration

This refers to proportion of sodium in relation to calcium and Magnesium in a water.

Sodium Adsorption Ratio = $\dfrac{Na}{\sqrt{\dfrac{Ca + Mg}{2}}}$

If SAR

10	=	Low sodic water
10 -18	=	Medium sodic water
18-26	=	High sodic water
26	=	Very high sodic water

Soluble sodium percentage

This explains proportion of sodium in relation to total cations in water

Soluble sodium percentage (SSP) = $\dfrac{Na}{Ca + Mg + K + Na}$

It SSP 60 = unsuitable for irrigation.

Residual sodium carbonate

This refers to proportion of carbonates and bicarbonates in relation calcium and Magnesium in waters.

Residual sodium carbonate = $(CO_3 + HCO_3) - (Ca + Mg)$

If RSC

1.25 meq/L	- Good
1.25 – 2.5 meq/L	- Fair
2.5 meq/L	- unsuitable

Permeability Index

This refers to proportion of sodium and bicarbonate in relation to cations in water.

Permeability Index (PI) = $\dfrac{Na + HCO_3}{Ca + Mg + Na} \times 100$

If PI 60 - unsuitable for irrigation.

Besides above parameter, concentration of specific ion if exceeds certain limits in water then that water may not be suitable for irrigation. Excess of any ion (CO_3 HCO_3 Cl, SO_4, No_3, B, Na, Fl) including heavy metal like Nickel, lead cadmium etc is injurious to plants. Boron is excessively available is some locations which makes the water quality poor.

Boron **PPM**

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0.5	=	Low B waters	can be used for irrigation
0.5 to 1	=	Medium B waters	
1.0 to 2	=	High B waters - Resistant crops can be grown	
2.0 to 4	=	Very high B waters	unsuitable
4.0	=	Excessive B waters	unsuitable

Fluorine

1ppm	=	Good
1ppm	=	Problematic

Management of poor quality waters

Saline waters

Various management techniques employed for saline soils can be followed to manage saline waters when used for irrigation.

Sodic waters

Calculated quantities of gypsum added based on RSC along with irrigation waters to reduce the ill effect of sodicity on soil and plants. The techniques employed for soil sodicity can be followed.

Remote sensing

Science and art that permits us to obtain information about an object or phenomenon or area through the analysis of data acquired by a sensing device without its being in contact with that object or phenomenon or area.

Drawbacks of Traditional methods

Although first generation realistic and factual data can be collected through traditional ground survey methods, these techniques suffer from following drawbacks.

- Data collection can not be done throughout the year due to unfavourable weather conditions.
- Data collection from inaccessible areas is not possible.
- Date collection through traditional methods is time consuming and there is wide gap between data collection and its possible utilization.

Advantages of Remote sensing

- Remote sensing technique provide the synoptic view of large areas.
- The data are collected on a permanent basis.
- The data are an unbiased record of the objects.
- The data are amenable for multi-disciplinary use i.e. the same data can be used for studies in forestry, soil science, hydrology and geology.
- The process of data acquisition and analysis is faster
- Satellite data are received periodically and helps in updating the information and monitoring the changes at short intervals.
- This have unique capability of recording data in visible, as well as invisible parts of electromagnetic spectrum.

Basic processes of remote sensing

The two basic processes involved are

- Data acquisition and
- Data analysis

The elements of the data acquisition process are energy sources, propagation of energy through the atmosphere, energy interaction with earth surface features, re-transmission of energy through the atmosphere, air borne and / or space borne sensors, resulting in the generation of sensor data in pictorial and / ori digital form. In short we use sensors to record variations in the way earth surface features reflect and emit electromagnetic energy.

The data analysis process involves examining data using various viewing and interpretation devices to analyze pictorial data and / or a computer to analyse digital sensor data. Reference data about the resources being studied (such as soil maps, crop statistics and field check data) are used when and where available to aquist in the data analysis. With the aid of the reference data, the analysis extracts information about the type, extent, location and condition of the various resources over which the sensor data were collected. This information is then complied, generally in the form of hard copy maps and tables or as computer files that can be merged with other "layers" of information's in a geographic information system (GIS). Finally the information is presented to the users who apply it to their decisions –making process.

Energy sources and radiation principles

Visible light is only one of many forms of electromagnetic energy. Radio waves, heat, ultraviolet rays and X rays are other familiar forms. All this energy is inherently similar and radiates in accordance with basic wave theory.

This theory describes electromagnetic energy is traveling in a harmonic, sinusoidal fashion at the "Velocity of light". The distance from one peak to the next is the wave length and the number of peaks passing a fixed point in space per unit time is the wave frequency.

Waves obey the general equation

$$C = v \lambda$$

Where,

C = is essentially a constant (3×10^8 m/sec.) – Velocity of light

V = frequency

λ = wave length.

In remote sensing, it is most common to categorize electromagnetic waves by their wave length location within the electromagnetic spectrum. The most prevalent unit used to measure wave length along the spectrum is the micrometer (μm). A micrometer equals to 1×10^{-6}m.

Forms of electromagnetic energy

		(Wave length)
Television and radio waves	-	(> 30 cm)
Micro waves	-	(0.1 – 30 cm)
Far infrared	-	(7.0 – 15.0 µm)
Thermal infrared	-	(3.0 – 14.0 µm)
Mid infrared	-	(1.3 – 3.0µm)
Near infrared	-	(0.7 – 1.3 µm)
Visible	-	(0.4 – 0.7 µm)
X rays R rays Cosmic rays	-	up to 0.03 µm

Most common sensing system operate in one or several of the visible, infrared or micro waves.

Micro waves : RADAR, Scateriometer , Altimeter, Micro wave radiometer.

IR range : Spectrometers, Radiometers, polarimeters, laser based active sensing system.

Visible : Mostly used for natural resource mapping.

Although many characteristics of electromagnetic radiation are most easily described by wave theory, another theory offers useful in lights into low electromagnetic energy interacts with matter. This theory (particle theory) suggests that electromagnetic radiation is composed of many discrete units called "Photons" of "quanta". The energy of a quantum is given by

$$Q = h\,v$$

Where,

Q = Energy of a quantum, Joules (J)

h = Planck's constant, 6.626×10^{-34} J sec.

v = frequency ($C = v\lambda \rightarrow V = \frac{C}{\lambda}$)

By relating wave and quantum models of electromagnetic radiation behaviour by substituting $\frac{C}{\lambda}$ for V in the above equation.

$$Q = \frac{h\,c}{\lambda}$$

$\therefore$ Quantum is inversely proportional to wave length. The longer the wave length involved the lower its energy content. This has important implications in remote sensing from the stand point that naturally emitted long wave length radiation, such as microwave emission from terrain features, is more difficult to sense than radiation of shorter wave lengths, such as emitted thermal IR energy.

The sun is the most obvious source of electromagnetic radiation for remote sensing. However all matter at temperatures above absolute zero (0° K or - 273°C) continuously emits electromagnetic radiation. Thus terrestrial objects are also source of radiation though it is of considerable different magnitude and spectral composition than that of the sun. Thus energy radiated by objects is a function of the surface temperature of the object. This property expressed by stefan – Boltzmann Law, which is

$$M = \sigma T^4$$

M = Total radiant existence from the surface of a material watts (w) m^{-2}.

σ = Stefan – Boltzmann constant 5.6697×10^{-8} ($Wm^{-2}\ °K^{-4}$)

T^4 = Absolute temperature (ok) of the emitting material.

It is important to note that the total energy emitted from an object varies as T^4 and therefore increases very rapidly with increase in temperature.

Energy interactions with earth surface features

When electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible. Various fractions of the energy incident on the element are reflected, absorbed and / or transmitted. Applying the principle of conservation of energy, the interrelationship between these three energy interactions are

$$EI(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

(Incident energy) = (Reflected) + (Absorbed) + (Transmitted)

The proportion of energy reflected, absorbed and transmitted varies with earth surface features. This depends on physical and chemical characteristics of features. Further proportion of ER, EA, ET vary at different wave lengths of electromagnetic radiation for a given feature. The above facts of electromagnetic spectrum and earth surface features responses to electromagnetic spectrum permits us to distinguish different features on an image / photography / digital data obtained.

Remote sensing –platforms

Platforms play a vital role in remote sense data acquisition. Platforms may be airborne or space borne depending upon the objects under study on earth surface as also on the sensors employed.

Air borne platforms: e.g. Balloons, Aircraft, rockets.

Balloons: These are designed and used for specific projects. Though the use of balloons is commonly restricted by meteorological factors such as wind velocity, direction etc. their application in resource mapping has been significantly useful.

Air craft

Air craft are commonly used as remote sensing platforms for obtaining aerial photographs. They are considered useful for regional coverage and large scale mapping. Flexibility of altitude in flying and data acquisition as per the need, is the added advantage. To use an air craft as a remote sensing platform, it is important that it should have maximum stability, free from vibration and oscillations and it should have the capacity to fly with λ uniform speed. In India, four types of aircraft are commonly used in acquiring aerial photography.

Aircraft	Minimum speed (km/hr)	Height ceiling (m)	Flying agency
Dakota	240	6000-700	IAF/ NRSA
Arro	600	8000	IAF
Cessna	350	9000	IAF
Canberra	560	5000	IAF/ NRSA

IAF - Indian Air Craft

NRSA - National Remote Sensing Agency

However, non conventional aircraft, such as helicopters, drones and sail planes have also been used for low altitude photography, television photography etc.

Space borne platforms

Space borne platforms, i.e., satellites have proved to be of vital use in natural mapping, meteorological and communication applications. Satellites are free flying orbiting vehicles, whose motion is governed by the gravity, and atmosphere. The entire earth or any of it's designated portions can be suitably covered by these satellites at specified intervals. Synoptic coverage of the earth on a periodic basis is therefore of immense use in many applications, particularly the ones where change analysis is to be carried out. Such platforms are least affected by disturbances in the atmosphere and helpful in viewing extraterrestrial bodies.

Broadly, satellites can be grouped under two categories, depending upon the types of orbits in which they move. They are

1. Geo-stationary satellites
2. Sun- synchronous satellites.

Geo-stationary / earth synchronous satellites.

The orbit in which these satellites move is called geo-stationary or geo-synchronous orbit. These satellites are placed in an orbit at a distance of 36,000km above the equator. At this altitude, the orbital speed of the satellite is same as that of earth's rotation speed and therefore, the is satellites appears to be stationary with respect to earth's movement. Such satellite cover the same area continuously over which they are flying, as well as their response of information transmission is rapid. However, the spatial resolution of the data produced is poor (1 km or more). Hence geostationary satellites are mostly used for weather forecasting and communication purposes. GOES (USA) and INSAT (India) are the examples of geostationary satellites.

Sun synchronous / polar/ Natural resources satellites

These satellites provide global coverage with high resolution. Such data is primarily used for applications in resource surveys and monitoring. They move is a low earth orbit at 800-1000km altitude over or near the north and south poles. The orbit is known as polar or sun synchronous orbit, coinciding with the plane of the sun i.e., the orbit remains in a constant plane relatively to the sun's position while the earth spins below it. The sun synchronous satellites normally pass a particular place at the same local time after a regular interval of time, providing repetitive converge of the place. LANSAT (USA), SPOT (French) and IRS (India) series are grouped under this category.

Sensors

A device that receives electromagnetic radiation from the objects on the earth surface. This sensor converts theses radiations into electrical signals and presents it in a form suitable for obtaining information about the land / earth resource as used by an information gathering systems. The specific parameters of sensors are

1. Spatial resolution.
2. Spectral resolution.
3. Radiometric resolution
4. Temporal resolution

Spatial resolution

The minimum detectable area on the ground by a detector placed on a sensor is called the spatial resolution. Simply it can also be defined as "Dimensions of the smallest object or minimum detectable area which can be resolved by the sensor". The "swath" is related features of spatial resolution and instantaneous field view of a detector (IFOV) of a sensor, which can be explained as the width of a strip of a terrain recorded by a sensor.

Spectral resolution

The smallest amount of spectral change that can be detected by a sensor is called the spectral resolution. It is a function of the location and breath of the wave length region. The finner the spectral channels, the better is the spectral resolution and therefore, the satellite data recorded in the narrow spectral bands are extremely useful for natural resource survey and mapping.

Radiometric resolution

The number of grey levels / values which a sensor can distinguish between completes black and white. The more the grey levels, the better the radiometric resolution. For example, in LANDSAT TM there are 256 grey levels (0 -255) and in IRS LISS-II the radiometric resolution is 128 (0 -127).

Temporal resolution

The temporal resolution is characterized by the smaller period of repetitive coverage. For example, the resolution for LANDSAT is 18 days and for IRS 20 days, SPOT gives the best revisit time i.e. in four days, one particular area can be revisited.

Sensors can be grouped, either on the basis of energy source or on the basis of wave bands employed. Based on energy sources, sensors are classified as follows

1. Active sensor

An active sensor operates by emitting its own energy which is needed to detect the various phenomena (eg.: RADAR, Camera with flash gun)

2. Passive sensor

The operation of passive sensor is dependent on the existing sources of energy, like sun (eg.: Photographic systems, multi spectral scanners)

Photographic cameras

The photographic system, having conventional camera with black and white photography, is the oldest and probably, so far the most widely used sensor for recording information about ground objects. Photographic cameras have been successfully used from aircraft, balloons and from manned and unmanned space craft. In this system the information is limited to size and shape, as the films used are sensitive only to visible region of spectrum (0.4.-0.7 cm). for infrared imagery, films with response extending upto 0.9 cm are available. The mid IR and thermal IR regions, which are of great interests, can not be covered with photographic cameras.

Return Beam Vidicon (RBV):

This is very similar to television camera. In such system, the ground image is formed by a fixed camera lens on a photosensitive semi transparent sheet. The image is created on this surface as electrical charge or potential. The television camera was the first electronic system which took images of earth from space. Earlier this was used in meteorological observations. Single and multispectral band systems available. The basic disadvantage of multispectral band system is the difficulty of registration in all the bands. Further limitations are include limited spectral response, low resolution, poor dynamic range, poor radiometric accuracy and geometric distortions. RBV is no more employed in any remote sensing system.

Thermal system:

Sensors which operate in infrared and a part of microwave region are called thermal sensors. These are based on the principle of Stefan- Boltmann Law of radiation and utilize the scanning method for recording electromagnetic energy. Thermal images are generally found to have large distortions.

Optical-mechanical scanners:

The limitations largely noticed with photographic and TV image in systems are overcome in optical-mechanical scanners, but they also have their own limitations. Such scanners have a combination of beam splitters and filters for spectral band selection. This imaging system has the advantage that any set of desired spectral bands can be selected with appropriate filters and detector combinations. The most widely used sensor in this category is the multi spectral scanner (MSS) on board LANDSAT series. MSS has four spectral bands convening from 0.5 to 1.1 cm region.

Redar and microwave sensors:

It's application to natural resources is considerably less developed as compared to visible and IR maize interpretations. Active microwave systems (also called radar system) map the terrain features by transmitting a series of microwave pulses and recording transmitting a series of microwave pulses and recording the strength and timing of echoes reflected from objects in the systems field of view. These system are much more complex because of the use of transmission, modulation and measurement of Doppler frequency. Microwaves sensors have distinct advantages because they are unaffected by atmosphere conditions, and are thus able to penetrate smoke, clouds, haze and snow. Under this system, plan position indicator (PPI) side looking airborne radar (SCAR) and synthetic aperture radar (SAR) can be grouped. These sensors are useful in temperate and cloudy tropical regions and find out real time of rainfall.

Advanced Remote sensors:

Some of the advanced remote sensors are Linear imaging and self scanning sensor (LISS) : These sensors use an array of solid state devices for scanning. The array may be made of photo-diodes, photo-transistors or charge coupled devices (CCDs).These sensor give a two dimensional picture.

IRS service carry solid state scanner which in known as push-broom scanners. IRs IC carries LISS III camera, panchromatic camera (PAN) and wide field sensor (WiFS).

The PAN has been designed to provide data with a spatial resolution of 5.8 m in stereo mode, with a ground surath of 70 km, where WiFS provides data in two spectral bands, with a spatial resolution of 188 m and a ground swath of 810 km.

The detection of electromagnetic energy can be performed either photographically or electronically. The process of photography uses chemical reactions on the surface of a light sensitive film to detect energy variations within a scene. Photography is reserved exclusively for image that wave detected as well as recorded on film. Photographic systems offer many advantages: They are relatively simple and in expensive and provide a high degree of spatial detail and geometric integrity.

Electronic sensors generate an electrical signal that corresponds to the energy variations in the original scene. A familiar example of electronic sensor is a video camera. Although considerably more complex and expensive than photographic systems, electronic sensors offer the advantages of a broader spectral range of sensitivity, improved calibration potential, and the ability to electronically transmit data. Electronic sensor signals are generally recorded on to magnetic tupe. Subsequently, the signals may be converted into image form image is pictorial representation of image however a photographs.

Aerial photographs:

Photography taken from the air with the camera pointing vertically or with an angle downwards at the time of exposure.

Types / kinds of Aerial photographs:

Based on deviation on optical axis of camera from vertical they are classified as

1. Vertical photography
2. Low oblique photography
3. High oblique photography

Vertical photography;

The vertical photography are taken with frame cameras along flight lines with the optical axis of the camera vertical or heavly so at the time of exposure of the film. A small tilt generally less than 2° on an average and not more generally less than 2° on an average and not more than 3° for a single photography is generally permissible. Vertically photography is the only method of systematic coverage.

Low oblique photography:

Low oblique photography are taken with the optical axis of camera tilted at an angle less than 30° from the vertical. The horizon is not seen in the photo.

High oblique photography:

This is taken with optical axis of camera tilted at an angle of about 60° with the vertical. The horizon is visible in the photo.

Based on the combination of cameras and lenses aerial photography are classified follows.

1. Single camera photography
2. Twin camera photography
3. Tricamera photography
4. Small camera photography
5. Continuous strip photography
6. Image motion compensation photography

Singe camera photography:

According to field of view photographs this can be further classified as normal angle, wide angle and super wide angle.

Twin camera photography;

Two cameras are used to take aerial photographs. These cameras are combined in two ways. They are Traverse twin camera and convergent twin camera photography. By using convergent cameras, successive pair of photography. By using convergent cameras, successive pair of photographs of 100% overlap can be obtained. Maps of wish accuracy are prepared by these photographs.

Tricamera photography:

Photography is taken with three cameras equipped with wide angle sensor mounted on a rigid frame.

Small camera photography:

Photography taken from 35 mm or 70 mm camera which are small and light is called small camera photography. This photography is mainly used for reconnaissance purposes.

Continuous strip photography:

In strip cameras film is moved in the focal plane of camera behind a slit and the shutter is open all the time. The photography is continuous and hence no film is wasted and is used in large scale mapping.

Scale of photography

		Scale	Utility
1.	Very large scale	1 : 10,000 and larger	Logging planning Road alignment Diseases damage survey wild life management
2.	Large scale	1 : 10,000 to 1,20,000	Detailed inventory and working plane maps
3.	Medium scale	1 : 20,000 to 1,40,000	Selection of site for afforestation, pasture.
4.	Small scale	1 : 40, 000 and smaller	Broad land are survey.

Aerial photographys are available with surveyor general of India, Dehradun, It can also be obtained from Directorate of survey (Air), New Delhi. Satellite data can be obtained from National Remote sensing Agency, Hyderabad.

Satellite Remote Sensing:

Remote sensing data in unique in it is ability to provide a synoptic view of large areas and the capability to repetitively cover the same area after a regular interval. The data provides information for a variety of applications, such as agriculture, forestry, soil mapping, urban sprawl, geology and hydrology.

Kinds / Forms of satellite data:

Space photographs:

These include metric and not metric black and white, Colour and infrared (dipositive and negative) mosaics and orthophotographs.

Satellite images :

These include films, paper prints false colour composite (FCC), computer compatable tape (CCT), compact disks (CD) and floppies.

The above products are prepared from the data collected by the following satellites.

LANDSAT – Multispectral scanner & Thematic mapper (MSS & TM) (USA)

SPOT – High Resolution visible (HRV)

IRS – Linear Imaging Self Scanner I, II & III (LISS)

(India)

Orthophotographs:

They are photomaps. Like map they have one scale and like photographs they show the terrain in actual detail.

Aerial mosaics:

Aerial mosaics is an assemblaze of aerial photographs, the edges of which are cut and matched to show a single large view of the terrain.

Controlled mosaic:

Controlled mosaic is assembled from rectified photographs. The assembly is fitted to plotted controlled points as the rectified photos have a constant scale.

Uncontrolled mosaics :

Uncontrolled mosaics are assembled by matching the corresponding image on adjunct photos. The mosaic have no horizontal control.

Semi controlled mosaics :

Semi controlled mosaics are assembled to a common scale without ground control. It does not use rectified photos but the photos are brought to the scale of map by enlarging or reducing the scale.

Remote sensing satellites:

1. LANDSAT Series : 1,2,3,4,5,6 and 7
2. SPOT : 1,2,3
3. IRS : Bhaskara 1,2 IRS 1 A/1 B/ 1 C/ 1 D, IRS P2/P3/P4 etc.

Geostationary satellites of India used for meteorological and communication purposes are

INSAT - 1 A/ 1 B / 1C/1 D

- 2 A / 2 B / 2 C/ 2 D/ 2 E etc.

Remote sensing Institutes in India:

NRSA, Hyderabad : is mainly responsible for acquisition, processing and dissemination of satellite /aerial data processing and dissemination of satellite /aerial data and training the personnel in various application techniques. The space application centre (SAC), Ahamedabad and the Indian Space Research Organisation (ISRO), Bangalore are mainly responsible for the design and launching of sensors and platforms, including statellite launch vehicles. The National Natural Resource Management System (NNRMS) and Natural Resources Information system (NRIS) as well as a chain of Regional Remote Sensing Service Centres (RRSSCs) and State Remote Sensing Application Centres (SRSACs) provide operational resource survey service to the users using modern remote sensing techniques.

Stereovision

When a person with normal vision in both the eyes views the object, the two eyes which are separated by a distance look at it from two different angles simultaneously and two different impressions of the object are formed. Brain fuses these two impressions and a three dimensional impression of an object is obtained. This property of eyes to see the objects in three dimension is know as stereovision. In the same manner it is possible to get a three dimensional impression of the terrain by looking at two photographs of the terrain taken from two different points. For this purpose the photos must fulfill the following conditions.

Table 2.5 The IRS satellite constellation (NRSA, 1995)

Satellite	Launch	Instruments	Spatial	Swath	Repeat coverage
IRS 1 A	1998	LISS –I Multispectral LISS-II Multispectral	72.5 m 36.25m	148 km 74 km	22 days
IRS 1B	1991	LISS-I Multispectral LISS-II Multispectral	72.5 m 36.25 m	48 km 74 km	22 days
IRS P2	1994	LISS –II Multispectral	32 x 37 m	67 km	24 days
IRS 1C	1995	LISS-III Multispectral	23.5 m VNIR	142 km	24 days

		WiFS Wide- Field Panchromatic	70.5 m SWIR 188 m	148 km 774 km 70 km	5 days 5 days
IRS P3	1996	MOS-A MOS-B MOS-C WiFS X-ray Astronomy payload	2.5 x 2.5 m 720 x 580 m 1 x 0.7 km 188 m	248 km 248 km 248 km 774 km	- - - 5 days
IRS 1D	1997	LISS-III Multispectral WiFS Wide- Field Panchromatic	23.5 m VNIR 70.5 m SWIR 188 m <10m	142 km 148 km 774 km 70 km	24 days 5 days 5 days
IRS P4	1999	Ocean Color Monitor Mulifrequency Scanning Microwave Radiometer	12 bits 120 m/80m/ 40m/40/m	1420 km	2 days

- The same scene should be covered in both the photographs ie. The photographs should have an overlap and it is in this portion of photographs that the stereo-vision will be possible.
- The scale of two photographs should be approximately the same.
- The camera axis at the time of exposure must be approximately in the same plane.
- The ratio of distance between the two camera stations and flying height must have an appropriate value. The ideal value is 0.25. However, values upto 2 can be used.

Stereoscopes:

Lens stereoscope:

They are portable and comparatively in expensive. Most are small instruments with folding legs. The lens spacing can usually be adapted from about 45 to 75 mm to accommodate individual eye spacings. Lens magnification is typically 2 power. It is not possible to view entire 240 mm aerial photographs without raising the edge of one of the photos.

Mirror stereoscopes:

Use a combination of prisms and mirrors to separate the lines of sight from each of the viewers eyes. The distance between the wing mirrors much greater than eyepiece spacing so that a pair of 240 mm air photos can be viewed earily. Such stereoscopes typically have little or no magnification. Binoculars can be fitted to provide a magnification of 2 to 4 power.

Scanning mirror stereoscopes:

This can be used with 1.5 to 4.5 power magnification and has a built in provision for moving the field of view across the entire stereo overlap area of the photos without moving either the photos or the stereoscopes.

Zoom stereoscope:

This has a continuously variable magnification of 2.5 to 10 power. They are expensive precision instruments, typically with a high lens resolution.

Light table zoom stereoscope:

This has a provision of light source attached to zoom stereoscope for better viewing of colour infrared film transparencies.

Air photographs/satellite image interpretation:

The success in interpretation depends on the following.

- Training and experience of the interpreter
- Nature of the object being interpreted and
- The quality of the product used for interpretation.

Basic characteristics of features used in Inter pretation:

Shape:

It refers to general form, configuration, or outline of the individual objects. Numerous components of environment can be identified with reasonable certainty, merely by their shapes or forms. This is true for both the naturl features (e.g. Geological structures) as well as man made objects (e.g.) different type of industrial plants and buildings.

Size:

The size of an object is one of the most useful clues in the possible identification. Objects can easily be picked up from photos if the scale is large. An irrigation ditch and an anti tank ditch are very much alike except in size, and simple measurement may be sufficient to make the identification.

Pattern:

Repetitive arrangements of both natural and cultural features are quite common. Patterns are clearly visible on images and also capture many small but significant patters which might be overlooked by the ground observer. Cultural features are conspicuous because they consist of straight lines or regular configurations. A road and railway like may look much alike in a photography/imagery, but an interpreter can separate them by the slight configurations required by their function. For example, a road may have fairly steep grades, sharp curves and many intersections while a railway has gentle grades, wide curves and few intersections.

Shadow:

It defines outline of an object and its length may help to estimate its height as well as elevational out line of an object. Shadows are especially useful in geomorphological studies where micro relief features may be easier to detect under conditions of low angle solar illumination than when the sun is high the sky.

Tone or color:

Tone refers to the colour or relative brightness of objects in aerial data. Different objects emits or reflect different wavelengths and intensities of radiant energy. Such differences may be recorded as variations of pictures tone, colour or density. In black and white images, the tone varies from light grey to dark. The terms light, medium and dark are used to describe the variations in tone.

Texture:

Texture is the frequency of tonal change on photographic image and is created by tonal repetitions of groups of objects which are two small to be disurned as individuals. Common photography textures include smooth, rippled, mottled, lineated and irregular. This is very important unit for rock identification.

Site:

At an advanced stage in a photo interpretation procedure, the location of objects with respect to terrain features of other objects may be helpful in defining the identification and classification of certain picture contents. For example, certain tree species would be expected to occur on well drained upland sites, whereas other tree species would be expected to occur on poorly drained lowland sites.

Interpretation methods:

Two methods available. They are

1) Visual interpretation using keys
2) Digital interpretation using computers.

Images Interpretation keys (visual)

1) **Selection key** :

   It contains numerous photography examples with supporting text. The interpreter selects the features or conditions found an the image under study.

2) **Elimination key:**

   It is arranged so that interpretation proceeds step by step, from general to specific and leads to the elimination of all features or conditions except the ones being identified.