Problem soils and their management

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> "The multiple roles of soils often go unnoticed. Soils don't have a voice, and few people speak out for them. They are our silent ally in food production."
>
> **Jose Graziano da Silva, FAO Director-General**

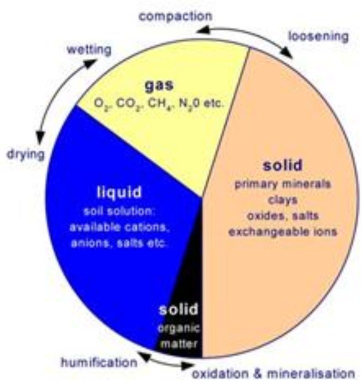
Soil is a natural finite resource base which sustains life on earth. It is a three phase dynamic system that performs many functions and ecosystem services and highly heterogeneous. Soil biota is the biological universe which helps the soil in carrying out its functions. Often soil health is considered independently without referring to interlinked soil functions and also based on soil test for few parameters. Physical condition of soil and biological fertility are overlooked in soil health management which needs revisiting of soil users. Recognising the importance of soil health in all dimensions, 2015 has been declared as the International Year of Soils by the 68th UN General Assembly. Food and Agriculture organisation of the United Nations has formed Global soil partnership with various countries to promote healthy soils for a healthy life and world without hunger. India, the second most populous country in the world faces severe problems in agriculture. It is estimated that out of the 328.8 m ha of the total geographical area in India, 173.65 m ha are degraded, producing less than 20% of its potential yield (Govt. of India, 1990).

Soil heterogeneity is the reasons for the diverse nature of cropping and production pattern. Soil heterogeneity is the case where soil in a relatively small area varies greatly in texture, fertility, topography, moisture content, drainage etc. If it exists in large scale due to the parent material or manmade activities, then the problem of soil suitability to agriculture arises. (Fig : 3)

Soil consists of a solid phase (minerals and organic matter) as well as a porous phase that holds gases and water. Accordingly, soils are often treated as a three-state system as shown in fig 1. From an agriculture point, the soil should support all the functions as in fig 2

The soils which possess characteristics that make them uneconomical for the cultivation of crops without adopting proper reclamation measures are known as problem soils.

Often we resort to chemical means of reclamation that leads to



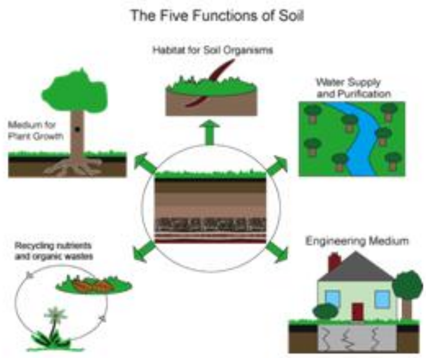


Fig 1. Soil - a three state system http://vro.depi.vic.gov.au/dpi/vro/vroimages.nsf/Images/soilhealth_7898_fig5/$File/7898_fig5.jpg	Fig 2. Soil functions Source:http://soilsurvey.cares.missouri.edu/tutorial/images/functions.gif

impairment of ecosystem functions. Resorting to natural means and integrated methods will resolve the issue and prevent causing irreparable damage

Types of problem soils

- Physical problem soils
- Chemical Problem soils
- Biological Problem soils
- Nutritional problem soils as a result of above constraints

1. Soils with Physical problems

1.1. Slow permeable soils/Impermeable soils and their management

Occurrence and Causes

In Tamil Nadu, the area under slow permeable soils is around 7,54,631 ha (7.5% of TGA). Slow permeable soil is mainly due to very high clay content, infiltration rate < 6cm/day, so more runoff which eventually leads to soil erosion and nutrient removal. Since the capillary porosity is high it leads to impeded drainage, poor aeration and reduced conditions.

Remedial measures

(i) Incorporation of organics: Addition of organics namely FYM/composted coir pith/press mud at 12.5 t ha^{-1} found to be optimum for the improvement of the physical properties

(ii) Formation of ridges and furrows: For rainfed crops, ridges are formed along the slopes for providing adequate aeration to the root zone.

iii) Formation of broad beds: To reduce the amount of water retained in black clay soils during first 8 days of rainfall, broad beds of 3-9 m vide should be formed either along the slope or across the slope with drainage furrows in between broad beds.

iv). providing open/ subsurface drainage

v). Huge quantity of sand /red soil application to change the texture

vi). Contour /compartmental bunding to increase the infiltration

vii). Application of soil conditioners like vermiculite to reduce runoff and erosion

1.2. Soil surface crusting

Occurrence and Causes

In Tamil Nadu, surface crusting is prevalent in Trichy, Thanjavur, Pudukottai, Cuddalore and Sivaganga districts and mostly in red soil areas. In Tamil Nadu, the area under soil crusting is around 4,51,584 ha (4.49% TGA). Surface crusting is due to the presence of colloidal oxides of iron and aluminium in soils which binds the soil particles under wet regimes. On drying it forms a hard mass on the surface. It is predominant in Alfisols but also occur in other soils too. (Fig : 4)

Impact on soil properties

- Prevent germination of seeds and retards root growth
- Results in poor infiltration and accelerates surface runoff
- Creates poor aeration in the rhizosphere
- Affects nodule formation in leguminous crops

Remedial measures

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

- Farm yard manure or composted coir pith @ 12.5 t ha^{-1} or other organics may be applied to improve the physical properties of the soils
- Scraping the surface soil by tooth harrow will be useful.
- Bold grained seeds may be used for sowing on the crusted soils.
- More number of seeds/hill may be adopted for small seeded crops.
- Sprinkling water at periodical intervals may be done wherever possible.
- Resistant crops like cowpea can be grown.

1.3. Sub soil hard pan

Occurrence and Causes

Sub soil hard pan is commonly found in red soils. Though soil is fertile, crops cannot absorb nutrients from the soil which leads to reduction in crop yields. In Tamil Nadu, it is prevalent in Coimbatore, Erode, Dharmapuri, Trichy, Cuddalore, Villupuram, Pudukottai, Sivagangai, Madurai and Salem districts particularly under rainfed conditions. In Tamil Nadu, the area under subsoil hardpan is around 10, 54,661 ha (10.48% TGA) The reasons for the formation of sub surface hard pan in red soils is due to the illuviation of clay to the sub soil horizons coupled with cementing action of oxides of iron, aluminium and calcium carbonate.

Impact on soil physical properties

The sub soil hard pan is characterized by high bulk density(>1.8 Mg m^{-3}) which in turn lowers infiltration, water holding capacity, available water and movement of air and nutrients with concomitant effect on the yield of crops.

Chiselling technology to overcome the sub soil hard pan

The field is to be ploughed with chisel plough, a tractor drawn heavy iron plough at 50 cm interval in both the directions. Chiselling helps to break the hard pan in the sub soil besides it ploughs up to 45 cm depth. Farm yard manure or press mud or composted coir pith at 12.5 t ha^{-1} is to be spread evenly on the surface. The field should be ploughed with country plough twice for incorporating the added manures. The broken hard pan and incorporation of manures make the soil to conserve more moisture.

1.4. Shallow soils

Occurrence and Causes

In Tamil Nadu, shallow soils occur over an area of around 1,16,509 ha (1.16.% TGA). Shallow soils are formed due to the presence of parent rocks immediately below the soil surface (15-20 cm depth).

Impact

The shallow soil restricts root elongation and spreading. Due to shallowness less volume of soil is available exhaustive soil nutrients.

Management

- Growing shallow rooted crops.
- Frequent renewal of soil fertility
- Growing crops that can withstand shallowness(Mango, country goose berry, fig, tamarind, ber and cashew etc)

1.5. Highly permeable soils

Occurrence and Causes

Sandy soils containing more than 70 per cent sand fractions occur in coastal areas, river delta and in the desert belts. Such soils occur in Coimbatore, Trichy, Kanyakumari, Tuticorin, Thanjavur and Tirunelveli districts and in part of coastal areas in Tamil Nadu. A total area of 24,12,086 ha in Tamil Nadu are affected by excessively permeable soils

Impact

Excessive permeability of the sandy soils results in poor water retention capacity, very high hydraulic conductivity and infiltration rates. 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. So whatever the nutrients and water added to these soils are not utilized by the crops and subjected to loss of nutrients and water. In addition, it is not providing anchorage to the crops grown.

Management technology

 The soils should be ploughed uniformly.

 Twenty four hours after a good rainfall or irrigation, the soil should be rolled 10 times with 400 kg stone roller of 1 m long or an empty tar drum filled with 400 kg sand at optimum moisture (13 %)

 Then shallow ploughing should be given and crops can be raised.

 Application of clay soil up to a level 100 t ha-1 based on the severity of the problem and availability of clay materials

 Application of organic materials like farm yard manure, compost, press mud, sugar factory slurry, composted coir pith, sewage sludge etc

 Providing asphalt sheet, polythene sheets etc. below the soil surface to reduce the infiltration rate

 Crop rotation with green manure crops like Sunhemp, sesbania, daincha, kolinchi etc

 Frequent irrigation with low quantity of water

 Frequent split application of fertilizers and slow release fertilizers like neem coated urea

1.6. Heavy clay soils

Clay soils are referred as heavy soils. To be classified as clay soil, it should be made up of about 40% clay particles, the finest particles found in soil.This is also slowly permeable soils.

Main production constraints

Heavy have very hard consistence when dry and very plastic and sticky ("heavy") when wet. Therefore the workability of the soil is often limited to very short periods of medium (optimal) water status. However, tillage operations can be performed in the dry season with heavy machinery. Mechanical tillage in the wet season causes serious soil compaction.

They are imperfectly to poorly drained, leaching of soluble weathering products is limited. This is due to the very low hydraulic conductivity. Once the soil has reached its field capacity, practically no water movement occurs. Flooding can be a major problem in areas with higher rainfall. Surface water may be drained by open drains.

Most of the heavy clay soils belonging to Vertisols are chemically rich and are capable of sustaining continuous cropping. They do not necessarily require a rest period for recovery; because the pedoturbation continuously brings subsoil to the surface. However, the overall productivity normally remains low, especially where no irrigation water is available. Nitrogen is normally deficient as well as phosphorus. Potassium contents are variable. Secondary elements and micronutrients are often deficient. In semi-arid areas free carbonate and gypsum accumulations are common.

There are two broad groups of vertisols

Self-mulching Vertisols. These have a fine (granular or crumb) surface soil structureduring the dry season. When such soils are ploughed, the clods, after being subjected to repeat wetting and drying, disintegrate. Crusty Vertisols. These have a thin, hard crust in the dry season. When ploughed, crusty Vertisols produce large, hard clods that may persist for 2 to 3 years before they have crumbled enough to permit the preparation of a good seedbed. Such soils require mechanical tillage if they are to be cultivated.

The structural stability of high clay soils remains low. They are therefore very susceptible to water erosion. Slopes above 5 per cent should not be used for arable cropping, and on gentler slopes contour cultivation with a groundcover crop is advisable. When terracing, sufficient surface drainage must be provided. The strategies suggested for slowly permeable soils also hold good for clay soil.

1.7. Fluffy paddy soils

Occurrence and Causes

In Tamil Nadu, fluffy paddy soils are prevalent in Cauvery delta zone and in many parts of the state. It is formed due to the continuous rice-rice cropping sequence. In Tamil Nadu about 25,919 ha of land is affected by fluffiness (0.26 % of TGA)

The traditional method of preparing the soil for transplanting rice consists of puddling which results in substantial break down of soil aggregates into a uniform structure less mass. The solid and liquid phases of the soil are thus changed. Under continuous flooding and submergence of the soil for rice cultivation in a cropping sequence of rice-rice-rice, as in many parts of Tamil Nadu, the soil particles are always in a state of flux and the mechanical strength is lost leading to the fluffiness of the soils. This is further aggravated by in situ incorporation of rice stubbles and weeds during puddling.

Impact of fluffiness

Sinking of draught animals and labourers is one of the problems during puddling in rice fields which is 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, it leads to low bulk density and very rapid hydraulic conductivity which in turn affects anchorage to the roots and the potential yield of crops is adversely affected.

Management Methodology

- Irrigation should be stopped 10 days before the harvest of rice crop
- After the harvest of rice, when the soil is under semi-dry condition proctor moisture level, compact the field by passing 400 kg stone roller or an empty tar drum filled with 400 kg sand 8 times.
- Usual preparatory cultivation is carried out after compaction.

2. Chemical Problem soils

2.1. Salt - affected soils

The salt-affected soils occur in the arid and semiarid regions where evapo-transpiration greatly exceeds precipitation. The accumulated ions causing salinity or alkalinity include sodium, potassium, magnesium, calcium, chlorides, carbonates and bicarbonates. The salt-affected soils can be primarily classified as saline soil and sodic soil. The state-wise distribution of salt affected soils in India is presented in the following table.

Table - Extent and distribution of salt affected soils in India

(Area x1000ha)

States	Water logged		Salt affected area			Total
	Canal command	Total	Canal command	Outside canal	Coastal	
Andhra Pradesh	266	339	139	391	283	813
Bihar	363	363	224	176	Nil	400
Gujarat	173	484	540	327	302	1214
Haryana	230	275	455	Nil	Nil	455
Karnataka	36	36	51	267	86	404
Kerala	12	12	NA	NA	26	26
Madhya Pradesh	57	57	220	22	Nil	242
Maharashtra & Goa	6	111	446	NA	88	534
Orissa	196	196	NA	NA	400	400
Punjab	199	199	393	127	Nil	519
Rajasthan	180	348	138	984	Nil	1122
Tamil Nadu	18	128	257	NA	84	340
Uttar Pradesh	455	1980	606	689	Nil	1295
West Bengal	NA	NA	Nil	NA	800	800
Total	2190	4528	3469	3027	2069	8565

Tyagi, N.K., CSSRI

Saline soils

Saline soils defined as soils having a conductivity of the saturation extract greater than 4 dS m^{-1} and an exchangeable sodium percentage less than 15 Saline soils defined as soils having a conductivity of the saturation extract greater than 4 dS m^{-1} and an exchangeable sodium percentage less than 15. The pH is usually less than 8.5. Formerly these soils were called *white alkali* soils because of surface crust of white salts.

Formation

The process by which the saline soil formed is called Salinization. Saline soils occur mostly in arid or semi arid regions. In arid regions saline soils occur not only because there is less rainfall available
to leach and transport the salts but also because of high evaporation rates, which tend further to concentrate the salts in soils and in surface waters

Major production constraints

Presence of salts leads to alteration of osmotic potential of the soil solution. Consequently water intake by plants restricted and thereby nutrients uptake by plants are also reduced. In this soil due to high salt levels microbial activity is reduced. Specific ion effects on plants are also seen due to toxicity of ions like chloride, sulphate, *etc.*

Management of saline soils

The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage. Provision of lateral and main drainage channels of 60 cm deep and 45 cm wide and leaching of salts could reclaim the soils. Sub-surface drainage is an effective tool for lowering the water table, removal of excess salts and prevention of secondary salinisation. of ions like chloride, sulphate, *etc.*

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Irrigation management

Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces the effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip, sprinkler and pitcher irrigation have been found to be more efficient than the conventional flood irrigation method since relatively lesser amount of water is used under these improved methods.

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 (Sunhemp, Daincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity.

Crop choice / Crop management

Crops are to be chosen based on the soil salinity level. The relative salt tolerance of different crops is as follows:

Relative tolerance of crops to salinity

Plant species	Threshold salinity (dS m^{-1})	Plant species	Threshold salinity (dS m^{-1})
Field crops		**Vegetables**	
Cotton	7.7	Tomato	2.5

Sugarbeet	7.0	Cabbage	1.8
Sorghum	6.8	Potato	1.7
Wheat	6.0	Onion	1.2
Soybean	5.0	Carrot	1.0
Groundnut	3.2	**Fruits**	
Rice	3.0	Citrus	1.7
Maize	1.7	-	-
Sugarcane	1.7	-	-

Soil / cultural management

Planting the seed in the centre of the raised bed / ridge may affect the germination as it is the spot of greatest salt accumulation. A better salinity control can be achieved by using sloping beds with seeds planted on the sloping side just above the water line. Alternate furrow irrigation is advantageous as the salts can be displaced beyond the single seed row. Application of straw mulch had been found to curtail the evaporation from soil surface resulting in the reduced salt concentration in the root zone profile within 30 days.

2.2. Alkali / Sodic soils

Alkali or sodic soil is defined as a soil having a conductivity of the saturation extract less than 4 dS m^{-1} and an exchangeable sodium percentage greater than 15. The pH is usually between 8.5 – 10.0. Most alkali soils, particularly in the arid and semi-arid regions, contain $CaCO_3$

in the profile in some form and constant hydrolysis of $CaCO_3$ sustains the release of OH^- ions in soil solution. The OH^- ions so released result in the maintenance of higher pH in calcareous alkali soils than that in non – calcareous alkali soils.

Expected loss of soil productivity due to ESP in different soils

ESP	Loss in productivity (%)	
	Alluvium derived soils (Inceptisols / Alfisols)	Black soils (Vertisols)
Up to 5	Nil	Up to 10
5-15	<10	10-25
15-40	10-25	25-50
>40	25-50	>50

Formation

Soil colloids adsorb and retain cations on their surfaces. Cation adsorption occurs as a consequence of the electrical charges at the surface of the soil colloids. While adsorbed cations are combined chemically with the soil colloids, they may be replaced by other cations that occur in the soil the soil colloids. While adsorbed cations are combined chemically with the soil colloids, they may be replaced by other cations that occur in the soil solution. Calcium and magnesium are the principal cations found in the soil solution and on the exchange complex of normal soils in arid regions. When excess soluble salts accumulate in these soils, sodium frequently becomes the dominant cation in the soil solution resulting alkali or sodic soils.

Major production constraints

Excess exchangeable sodium in alkali soils affects both the physical and chemical properties of soils.

a) Dispersion of soil colloids

b) Specific ion effect

Reclamation of alkali / sodic soils

Physical Amelioration

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

- Deep ploughing is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also helps in improvement of aeration.
- Providing drainage is also practiced to improve aeration and to remove further accumulation of salts at root zone.
- Sand filling which reduces heaviness of the soil and increases capillary movements of water.
- Profile inversion – Inverting the soil benefits in improvement of physical condition of soil as that of deep ploughing.

Chemical Amelioration

Reclamation of alkali / sodic soils requires neutralization of alkalinity and replacement of most of the sodium ions from the soil – exchange complex by the more favourable calcium ions. This can be accomplished by the application of chemical amendments (the materials that directly or indirectly furnish or mobilize divalent cations, usually Ca^{2+} for the replacement of sodium from the exchange complex of the soil) followed by leaching to remove soluble salts and other reaction products. The chemical amendments can be broadly grouped as follows:

- *Direct Ca suppliers:* Gypsum, calcium carbonate, phospho-gypsum, etc.
- *Indirect Ca suppliers*: Elemental Sulphur, sulphuric acid, pyrites, $FeSO_4$, etc

Among them gypsum is, by far, the most commonly used chemical amendment. Calcium carbonate is insoluble in nature which of no use in calcareous sodic soils (have already precipitated $CaCO_3$) but can be used in non calcareoussodic soils (do not have precipitated $CaCO_3$) since pH of this soils are low at surface and favouring solubilisation of $CaCO_3$. Some of indirect suppliers of Ca *viz.* Elemental sulphur, sulphuric acid, iron sulphate are also used for calcareous sodic soils. These materials on application solubilise the precipitated $CaCO_3$ in sodic soils and releases Ca for reclamation.

Other sources

Distillery spent wash

Distillery spent wash is acidic (pH 3.8-4.2) with considerable quantity of magnesium. About 2 lakh litres of distillery spent wash can be added to an acre of sodic soil in summer months. Natural oxidation is induced for a period of six weeks with intermittent ploughing once in a month. In the second month (after 45-60 days) fresh water may be irrigated and drained. Such a treatment reduces the pH and exchangeable sodium percentage

Distillery effluent

Distillery effluent contains macro and micronutrients. Because of its high salt content, it can be used for one time application to fallow lands, About 20 to 40 tonnes per ha of distillery effluent can be sprayed uniformly on the fallow land. It should not be allowed for complete drying over a period of 20 to 30 days. The effluent applied field has to be thoroughly ploughed two times for the oxidation and mineralization of organic matter. Then the crops can be cultivated in the effluent applied fields by conventional methods.

Pulp and paper mill effluents

Pulp and paper effluents contain lot of dissolved solids and stabilized organic matter and if properly treated can safely be used for irrigation with amendments *viz.* pressmud @ 5 tonnes ha^{-1}, fortified pressmud @ 2.5 tonne ha^{-1} or daincha as in situ green manure.

Crop choice

Rice is preferred crop in alkali / sodic soil as it can grow under submergence, can tolerate fair extent of ESP and can influence several microbial processes in the soil. Agroforestry systems like silviculture, silvipasture *etc.* can improve the physical and chemical properties of the soil along with additional return on long-term basis. Some grasses like *Brachariamutica* (Para grass) and *Cynodondactylon* (Bermuda grass) *etc.* has been reported to produce 50% yield at ESP level above 30.

The sodicity tolerance ratings of different crops is given in table.

Relative tolerance of crops to sodicity

ESP (range*)	**Crop**
2-10	Deciduous fruits, nuts, citrus, avocado
10-15	Safflower, black gram, peas, lentil, pigeon pea
16-20	Chickpea, soybean
20-25	Clover, groundnut, cowpea, pearl millet

25-30	Linseed, garlic, cluster bean
30-50	Oats, mustard, cotton, wheat, tomatoes
50-60	Beets, barley, sesbania
60-70	Rice

*Relative yields are only 50% of the potential in respective sodicity ranges.

Relative tolerance of fruit trees to sodicity

Tolerance to sodicity	ESP	Trees
High	40-50	Ber, tamarind, sapota, wood apple, date palm
Medium	30-40	Pomegranate
Low	20-30	Guava, lemon, grape
Sensitive	20	Mango, jack fruit, banana

2.3. Saline-alkali/ sodic soils

Saline-alkali / sodic soil is defined as a soil having a conductivity of the saturation extract greater than 4 dS m^{-1} and an exchangeable sodium percentage greater than 15. The pH is variable and usually above 8.5 depending on the relative amounts of exchangeable sodium and soluble salts. When soils dominated by exchangeable sodium, the pH will be more than 8.5 and when soils dominated by soluble salts, the pH will be less than 8.5.

Formation

These soils form as a result of the combined processes of salinisation and alkalization. If the excess soluble salts of these soils are leached downward, the properties of these soils may change markedly and become similar to those of sodic soil.

Management of saline alkali soils

The reclamation / management practices recommended for the reclamation of sodic soil can be followed for the management of saline – sodic soil.

2.4. Acid soils

Soil acidity refers to presence of higher concentration of H^+ in soil solution and at exchange sites. They are characterized by low soil pH and with low base saturation. The ranges in soil pH and associated degree of acidity are as follows:

pH range	**Nature of acidity**
3-4	Very strong
4-5	Strong
5-6	Moderate
6-7	Slight

In acid soil regions (ASR) precipitation exceeds the evapo-transpiration and hence leaching is predominant causing loss of bases from the soil. When the process of weathering is drastic, the subsoil and in many cases, the whole profile becomes acidic.

Occurrence

Acid soils occupy approximately 60% of the earth land area and are arise under humid climate conditions from carbonaceous less soil forming rocks in all thermal belts of the earth.

- World wide – 800 M ha
- India - 100 M ha
- Tamil Nadu - 2.6 M ha (20% of GA)

95% of soils of Assam and 30% of geographical area of Jammu and Kashmir are acidic. In West Bengal, 2.2 M ha, in Himachal Pradesh, 0.33 M ha, in Bihar, 2 Mha and all hill soils of erstwhile Uttar Pradesh come under acid soils. About 80% of soils in Orissa, 88% in Kerala, 45% in Karnataka and 20% in Maharastra are acidic. The laterite zone in Tamil Nadu is covered with acid soil and about 40,000 ha are acidic in Andhra Pradesh.

Sources of soil acidity

- Leaching due to heavy rainfall
- Acidic parent material and alumina silicate minerals
- Acid forming fertilizers
- Humus and other organic acids
- Carbon dioxide and hydrous oxides
- Acid rain

Production constraints

- Increased solubility and toxicity of Al, Mn and Fe
- Deficiency of Ca and Mg,
- Reduced availability of P and Mo and
- Reduced microbial activity

Management of acid soils

Management of the acid soils should be directed towards enhanced crop productivity either through addition of amendments to correct the soil abnormalities or by manipulating the agronomic practices depending upon the climatic and edaphic conditions.

Soil amelioration

Lime has been recognized as an effective soil ameliorant as it reduces Al, Fe and Mn toxicity and increases base saturation, P and Mo availability of acid soils. Liming also increases atmospheric N fixation as well as N mineralization in acid soils through enhanced microbial activity. However, economic feasibility of liming needs to be worked out before making any recommendation.

Liming materials

Commercial limestone and dolomite limestone are the most widely used amendments. Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime. Among, the naturally occurring lime sources calcitic, dolomitic and stromato litic limestones are important carbonates.

The other liming sources are marl, oyster shells and several industrial wastes like steel mill slag, blast furnace slag, lime sludge from paper mills, pressmud from sugar mills, cement wastes, precipitated calcium carbonate, etc equally effective as ground limestone and are also cheaper. Considering the efficiency of limestone as 100%, efficiencies of basic slag and dolomite are 110 and 94 % respectively. Basic slag and pressmud are superior to calcium oxide or carbonates for amending the acid soils. Fly ash, a low- density amorphous ferro-alumino silicate, also improves pH and nutrient availability.

Lime requirement of an acid soil may be defined as the amount of liming material that must be added to raise the pH to prescribed value. Shoemaker *et al*. (1961) buffer method is used for the determination of lime requirement of an acid soil.

Crop choice

Selection of crops tolerant to acidity is an effective tool to counter this soil problem and breeding of such varieties is of specific importance for attaining higher productivity, particularly in areas where liming is not an economic proposition. The crops can be grouped on the basis of their performance in different soil pH range.

Relative tolerance of crops to soil acidity

Crops	**Optimum pH range**
Cereals	
Maize, sorghum, wheat, barley	6.0-7.5
Millets	5.0-6.5
Rice	4.0-6.0
Oats	5.0-7.7
Legumes	
Field beans, soybean, pea, lentil etc.	5.5-7.0
Groundnut	5.3-6.6
Others	
Sugarcane	6.0-7.5
Cotton	5.0-6.5

Potato	5.0-5.5
Tea	4.0-6.0

2.5. Acid Sulphate soils

Acid sulphate are drained coastal wetland soils that have become acid (pH<4) due to oxidation of the pyritic minerals in the soil. Undrained soils containing pyrites need not be acid and they are called potential acid sulphate soils.

Types of acid sulphate soils

Potential acid sulphate soils

ASS which have not been oxidised by exposure to air are known as potential acid sulfate soils (PASS). They are neutral in pH (6.5–7.5) , contain unoxidised iron sulfides, are usually soft, sticky and saturated with water and are usually gel-like muds but can include wet sands and gravels have the potential to produce acid if exposed to oxygen

Actual acid sulphate soils

When PASS are exposed to oxygen, the iron sulfides are oxidised to produce sulfuric acid and the soil becomes strongly acidic (usually below pH 4). These soils are then called actual acid sulfate soils (AASS). They have a pH of less than 4, contain oxidised iron sulfides, vary in texture and often contain jarosite (a yellow mottle produced as a by-product of the oxidation process).

Occurrence in India

Soil with sufficient sulphides (FeS_2 and others) to become strongly acidic when drained are termed acid sulphate soils or as the Dutch refer to those soils *cat clays*. When allowed to develop acidity, these soils are usually more acidic than pH 4.0. Before drainage, such soils may have normal soil pH and are only *potential acid sulphate soils.* Generally acid sulphate soils are found in coastal areas where the land is inundated by salt water. In India, acid sulphate soil is, mostly found in Kerala, Orissa, Andhra Pradesh, Tamil Nadu and West Bengal.

Formation of Acid Sulphate Soils

Land inundated with waters that contain sulphates, particularly salt waters, accumulate sulphur compounds, which in poorly aerated soils are bacterially reduced to sulphates. Such soils are not usually very acidic when first drained in water.

When the soil is drained and then aerated, the sulphide (S^{2-}) is oxidized to sulphate ($SO^{2-}{}_4$) by a combination of chemical and bacterial actions, forming sulphuric acid (H_2SO_4). The magnitude of acid development depends on the amount of sulphide present in the soil and the conditions and time of oxidation. If iron pyrite (FeS_2) is present, the oxidized iron accentuates the

acidity but not as much as aluminium in normal acid soils because the iron oxides are less soluble than aluminium oxides and so hydrolyze less.

Characteristics

Acid sulphate soils contain a *sulphuric horizon* which has a pH of the 1 : 1 soil : water ratio of less than 3.5,plus some other evidences of sulphide content (Yellow colour).

Such strong acidity in acid sulphate soils results toxicities of aluminium and iron, soluble salts (unless leached), manganese and hydrogen sulphide (H_2S) gas. Hydrogen sulphide (H_2S) often formed in lowland rice soils causing akiochi disease that prevents rice plant roots from absorbing nutrients.

Management of Acid Sulphate Soils

Management techniques are extremely variable and depend on many specific factors *viz,* the extent of acid formation, the thickness of the sulphide layer, possibilities of leaching or draining the land etc. The general approaches for reclamation are suggested bellow:

Keeping the area flooded. Maintaining the reduced (anaerobic). Soil inhibits acid development, the use of the area to rice growing. Unfortunately, droughts occur and can in short time periods cause acidification of these soils. The water used to flood the potential acid sulphate soils often develop acidity and injure crops. Controlling water table. If a non-acidifying layer covers the sulphuric horizon, drainage to keep only the sulphuric layer under water (anaerobic) is possible. Liming and leaching. Liming is the primary way to reclaim any type of acid soil. If these soils are leached during early years of acidification, lime requirements are lowered. Leaching, however, is difficult because of the high water table commonly found in this type of soil and low permeability of the clay. Sea water is sometimes available for preliminary leaching.

2.6. Calcareous soil

Calcareous soil that contains enough free calcium carbonate ($CaCO_3$)and give effervescence visibly releasing CO_2 gas when treated with dilute 0.1 N hydrochloric acid. The pH of calcareous soil is > 8.5 and it is also regarded as an alkaline (Basic) soil. (Fig :7)

Formation

The soil are formed largely by the weathering of calcareous rocks and fossil shell beds like varieties of chalk, marl , lime stone and frequently a large amount of phosphates. Soils are often very fertile. Soils also can become calcareous through long term irrigation with water contains small amounts of dissolved $CaCO_3$ that can accumulate with time. Calcareous soils can contain from 3% to >25% $CaCO_3$ by weight with pH values with a range of 7.6 to 8.3.

Management of Calcareous soil

Fertilizer management in calcareous soils is different from that of non calcareous soils because of the effect of soil pH on soil nutrient availability & chemical reactions that affect the loss or fixation of some nutrients. The presence of $CaCO_3$ directly or indirectly affects the chemistry & availability of nitrogen (N) Phosphorus(P), Magnesium(Mg), Potassium (K), Manganese (Mn), Zinc (Zn) and iron (Fe). The availability of copper (Cu) also is affected. Application of acid forming fertilizers such as ammonium sulphate and urea fertilizers, sulphur compounds, organic manures and green manures considered as effective measures to reduce the pH of soil to neutral pH value

2.7. Man made polluted soils

Soil contamination is the presence of man-made chemicals or other alteration of the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. This occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage. The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies.

The unscientific disposal of untreated or under-treated effluents has resulted in accumulation of heavy metals in land and water bodies. Heavy metal contamination due to the sewage and sludge application to soils imposes a major limitation on potential land use. Cultivated areas under peri-urban agriculture are worst affected by this problem. The heavy metals accumulating in soil may get entry into the human and animal food chain through the crops grown on it. In Tamil Nadu State, where 55% of India's tanning industry is located, over 35 000 ha of land have become unfit for agriculture. Pollution from tannery effluent has rendered areas unsuitable for rice and sugar cane, declining by 40% and 80% respectively. The quality of coconuts produced on contaminated land deteriorated, making them no longer commercially viable. Villagers also reported skin rashes from contact with well water. In many areas of Tamil Nadu pollution to groundwater forced villagers to travel 4-5 km for water. Much of this contaminated groundwater became unsuitable for irrigation, and estimated 600-900 wells in the region fell into disuse.

Heavy metals prevailing in soils and their regulatory limits

Elements	**Conc. range (mg kg^{-1})**	**Regulatory limit (mg kg^{-1})**
Lead	1-6900	600
Cadmium	0.1-345	100
Arsenic	0.1-102	20
Chromium	0.005-3950	100
Mercury	0.01-1800	270
Copper	0.03-1550	600
Zinc	0.15-5000	1500

Management of soil pollution

Bioremediation

Bioremediation can be defined as any process that uses microorganisms, fungi, green plants or their enzymes to return the environment altered by contaminants to its original condition. Bioremediation may be employed to attack specific soil contaminants, such as degradation of chlorinated hydrocarbons by bacteria. An example of a more general approach is the cleanup of oil spills by the addition of nitrate and / or sulfate fertilizers to facilitate the decomposition of crude oil by indigenous or exogenous bacteria.

Important and widely reported hyper-accumulators used for metal remediation

Elements	**Plant species**	**Max conc. (mg kg^{-1})**
Cadmium	*Thlaspicaerulescens*	500
Copper	*Ipomoea alpine*	12300
Cobalt	*Haumaniuastrumrobertii*	10200
Lead	*Thlaspirotundifolium, Brassica juncea, Zea mays*	8200
Nickel	*Alyssum lesbiacum, Sebertiaaccuminata*	47500
Zinc	*Thlaspicaerulescens, Brassica juncea, B. oleracea, B. campestris*	51600
Selenium	*Brassica juncea, B. napus*	900
Chromium	*Brassica juncea, Helianthus annus*	1400

Microorganisms used for metal remediation

Elements	**Microorganisms**
Cadmium	*Citrobacter spp.*
Copper	*Bacillus spp.*
Cobalt	*Zooglea spp.*
Nickel	*Zooglea spp.*
Zinc	*Bacillus spp.*
Chromium	*Pseudomonas ambigua, Chlamydomonas sp, Oscillatoria sp., Arthrobacter sp., Agrobacterium sp.,*

3. Biological problems in soils

3.1. SOC and microbial population

Biological problems often results from management practices and anthropogenic influence. Soil organic carbon (SOC) is the main source of energy for soil microorganisms and a trigger for nutrient availability through mineralization. Humus participates in aggregate stability, and nutrient and water holding capacity. Organic acids (e.g., oxalic acid), commonly released from decomposing organic residues and manures, prevents phosphorus fixation by clay minerals and improve its plant availability, especially in subtropical and tropical soils. An increase in SOM, and therefore total C, leads to greater biological diversity in the soil.

Problems

A direct effect of poor SOC is reduced microbial biomass activity, and nutrient mineralization due to a shortage of energy sources. In non-calcareous soils, aggregate stability, infiltration, drainage, and airflow are reduced. Low SOC results in less diversity in soil biota with a risk of the food chain equilibrium being disrupted, which can cause disturbance in the soil environment (e.g., plant pest and disease increase, accumulation of toxic substances).

Improving Carbon Levels

No till farming, continuous application of manure and compost, and use of summer and/or winter cover crops. Burning, harvesting, or otherwise removing residues decreases SOC.

3.2. Earthworms

Earthworms play a key role in modifying the physical structure of soils by producing new aggregates and pores, which improves soil tilth, aeration, infiltration, and drainage. Earthworms produce binding agents responsible for the formation of water-stable macro-aggregates. They improve soil porosity by burrowing and mixing soil. As they feed, earthworms participate in plant residue decomposition, nutrient cycling and redistribution of nutrients in the soil profile. Their casts, as well as dead or decaying earthworms, are a source of nutrients. Roots often follow earthworm burrows and uptake available nutrients associated with casts.

Problems

Low or absent earthworm populations are an indicator of little or no organic residues in the soil and/or high soil temperature and low soil moisture that are stressful not only to earthworms, but also for sustainable crop production. Earthworms stimulate organic matter decomposition. Lack of earthworms may reduce nutrient cycling and availability for plant uptake. Additionally, natural drainage and aggregate stability can be reduced.

Improving Populations

The practices that boost earthworm populations are Tillage Management (no-till, strip till, ridge till), Crop Rotation (with legumes) and Cover Crops, Manure and Organic By-product Application , Soil Reaction (pH) Management and proper irrigation or drainage

3.3. Soil Respiration

Carbon dioxide (CO_2) release from the soil surface is referred to as soil respiration. This CO_2 results from several sources, including aerobic microbial decomposition of soil organic matter (SOM) to obtain energy for their growth and functioning (microbial respiration), plant root and faunal respiration, and eventually from the dissolution of carbonates in soil solution. Soil respiration is one measure of biological activity and decomposition and also known as carbon mineralization.

Soil respiration reflects the capacity of soil to support soil life including crops, soil animals, and microorganisms. In the laboratory, soil respiration can be used to estimate soil microbial biomass and make some inference about nutrient cycling in the soil. Soil respiration also provides an indication of the soil's ability to sustain plant growth.

Problems

Reduced soil respiration rates indicate that there is little or no microbial activity in the soil. It may also signify that soil properties that contribute to soil respiration (soil temperature, moisture, aeration, available N) are limiting biological activity and SOM decomposition. With reduced soil respiration, nutrients are not released from SOM to feed plants and soil organisms. This affects plant root respiration, which can result in the death of the plants. Incomplete mineralization of SOM often occurs in saturated or flooded soils, resulting in the formation of compounds that are harmful to plant roots,(e.g. methane and alcohol). In such anaerobic environments, denitrification and sulphur volatilization usually occur, contributing to greenhouse gas emissions and acid deposition.

Improving Soil Respiration

The rate of soil respiration under favorable temperature and moisture conditions is generally limited by the supply of SOM. Agricultural practices that increase SOM usually enhance soil respiration.

3.4. Soil Enzymes

Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate.

Problems

Absence or suppression of soil enzymes prevents or reduces processes that can affect plant nutrition. Poor enzyme activity (e.g., pesticide degrading enzymes) can result in an accumulation of chemicals that are harmful to the environment; some of these chemicals may further inhibit soil enzyme activity.

Improving Enzyme Activity

Organic amendment applications, crop rotation, and cover crops can be used to enhance enzyme activity The positive effect of pasture is associated with the input of animal manure and less soil disturbance. .Agricultural methods that modify soil pH (e.g., liming) can also change enzyme activity.

4. Eroded soils

Soil erosion is defined as the detachment and transportation of soil mass from one place to another through the action of wind, water in motion or by the beating action of rain drops. Erosion extensively occurs in poorly aggregated soils (low humus) and in a higher percentage of silt and very fine sand. Erosion increases when soil remains bare or without vegetation. In India about 86.9% soil erosion is caused by water and 17.7% soil erosion is caused by wind. Out of the total 173.6 Mha of total degraded land in India, soil erosion by wind and water accounts for 144.1 Mha (Govt. of India, 1990). The surface soil is taken away by the runoff causing loss of valuable topsoil along with nutrients, both native and applied. In India about 5334 million tones (16.35 tonnes/ha/year) of soil is being eroded annually due to agriculture and associated activities and 29% of the eroded materials are permanently lost into the sea.

Types of erosion

Natural or geologic erosion ranges from very little in undisturbed lands to extensive in steep arid lands. Geological erosion takes place, as a result of the action of water, wind, gravity and glaciers and it takes place, at such slow rates that the loss of soil is compensated for the formation of new soil under natural weathering processes. It is sometimes referred to as normal erosion.

Accelerated erosion caused by the disturbances of people (cutting forests, cultivating lands, constructing roads and buildings etc.) and is increasing as the population increases. In this erosion, the removal of soil takes place at a much faster rate than that of soil formation. It is also referred to as abnormal erosion.

4.1. Causes of Water Erosion

Water erosion is due to the dispersive action, and transporting power of water. Water erosion of soil starts when raindrops strike bare soil peds and clods, resulting the finer particles to move with the flowing water as suspended sediments. The soil along with water moves downhill, scouring channels along the way. Each subsequent rain erodes further amounts of soil until erosion has transformed the area into barren soil. Water erosion may occur due to the removal of protective plant covers by tillage operation, burning crop residues, overgrazing, overcutting forests etc. inducing loss of soil.

Raindrop / Splash Erosion.

Rain drop splash erosion results from soil splash caused by the impact of falling rain drops. The continued impact of raindrops compacts the soil and further seals the surface-so that water cannot penetrate into the soil and as a result causing more surface run off.

Sheet Erosion

Sheet erosion is the removal of a fairly uniform layer of surface soil by the action of rainfall and runoff water on lands having a gentle or mild slope, and results in the uniform "skimming off of the cream" of the top soil with every hard rain, In this erosion, shallow soils suffer greater reduction in productivity than deep soils. It is slow process but dangerous. Movement of soil by rain drop splash is the primary cause of sheet erosion.

Rill Erosion

Rill erosion is the removal of surface soil by running water, with the formation of narrow shallow channels that can be levelled or smoothed out completely by normal cultivation. Rill erosion is more apparent than sheet erosion. Rill erosion is more serious in soils having a loose shallow top soil. This type of soil erosion may he regarded as a transition stage between sheet and gully erosion.

Gully Erosion

Gully erosion is the removal of soil by running water, with the formation of channels that cannot be smoothed out completely by normal agricultural operation or cultivation. Gully erosion is an advanced stage of rill erosion. Unattended rills get" deepened "and widened every year and begin to attain the form 'of "gullies. During every rain, the rain water rushes down these gullies, increasing their width, depth and length.(Fig :8)

Stream Channel Erosion

eam channel erosion is the scouring of material from the water channel and the cutting of banks by flowing or running water. This erosion occurs at the lower end of stream tributaries. Stream bank erodes either by runoff flowing over the side of the stream bank, or by scouring or undercutting. Scouring is influenced by the velocity and direction of flow, depth and width of the channel and soil texture.

Harmful Effects of Water Erosion/Constraints

Water erosion causes various damages to the lands as follows:

(i) Loss of top fertile soil. The surface soil lost as runoff consists of fertile soils and fresh or active organic matter.

(ii) Accumulation of sand or other unproductive coarse soil materials on other productive lands. In the plains, fertile lands have been made unproductive by the deposition or accumulation of soil material brought down from the hills by streams and rivers.

(iii) Silting of lakes and reservoirs. Soil erosion from the catchment areas of reservoirs results in the deposition of soil, thus reducing their storage capacity

(iv) Silting of drainage and water channels. Deposition of silt in drainage ditches in natural streams and rivers reduces their depth and capacity

and overflows and flooding of downstream areas increase with damage to agricultural crops and also man-made structures.

(v) Decreases water table. With the increase in runoff, the amount of water available for entering the soil is decreased. This reduces the supply of water to replenish the ground water in wells, the yield of well is reduced.

(vi) Fragmentation of land. Water erosion especially gully erosion may divide the land into several valleys and ridges and thus fields become smaller and more numerous. Crop rows are shortened, movement from field to field is obstructed and a result the value of land is decreased.

4.2. Wind erosion

Soil erosion by wind has caused an accumulation of eroded particles in loess, a type of soil which makes up some of the world's most fertile and productive regions. Soil conditions conducive to wind erosion are most commonly found in arid and semi-arid areas where rainfall is insufficient and no vegetative cover on the land. The most serious damage caused by wind erosion is the change in soil texture. Since the finer soil particles are subject to movement by wind, wind erosion gradually removes silt, clay and organic matter from the top soil, leaving the coarser soil material.

Wind erodes the soil in three steps

The soil particles are carried by the wind in three ways namely saltation, suspension and surface creep.

Saltation: It is a process of soil movement in a series of bounces or jumps. Soil particles having sizes ranging from 0.05 to 0.5 mm generally move in this process. Saltation movement is caused by the pressure of the wind on the soil particle, and collision of a particle with other particles. The height of the jumps varies with the size and density of the soil particles, the roughness of the soil surface, and the velocity of the wind.

Suspension. Suspension represents the floating of small sized particles in the air stream. Movement of such fine particles in suspension is usually started by the impact of particles in saltation. Once these fine particles are picked up by the particles in saltation and enter the turbulent air layers, they can be lifted upward in the air and .they are often carried for several miles before being redeposit elsewhere. Dust particles will fall on the surface only when the wind subsides or the rain washes them down.

Surface Creep. Surface creep is the rolling or sliding of large soil particles along the ground surface. They are too heavy to be lifted by the wind and are moved primarily by the impact of the particles in saltation rather than by direct force of the wind. The coarse particles tend to move closer to the ground than the fine ones.

Threshold Velocity. Threshold velocity is the minimum wind velocity required to initiate the movement of soil particles. Threshold velocity varies with the soil conditions and nature of ground surface.

Impact of erosion on crop yield

- Erosion reduces the capacity of the soil to hold water leading to severe water stress.
- Erosion contributes to losses of plant nutrients, which wash away with the soil particles. Because sub-soils generally contain fewer nutrients than top-soils, more fertilizer is needed to maintain crop yields. This, in turn, increases production costs. Moreover, the addition of fertilizer alone cannot compensate for all the nutrients lost when topsoil erodes.
- Erosion reduces yields by degrading soil structure, increasing soil erodibility, surface sealing
- and crusting. Water infiltration is reduced, and seedlings have a harder time breaking through the soil crust. Erosion reduces productivity because it does not remove topsoil uniformly over the surface of a field. Typically, parts of an eroded field still have several inches of topsoil left; other parts may be eroded down to the subsoil. This makes it practically impossible for a farmer to manage the field properly, to apply fertilizers and chemicals uniformly and obtain uniform results. He is also unable to time

his planting, since an eroded part of the field may be too wet when the rest of the field is dry and ready.

Best Management Practices: that are used to control erosion factors of both wind and water are

- ***Crop rotation-*** improves the overall efficiency of nitrogen uptake and utilization in the soil. If certain cover crops are planted in the winter, erosion and runoff is prevented when the ground thaws, and nutrients are trapped in the soil and released to the spring crops.
- ***Contour cultivation-*** On gently sloping land, a special tillage practice carried out on the contour of the field can reduce the velocity of overland flow. Contour cultivation should not be carried out on steep slopes because it will merely make the erosion situation worse.
- *Strip cropping*- It is a technique in which alternate strips of different crops are planted in the same field. There are three main types: contour strip cropping, field strip cropping, and buffer strip cropping. If the strips are planted along the contour, water damage can be minimized; in dry regions, if the strips are planted crosswise to the contour, wind damage is also minimized.
- ***Terraces-*** Constructing bench-like channels is otherwise known as terraces, enables water to be stored temporarily on slopes to allow sediment deposition and water infiltration. There are three types of terraces: bench terraces
- contour terraces, and parallel terraces. It will control erosion in wetter areas by reducing the length of the slope.
- ***Grassed Waterways -*** They force storm runoff water to flow

down the center of an established grass strip and can carry very large quantities of storm water across a field without erosion. Grass waterways are also used as filters to remove sediment, but may sometimes lose their effectiveness when too much sediment builds up in the waterways. To prevent this, it is important that crop residues, buffer strips, and other erosion control practices and structures be used along with grass waterways for maximum effectiveness.

- ***Diversion structures-*** These are channels that are constructed across slopes that cause water to flow to a desired outlet. They are similar to grass waterways and are used most often for gully control.
- ***Drop structures -*** Are small dams used to stabilize steep waterways and other channels. They can handle large amounts of runoff water and are effective where falls are less than 2.5 meters
- ***Riparian strips -*** These are merely buffer strips of grass, shrubbery, plants, and other vegetation that grow on the banks of rivers and streams and areas with water conservation problems. The strips slow runoff and catch sediment. In shallow water flow, they can reduce sediment and the nutrients and herbicides attached to it by 30% to 50%.
- ***No-till planting-*** This planting system prepares a seedbed 2 inches wide or less, leaving most of the surface undisturbed and still covered with crop residues. The result is a wetter, colder environment that protects the seed and soil with its insulating effect of the surface residue.

- ***Strip Rotary-*** Tillage A strip four to eight inches wide and two to four inches deep is prepared by a rotary tiller, while the rest of the soil is left undisturbed. The soil is conserved because of the crop residues between the tillage strips
- ***Till Planting*** **-**This plowing technique sweeps the crop residues into the area between the rows of crops. Soil density between these rows remains relatively high because of the absence of tillage. This soil is difficult for raindrops to detach and runoff to move.
- ***Annual Ridges*** **-** Also known as permanent ridges or ridge tillage, the annual ridges are formed by using a rolling disk bedder, and planting is done after only minor spring seedbed preparation. The extent of soil conservation depends on the amount of residue left and the row direction. Planting on the contour plus increased surface residues greatly reduce soil loss.
- ***Chiseling***- This system does not turn the soil over, but rather leaves it rough and cloddy with plenty of crop residue remaining. The soil density and amount of covering depends on the depth, size, shape, spacing, and so on of the chisel blades. The residue and rough, cloddy surface of the soil reduces raindrops impact and reduces runoff velocities thus reducing erosion.
- ***Disking*****-** This system pulverizes the soil and gives great soil density The effect is similar to that of chiseling with results also depending on the depth, size, spacing, and so on of the disk blades. The deeper the disking, the fewer the residues that remain on the surface.

Sustaining soil health is the imminent need of the hour

Soil health is defined as the continued capacity of soil to function as a vital living system, which include sustaining biological productivity of soil, maintain the quality of surrounding air and water environments, as well as promote plant, animal, and human health. Soil function include sustaining biological diversity, activity and productivity, regulating water and solute flow, filtering, buffering, degrading organic and inorganic materials, storing and cycling nutrients and carbon, providing physical stability and support.

Soil health deals with both the inherent and dynamic soil quality. The former relates to the natural (genetic) characteristics of the soil (e.g., texture), which are the result of soil-forming factors. They are generally cannot easily be amended. On the other hand, the dynamic soil quality component is readily affected by management practices and relates to the levels of compaction, biological functioning, root proliferation, etc which is of most interest to growers because good management allows the soil to come to its full potential.

Soil quality or health cannot be determined by measuring only crop yield, water quality, or any other single outcome but with indicators which are measurable properties of soil or plants that provide clues about how well the soil can function.

Indicator	**Relationship to Soil Health**
Soil organic matter (SOM)	Soil fertility, structure, stability, nutrient retention; soil erosion

Physical: soil structure, depth of soil, infiltration and bulk density; water holding capacity	Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability
Chemical: pH; electrical conductivity; extractable N-P-K	Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss
Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.	Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure

In the International Year of soils, policy makers, scientists and all stake holders should pledge to really protect the soil through multifaceted approach including input management like water, manures, fertilizers and revamp soil health management programmes and evolving more soil health indicators specific to a region and resort to more of physical and biological fertility management and precise agriculture which naturally will take care of all other functions. Many interactions hitherto neglected involving soil, plant, microbe, water and atmosphere should be focussed. Sustainable soil management is essential for getting food, feed, fibre, fuel, medicines and ecosystem services. It is a non renewable resource and managing sustainably needs increasing soil organic matter content, using nutrients wisely, keeping soil surface vegetated, promoting crop rotations and diversification and reducing erosion. It is imperative to solve the soil constraints and make the lands highly productive on a sustainable basis, we need to develop technologies suitable to specific locations which will be economically feasible and workable at farmer's field. Though emphasis is on increasing the current yield level, attention should also be given to prevent soil degradation and also develop suitable technologies to reclaim the problem soils.

The nation that destroys soil destroys itself – Franklin Roosevelt, 1937

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