REVIEW ARTICLE

RECENT ADVANCEMENTS FOR RECLAMATION OF PROBLEMATIC SOILS

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Received-05.02.2021, Revised-16.02.2021, Accepted-27.02.2021

Abstract: Sustainable agricultural development and food security will be one of the key challenges for India in this century. Around 65% of the India's population is living in rural area with agriculture as their livelihood support system. The vast majority of Indian farmers are small and marginal. Their farm size and the quality is deteriorating due to increase nutrient withdrawal, soil erosion, higher insect pest outbreak, adverse impacts of climate and accumulation of toxic elements in soil and water resources. All of these factors combined with increased rate of land degradation are contributing in declining in agricultural productivity leading to threat of food security. Since land resources are limited and decreasing due to diversified land uses, appropriate measures are required to reclaim degraded and wastelands, so that areas going out of cultivation due to social and economic reasons are replenished by reclaiming these lands and by checking further loss of production potential. The present review will through light on the existing and future problems related to soil practices and appropriate measures to overcome soil degradation problem.

Keywords: Conservation agriculture, Land degradation, Nutrient management

INTRODUCTION

Soil is the most important component of earth for crop production. Soil physical, chemical and biological properties are deciding factors for the quantity and quality of agricultural produce. In India, it is estimated that out of 328.8 million hectares (mha) of geographical area,147 mha of land area is under degraded category, including 94 mha from water erosion, 16 mha from acidity, 14 mha from flooding, 9 mha from wind erosion, 6 mha from salinity and 7 mha from other or combination of above factors (Anonymous, 2005). Soil degradation may be natural (earthquakes, tsunamis, droughts, landslides, floods, fires etc., and human-induced (deforestation, faulty agricultural practices, improper management of crop residue, over-grazing, commercial/industrial development). Inappropriate practices include number tillage, mechanical impedence, and unbalanced use of fertilizers, inadequate water management techniques, higher pesticide use, poor organic carbon inputs and poor crop planning (Bhattacharyya *et al*., 2015). Rainfed areas are more subjected to a prolonged degradation being unable to full utilization of chemical fertilizers and fertility-enhancing practices like crop residue incorporation, composting, farmyard manure application, etc. Any deviation from optimum pH value, nutrient status, and residue recycling and water moisture in soil leads to problems in soil quality, and it requires all possible measures for their remedies (Bhattacharyya *et al.*, 2015).The improved techniques and technologies are required to make the soil suitable for farming.

The ground improvement techniques like deep ploughing, drainage, bunding, mulching, residue management, synthetic amendments are used to improve unfavorable conditions of soil to favorable conditions. The factors for adverse conditions of soil are compaction, salinity, alkalinity, sodicity, sandy soil, water logging, etc. Soil heterogeneity vary greatly in texture, fertility topography, moisture content, drainage etc., and is the probable reason for the diverse nature of cropping and production pattern (Siddiqui and Fatima, 2017). From agricultural point of view, the soils that possess characteristics like degraded structure, poor nutrient and management holding capacity, high erosion, chemical deteriorated condition makes it uneconomical for the cultivation of crops without adopting proper reclamation measures are known as problem soils. Problematic soils are mainly developed due to change in chemicals (salt) and Physical (colloidal) and biological parameters and they affect the socio economic condition of the residing people. (Lal 2015).

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Probable reasons of problematic soil

The problem arises due to the chemical factors in the soil, leading to chemical soil; acidic soil, saline soil, alkaline soil and sodic soil. While the physical factors responsible for problematic soil aredispersion of soils, compaction, swelling, water logging, sandy soils, and hardy soil

Characteristics and management strategies for problematic soils

Chemical problematic soil: Acidic Soilis a measure of hydronium ions present in the soil solution. Acid soil restricts crop growth in the higher rainfall regions (Getachew *et al*., 2019). Clays and organic matter in the soil carry a negative charge. In a non-acidic soil, this negative charge is balanced by the positive charge on certain plant nutrients, in particular calcium (Ca^{+2}), magnesium (Mg^{+2}) and potassium (K^{+}). As soils acidify, concentrations of other non-nutrient elements, like hydrogen (H+) and aluminum (Al^{+3}), increase and they take the place of nutrients such as calcium and magnesium on the clays and organic matter (Das *et al*. 2013). The over or blindapplication of nitrogenous fertilizers also increases acidity in soil. High aluminum and manganese create toxicity in plant roots resulting in poor and abnormal root development. Calcium and magnesium deficiency also reported in acidic soils which are required in adequate quantities for optimum root growth. Microbial activity and earthworm species are sensitive to soil acidity, as it cause slow available organic matter for earthworms.Agricultural ecosystems conserve plant nutrients less efficiently than other natural ecosystems. Differences in nutrient addition and removal from the ecosystem may be the cause of the increased acidification (Kennedy, 1986).

Another reason of problematic soil is salinity which comes from the excessive amount of salts in the soil. Soluble salts most commonly present as chlorides and sulphates of sodium, calcium and magnesium. The pH value of the saturated soil paste is always less than 8.2 and more often near neutrality (Abrol *et al*., 1980). Saline soils have an electrical conductivity of more than 4 dS/m at 25°C (Richards, 1954). In addition, salinity also decreases the moisture content of the soil making it dry and rough. Saline soil bears high compressibility, low bearing capacity, and more expansion of colloidal particles. Salinity is due to minerals and rocks weathering process of parent material. Also, Irrigation process can make the soil saline as the roots only absorb water leaving behind salts of water in the soil. Excess salts keep the clay in saline soils in a flocculated state so that these soils generally have good physical properties. Soil structure is generally good and tillage characteristics and permeability to water are even better than those of non-saline soils. In field conditions, saline soils can be recognized by the presence of white salt crusts on the surface. Plants grow on low saline soils often have a blue-green chlorosis followed by necrosis. Moderate salinity, leaves of the growing plants are darker blue-green in color than the normal leaves.

The main components that are present in the alkaline soil are sodium carbonates and sodium bicarbonates. The alkali soil has almost opposite properties than that of the acid soil like low shrinkage and low plastic limit and dispersed particle which occurs due to Sodium carbonates and bicarbonates which eventually increase due to weather conditions. Sodic soils have low physical properties. Sodium cations weaken the bond between the particles of soil and they eventually swell and disperse. Area of sodic soil has also increased due to more use of poor quality irrigation water. The sodic soil also degrades the soil structure and thus leading to a physical problem known as soil dispersion. It is also prone to wind and water erosion. Sodicsoil has no natural vegetation except some very hard grasses. After application of irrigation or rain, alkali soils turn black because of the humic acid fraction of organic matter, which is dissolved by Na_2CO_3 at high pH. During the process sodic soils become very slippery and soft when wet but very hard when dry. The chief characteristic of sodic soils from the agricultural stand point is that they contain sufficient exchangeable sodium to adversely affect the growth of most crop plants. Excess exchangeable sodium has an adverse effect on the physical and nutritional properties of the soil, with consequent reduction in crop growth, significantly or entirely. Dispersed and dissolved organic matter present in the soil solution of highly sodic soils may be deposited on the soil surface by evaporation causing a dark surface which termed as black sodic soils.

Table 1. Properties of problematic soil

Soils	**pH**	**EC**	**ESP**	**Factors responsible**	**Surface properties**
Acidic soil	>7	-	-	H+ and Al^{+3}	Rainfall regions, high shrinkage and high plasticity
Saline soils	<8.5	>4	<15	Soluble salts of sodium, calcium and magnesium, neutral salts (Cl-, SO4 2-) is higher than alkali salts(HCO3 -,CO3 2-)	high compressibility, low bearing capacity, and more expansion, white crust formation
Alkaline soil	ESP >15			Sodium carbonates and sodium bicarbonates, (HCO_3^- ,CO_3^{2-}) is higher than neutral salts(Cl^-, SO_4^{2-}).	low shrinkage and low plastic limit and dispersed particle
Non saline -Alkali soil/ sodic soils	>8.5	<4	>15	High concentration of exchangeable sodium	Deflocculated soil, Dark colored, compact soil, sodic soils become very slippery and soft when wet but very hard when dry
Saline -Alkali soil	8.5	>4	>15	Na^+ and soluble salts forms a transition stage between saline and alkali soils	Flocculation depends upon soil Na ion concentration
Waterlogged soil				Ion and secondary metabolite toxicity	High bulk density, compaction, anaerobic soils

Under field conditions after an irrigation or rainfall, sodic soils typically have convex surfaces. Upon dehydration cracks of 1-2 cm across and several centimeters deep form and close when wetted. The cracks, generally, appear at the same place on the surface each time the soil dries unless it has been disturbed mechanically. The principal cause of alkaline reaction of soils is the hydrolysis of exchangeable cations or salts such as $CaCO_3$, $MgCO_3$, Na_3CO_3, etc.

Chemistry behind exchangeable capacity of soil

Every soil has a definite capacity to absorb the positively charged constituents of dissolved salts, such as calcium, magnesium, potassium, sodium, etc. This is termed the cation exchange capacity. The various adsorbed cations can be exchanged and the extent of exchange depends upon their relative concentrations in the soil solution, valency and size of the cation involved, nature and amounts of other cations present in the solution or on the exchange complex, etc. Exchangeable sodium percentage (ESP) is, accordingly, the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milli-equivalents per 100 g of soil (Richards. 1954 and Hesse 1971).

Thus, Exchangeable sodium percentage (ESP)

$$= \frac{\text{Exchangeable Na (me/100 g soil)}}{\text{Cation exchange capacity (me/100 g soil)}} \times 100$$

Sodium Absorption ratio (SAR)- Hydrolysis of exchangeable cations during the removal of the index salt solution, fixing of ammonium ions from the index or replacement solution by the soil minerals and the dissolution of calcium carbonate or gypsum in the index or replacing solutions can all lead to low values of cation exchange capacity and therefore to high ESP estimates. To overcome some of these difficulties US Salinity Laboratory (Richards 1954) proposed that the sodium adsorption ratio (SAR) of the soil solution adequately defines the soil sodicity problem and is quantitatively related to the exchangeable sodium percentage of the soils. Sodium adsorption ratio, SAR, is defined by the equation:

$$SAR = Na^{+} / \sqrt{(Ca + Mg)^{++} / 2}$$

where all concentrations are in m mol (+)/litre.

Excess exchangeable sodium in sodic soils has a marked influence on the physical soil properties as the proportion of exchangeable sodium increases which results in the breakdown of soil aggregates and lowers the permeability of the soil to air and water. The concentration of the elements like calcium and magnesium in the soil solution is reduced as the pH increases due to formation of relatively insoluble calcium and magnesium carbonates by reaction with soluble carbonate of sodium, etc. and results in their deficiency for plant growth. Sodicity also increases the accumulation of certain elements in plants at toxic levels may result in plant injury or reduced growth. General characterstics of chemically degraded soils are enlist in table 1.

Table 1. Characterstics of degraded soil

Waterlogged soil-The word "water-logged" is referring to soil that is saturated with water and thus cannot keep oxygen between its particles (Collin, 2004).Soils saturated with water for a long time that give the distinctive gley horizons resulting from oxidation-reduction processes. Waterlogged soil has a permanently reduced layer with bluish green mottling (Robinson, 1949). This blocking of water is controlled by local geology, topography, drainage, and the amount of water supplied to the site (Holden, *et al.*, 2009). It is also the result of changing land use within the human environment. Sometimes the water-logged situation of an area is the outcome of all-round embanking with poor drainage system (Sahu, 2012). Water-logging happens due to unscientific management of water and obstruction of natural drainage systems by the haphazard embankment construction through disrupting the balance of inflow and outflow of water. Water-logging like flooding causes damage to agricultural lands affecting the crops and thus the livelihood and the economy of the country (Kumar and Kunte, 2012).

Management of degraded soil

1. Acidic soils

a. Neutralization of acid soils by adding lime

The agricultural limestone neutralizes the soil acidity. It replaces exchangeable acidic ions, such as hydrogen ions (H^+) with basic ions that may be calcium (Ca^{2+}) or magnesium (Mg^{2+}) ions. Liming application increases exchangeable Ca and Mg acid soils. The chemical process occurred as shown below

$Ca^{2+} + H^+ + H^+ + H^+ + H^+ + H^+$ + AgriculturalLime

Acid Soil Lime application

$\rightarrow Ca^{2+} + Ca^{2+} + H^+ + Ca^{2+}\ Mg^{2+} + H^+$

Limed Soil

The chemical reactions that take place in soil when lime is added. The lime applied dissolves and dissociates into calcium, bicarbonate, and hydroxide ions. The hydroxide neutralizes soil acidity by combining with hydrogen ions to form water. As the concentration of hydrogen ions decreases, the pH increases. The hydrogen ions are mainly held on cation exchange sites that must be removed from both the soil solution and the exchange sites for neutralization of soil acidity. The two step chemical reaction occurs when agricultural lime is added to an acid soil (Anon, 2016).

First Step

$CaCO_3 + H_2O$

Lime water

$\rightarrow Ca^{2+} + HCO_3^- + OH^- + 2H^+$
Calcium Dissolves Hydrogen (soil solution)
bicarbonate hydroxide
Second Step
$Ca^{2+} + HCO_3^- + OH^- + 2H^+$
Exchangeable
Calcium
$\rightarrow Ca^{2+} + 2H_2O + CO_2$
Water Carbon Dioxide

b. Other management practices for acidic soils

1. Reducing acidifying inputs rice residues, and addition of marbel cutting waste(Tozsin, et al. 2014).
2. Adoption of tolerant crop species and varieties like rice, cassava, mango, cashew, citrus, pineapple, cowpeas, blueberriesthat are adapted to the soil acidity
3. Using economically viable technology like micronutrient management, crop selection, and zero till methodalkaline materials for recycling of residue and water to lower down acidification
4. Adding micronutrients likemolybdenum and bio-fertilizer (rhizobium inoculation in Phaseolus vulgaris L.,)or lime supply after the growing season that enhance plants survival in acidity(Bambara and Ndakidemi, 2010).
5. Limingof soil with adequate amount is based on soil type, cropping system and rainfall intensity. It increases availability of P, Ca, Mg which lower down the accumulation of Fe and Mn inthe soil finally lowering the acidity of the soil
6. Addition of earthworms to utilizing root excretion of bicarbonate in response to manipulation of nitrate leaching and uptake
7. Reduced useof acidifying nitrogen fertilizers tominimizenitrate leachinglosses.
8. Addition of humic acid and bio fertilizers viz., plant growth promoting rhizobacteria (PGPR) which enhance P availability (Sarwar et al. 2014).
8. Lime pellet incorporation and inoculation of legume crops in crop cropping system prove to be efficient practices to overcome nutrient demand and for plant growth
9. Adoption of soil conservation to reduce washing out of base cations in highrainfall areas

Saline soils

Saline soil can be managed by using methods like scraping which is the process ofmechanical removal of the salts from the soil surface. (Siyal, 2002).Flushing ie. washing away the surface accumulated salts by flushing water over the soil. It is also used to desalinize soils having surface salt crusts(Ali, 2011).Another process is Leaching which is the most effective practiceoften accomplished by ponding fresh water on the soil surface and allowing it to infiltrate. Leaching is effective when the salty drainage water is discharged through subsurface drains that carry the leached salts out of the area under reclamation. Leaching should preferably be done when the soil moisture content is low and the groundwater table is deep (Litalien and Zee, 2020).Mulching is another important practice for the soil quality and productivity improvement in reclamation of coastal saline soils. (Zhang et al., 2014).Adoption of ridge and furrow method of crop establishment and sowing tolerant or semi-tolerant crop species and varieties.Balance use of fertilizers and various placement methods for P and K is highly effective for the crop yield response (Randall and Hoeft, 1988).Drainage of salt with rain water through drains or bundsto pre designed area or structure.The effect of gypsum application increases the infiltration rate in saline soil which might not be essential for either desalinization or de-sodication. Light textured soils having a higher infiltration rate are not likely to respond to gypsum application. In heavy textured soils, and where salts are leached with low electrolyte water, application of an amendment is desirable to h**a**sten reclamation. Another technique is Mole drains which include removal of salts in the channels and sub surface holes prove to be successful curative measure for heavy clay soils. International collaborations will foster the identification of salt tolerant rice varieties in India (Burman et al., 2018). Sharing of research, knowledge and skills will facilitate new development (e.g., amendment options, drainage design, crop varieties, utilization of microbial resources, utilization of ocean resources, etc.) at a faster pace in reclaiming salinity soils (Krishnamurthy et al., 2017).

Alkali soils

For successful crops production in alkali soils,ESP of the soil must be lowered which can be achieved by application of amendments like Gypsum (CaSO4.2H2O) which is the most commonly used amendment for reclamation. It should normally be broadcasted and incorporated.As far as scaling of gypsum doses are concerned, so far, it has been recommended for reclamation of upper 15 cm of soil to cover the root zone of cereal crops. However, reclamation of deeper layer of soil up to 30 cm wills double the cost of gypsum application. In order to address this issue, use of cheaper alternative (like sulphur, phospho-gypsum, marine gypsum, etc.) has to be explored and standardized for which a national research and development program will be required.Deeper depth of mixing of gypsum becomes inactivated and thereby reduces the effectiveness of the applied gypsum and yield of crops. To ensure proper dissolution of gypsum and leaching of replaced exchangeable Na+, the water is to be ponded/stagnated continuously on the soil for a period of 8-10 days (80% of gypsum gets dissolved). Reaction of gypsum as activity is below-

$Na_2CO_3 + CaSO_4- \rightarrow CaCO_3 + Na_2SO_4$

$2NaHCO_3 + CaSO_4- \rightarrow Ca(HCO_3)_2 + Na_2SO_4$.

Or

$2Na + $ **--**Soil+ $+ CaSO_4- \rightarrow Ca_2+$ **-** Soil $+ Na_2SO_4$.

2. **Organic amendments:** Addition of crop residues,straw, ground nut cakes, FYM, compost, poultry droppings, green manures, tree leaves and

saw dust. They Produce CO_2 (carbonic acid) and organic acids, they increase the solubility of calcite and lower the ESP (ref).

3. **Industrial by products:** Phospho-gypsum, Press mud, Molasses, Acid wash and Effluent from milk plantscan be used as organic amendments or fertilizers for agricultural systems. In addition, these composts could be used to produce alternative liquid organic fertilizers, based on the extraction of their humic- like fraction (Alburquerque et al. 2009).

4.**Cultivar or Variety:**Choice of crop, variety and plant population should be in skillful manner. Transplanting older seedling survive better in saline condition.The plantation of *Prosopisjuliflora* (Swartz) D.C., *Dalbergiasissoo* Roxb. Ex. D.C. and *Eucalyptus tereticornis* Sm. showed significant improvement through a reduction in the pH, electrical conductivity, exchangeable sodium percentage, and enhance in organic C, total N, and available P (Mishra et al., 2004). Building organic matter content, during decomposition it releases CO_2 and formation carbonic acid. This lowers the pH and enhances solubility of native $CaCO_3$ and adds a considerable amount of plant nutrients in the soil.

5. **Drainage:** Alkali soils have low infiltration rate and all the rain water accumulates to create surface water logging. This results anaerobic conditions due to oxygen stress. So, it is essential to provide surface and subsurface drainage system in the field.

6. **Good irrigation management:** Normally surface method of irrigation, such as furrow or basin type flood method is used for alkali soils. However the sprinkler method could be promising because of its ability to supply water uniformly and in small quantities. Ensure proper water management for uniform leaching of salts.

Sodic soils

Sodic soils require removal of the exchangeable sodium and its replacement by the more favourable calcium ions in the root zone. Soil amendments are materials, such as gypsum or calcium chloride, that directly supply soluble calcium for the replacement of exchangeable sodium, sulphuric acid and sulphur, that indirectly through chemical or bio-drainage action (*Eucalyptus tereticornis)*, make the relatively insoluble calcium carbonate commonly found in sodic soils available for replacement of sodium (Mishra *et al*.,2003).

Chemical amendments for sodic soil reclamation can be broadly grouped into two categories:

a. Soluble calcium salts, e.g. gypsum, calcium chloride.

b. Acids or acid forming substances, e.g. sulphuric acid, iron sulphate, aluminiumsulphate, lime-sulphur, sulphur, pyrite, etc.

In sodic soils Gypsum is widely used in reclamation: itis soluble in water to the extent of about one-fourth of total applied and is exists as direct source of soluble calcium. Qadir, et al, (1996) reported that the higher rate gypsum removed the more amount of Na^+ from the soil columns and caused a substantial decrease in soil salinity (EC) and sodicity (SAR).Gypsum reacts with both the Na_2CO_3, and the adsorbed sodium as follows:

$Na_2CO_3 + CaSO_4 \rightarrow CaSO_3 + Na_2SO_4$ (leachable)

$$^{Na}_{Na}\text{Clay micelle} + CaSO_4 \Leftrightarrow$$

Clay micelle + Na_2SO_4 (leachable)

Calcium chloride- Calcium chloride is chemically $CaCl_2\,2H_2O$. It is a highly soluble salt which supplies soluble calcium directly (Gadala, 2001). Its reactions in sodic soil are similar to those of gypsum:

$Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl$ (leachable)

$$^{Na}_{Na}\text{Clay micelle} + CaCl_2 \Leftrightarrow$$

Clay micelle + 2NaCl (leachable)

Sulphuricacid (H_2SO_4) is an oily corrosive liquid and is usually about 95 percent pure. Upon application to soils containing calcium carbonate it immediately reacts to form calcium sulphate and thus provides soluble calcium indirectly (Vaughan et al., 2013). Chemical reactions involved are:

$Na_2CO_3 + H_2SO_4 \rightarrow CO_2 + H_2O + Na_2SO_4$ (leachable)

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$

$$^{Na}_{Na}\text{Clay micelle} + CaSO_4 \Leftrightarrow$$

Clay micelle + Na_2SO_4 (leachable)

Iron sulphate and aluminiumsulphate (alum)- Chemically these compounds are $FeSO_4.7H_2O$ and $Al_2(SO_4)_3.18H_2O$ respectively. Both these solid granular materials usually have a high degree of purity and are soluble in water. When applied to soils, these compounds dissolve in soil water and hydrolyse to form sulphuric acid, which in turn supplies soluble calcium through its reaction with lime present in sodic soils (Redly and Utkaeva, 2009). Chemical reactions involved are:

$FeSO_4 + 2H_2O \rightarrow H_2SO_4 + Fe(OH)_2$

$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$

$$^{Na}_{Na}\text{Clay micelle} + CaSO_4 \Leftrightarrow$$

Clay micelle + Na_2SO_4 (leachable)

Sulphur (S) is a yellow powder ranging in purity from 50 percent to more than 99 percent. It is not soluble in water and does not supply calcium directly for replacement of adsorbed sodium. When applied for sodic soil reclamation, sulphur has to undergo oxidation to form sulphuric acid which in turn reacts with lime present in the soil to form soluble calcium in the form of calcium sulphate:

$2S + 3O_2 \rightarrow 2SO_3$ (microbiological oxidation)

$SO_3 + H_2O \rightarrow H_2SO_4$

$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO$

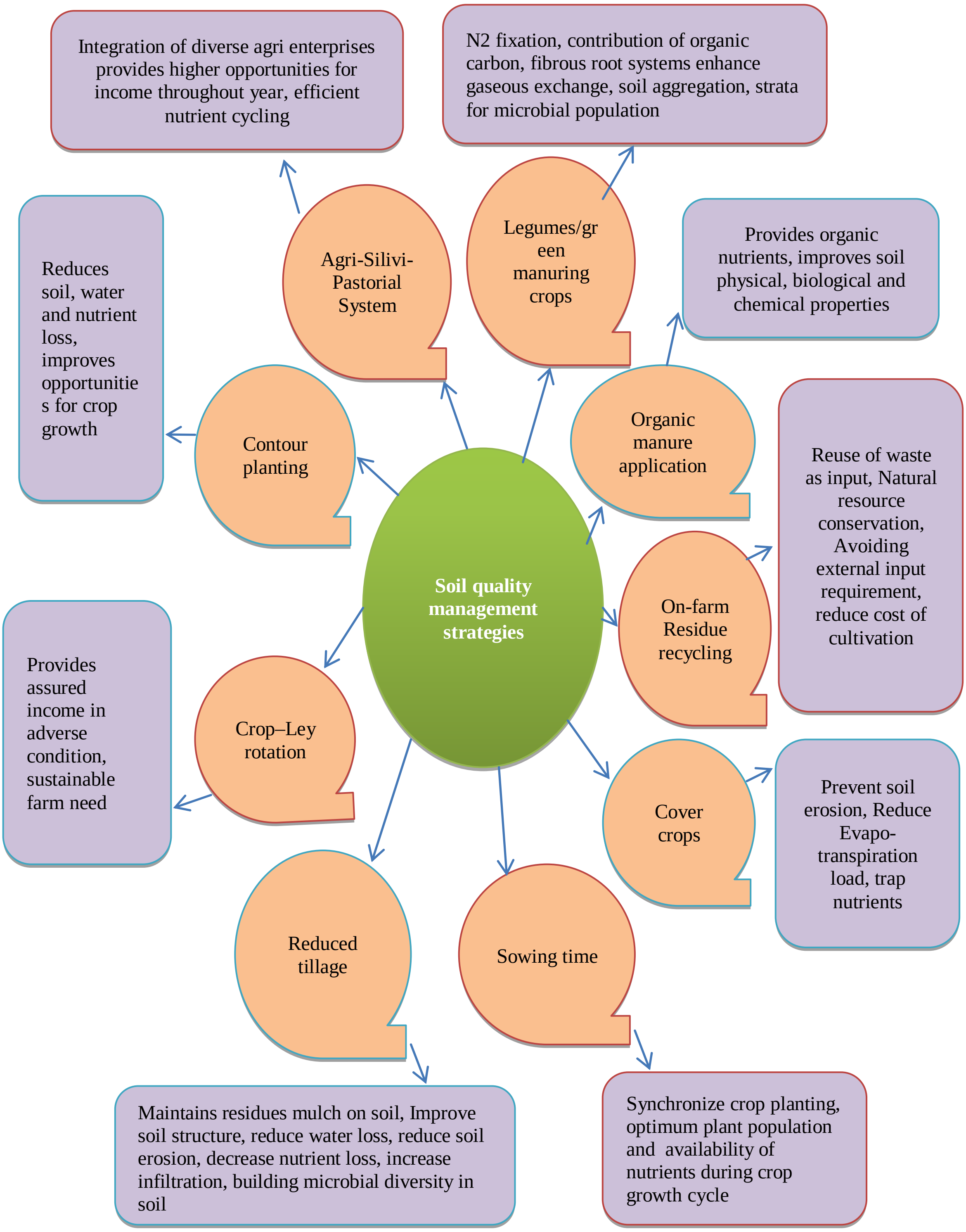
$$^{Na}_{Na}\text{Clay micelle} + CaSO_4 \Leftrightarrow$$

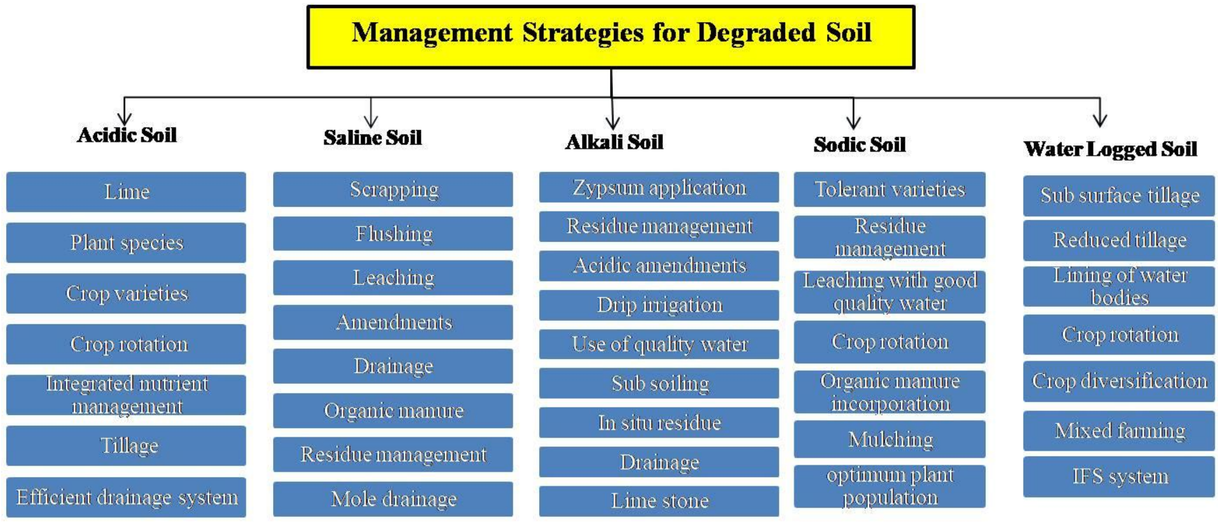
Clay micelle + Na_2SO_4 (leachable)

Water logged soils

Raised Bed Farming: In raised bed, physical manipulation creates favorable conditions for higher hydraulic conductivity, and decreases soil bulk density that result greater root penetration and good drainage. The FIRB (furrow irrigation and raised bed) technique is not only save the resources like water and nutrients and labour but also facilitates the greater diversification of the rice-wheat cropping systems and improve the physical properties of soil (Naresh *et al*., 2012).

Sub-surface drainage: Sub-surface drainage mostly practiced in areas with higher ground table. These drainage systems consist of open and pipe drains with variable drain depth and spacing. Managing water logging by combined drainage system with tube wells and horizontal drainage systems is more beneficial in maintaining the water table within the desirable depths.





Bio-drainage: Bio-drainage may be defined as "pumping of excess soil water by deep-rooted plants using their bioenergy for eg.,*Pongamiapinnata* and *Eucalyptus tereticornis*. This approach is relatively cheaper, sustainable and ecologically compatible relying on natural capability of vegetation to transpire water is a strategic tool for reclamation of waterlogged area for agricultural production. It might make drainage planning in irrigation commands socio-economically more relevant and environmentally sustainable (Chowdhury et al., 2011).

Crop management- Crop management is a primary option to increase crop production it also decrease the incidences of waterlogging includes early sowing *Pongamiapinnata* and *Casuarinaglauca*.Early sown wheat showed better crop growth than late sown. Early vigor may be linked with increased uptake of nitrogen.

Nutrient management- Application of essential nutrients with slow-release fertilizers for improving plant growth and development under waterlogged conditions. Application of farmyard manure increased P, Fe, Zn, Cu availability under flooded conditions. Appropriate application methods, timing and rate strategiesare essential to overcome hurdles of roots to absorb nutrients. In broadbed and furrows (BBF) method, nitrogen and phosphorus fertilization reduced days to heading, maturity, grain yield nitrogen and phosphorus uptakes by 12, 15, 90 183 and 252%, respectively in wheat. Thus, planting in broadbed and furrows (BBF), disregard of the bed size, with fertilizer application is recommended for bread wheat production on vertisols (Mekonen, et al., 2013).

CONCLUSION

Appropriate mitigation strategies for existing degraded soil must be based on sustainable development and nature conservation. Technologies like micro-irrigation, fertigation and management of problem soils using specific and necessary technologies increase can be useful for productivity of crops and fruits and reversing soil degradation (Das *et al*., 2013). Proper use of various farming enterprises, residues management, mulching, cover crops and introduction of legumes in cropping system are few other solutions for preventing land degradation. Future research should focus on enhancing nutrient and water use efficiencies and reduction in the pesticide use. Farmer involvement is essential at every stage in the implementation of resource conserving technologies, judicious irrigation water management, wasteland reclamation, watershed development, and a forestation. A well-defined integrated land use framework is needed for sustainable development of land with a scientific backing. Water-logging can be efficiently regulated by modulating land shapes, mechanical as well as bio-drainage, and controlled irrigation measures. Tolerant or resistant varieties and proper nutrient management can also be more effective for better survival of agricultural crops in waterlogged soils.

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