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RESEARCH ARTICLE

A REVIEW: IMPACT OF SOIL SALINITY ON ECOLOGICAL, AGRICULTURAL AND SOCIO-ECONOMIC CONCERNS

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Abstract

In recent years, salinization of soil is one of the challenging environmental concerns occurring all over the world. The effects of concentration of salt can be detected in both natural (primary) as well as man-made (secondary) environment. This is due to massive urbanization and industrialization in coastal regions, Soil salinity may lead to degradative changes in the composition of natural water resources, loss of fertile soil, loss of biodiversity, changes in local climatic conditions which in turn affects many aspects like, increasing salinization (salt affected soil) of lands converted in to non-productive conditions which significantly affects human life and posing major interruption to the economic development of farmers and their economy in the country. Furthermore, the overview of salinization and its effects on ecology, agriculture and economic growth and development is presented in this paper. Purpose of this review paper represented is according to most recent literature and refines knowledge on consistent research efforts for the types of soil salinity, problems of soil salinization, effect on plant growth and management strategies in agriculture to mitigate soil conditions in the salinity affected areas as well as rise in crop productivity and suggests future perspectives for on-going salinity research in the country.

Introduction:-

In India around 18% of the world's human population and 15% of the world's livestock population on merely 2.4% of the world's geographical area (Bhattacharya et al., 2015). Population growth in India has shown increasing trend with food production. Since independence, India has made significant success in agriculture sector. In spite of the technological modernizations in agriculture, this dramatically increased food production in the past few years, scares food insecurity triggers globally is being challenged by several environmental factors such as climate change (Parry et al., 1999; Rosenzweing et al.,2004;Godfray et al., 2010), diversion of arable lands for biofuel production and environmental degradation (Oldeman 1998; Pimentel, 2006; Escobar et al., 2009), intensive cropping, deforestation and biodiversity loss (Foley et al., 2005,Tscharntke et al., 2012), fresh water security (Lotze-Campen et al., 2008), increased population, urbanization and food wastage etc.(Parfitt et al., 2010; Pardeepkumar et al., 2020). The rising realization that climate change would poorly affect global food production of the majority of developing countries (Godfray et al., 2010).

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In general, many unwanted anthropogenic activities have caused severe harm to agro-ecosystem health, carbon and hydrological cycle and flora-fauna diversity which are vital to a sustainable future (Foley et al., 2005). In the recent trends, the competition for land use from housing, bio-energy and industrial sectors linked with severe water shortages and the alarming rate of natural resource degradation and biodiversity loss (FAO, 2011) which have necessitated a paradigm shift in the conventional ways and mean of food production. Thegoals of higher food requirements due to demographic, economic and trade liberalization are exerting heavy pressures on India's limited land and water resources.

The salinity issue is becoming more serious challenge in sustainable environment for food and nutritional security in the developing countries. A wide range of research articles are documented against soil salinity. Salinization of terrestrial and aquatic environment both are a significantly rising global problem in the last few years. Worldwide, approx. 950 million hector (ha) of land are estimated to be salt affected, with salinity affecting 23% of arable land (Szabolcs, 1985; Szabolcs, 1990). Globally saline soil hotspots include Argentina, China, India, Pakistan, Sudan, United States and many countries in Central and Western Asia (Aquast et al., 2016; Ghassemi et al., 1995), while as such the country India has a vast area under coastal agro-ecosystem with very low productivity, which is inhibited by the poorest farming(G.GururajaRao et al., 2019). Designing for the effective and sustainable development of this ecosystem requires adoption of integrated approach to soil and water practices and necessary measures to conserve the ecology. The major issues detected in coastal soils are: 1) Influence of tidal waves and periodical inundation by tidal water 2) Shallow water table enriched with salt to increase in soil salinity during winter and summer months 3) Heavy rainfall 4) poor surface and subsurface drainage condition 5) lack of irrigation water and acute salinity and 6) poor socioeconomic conditions of the farming community for using high investment technologies.

Soil salinity and its salinization:
An index of the concentration of salts occurs in soil is known as soil salinity which is usually expressed as electrical conductivity (EC). The process of buildup of salt concentration in soil is known as soil salinization. Such a level of salinization impacts on the agriculture production, environmental health, economics and quality of life. It involves a combination of processes like evaporation, salt precipitation and dissolution, salt transport and ion-exchange.

Salinity is a term that includes saline, sodic and alkaline soils (van Beek and Tóth, 2012), respectively defined as (a) higher salt concentration, (b) higher sodium cation (Na+) concentration, and (c) higher pH, often due to high CO_3^{2-} concentration, in the soil. Soil salinization leads to the change or even interference of the natural biological (Smith et al., 2015), biochemical (Decock et al., 2015), hydrological (Keesstra et al., 2012) and erosional (Berendse et al., 2015) Earth Cycles. In India, degradation of land due to soil erosion affects over 40% (150 m ha) of the total geographical area (Dabral et al., 2008). High salinization stages can thus result to the loss of the emerging resources, goods and services of soil which is impacting agricultural production and environmental health (Rengasamy, 2006), eventually evolving into a sociocultural and human health issue (Brevik et al., 2015) that obstructs economic and general welfare.

Primary Salinization: (Natural process in salinization of soil):
Natural salinization is the development of salts due to geological, hydrological and pedological processes. It includes physical and chemical weathering of rock materials or sediments with high salt content. Salts are released and made soluble and transported away from their source of origin through surface or groundwater streams. The salts brought down from the upstream by rivers to the plains and their deposition along with alluvial materials and weathering of rocks. In arid regions, the concentration of salts gradually increases until they start precipitating in soil due to limited natural precipitation and percolation, high vaporization and transpiration rates. In low lying areas with high groundwater table and locked topography which favors soil salinization. The fossil salt deposits (e.g., marine deposits) are also responsible for salinization in arid regions. Fossil salts can be dissolved under water storage or water transmission structures causing salinization (Bresler et al., 1982). The ingression of seawater along the coast surges salt contents in coastal areas (Rao et al., 2014). The salt loaded winds and rains (sea sprays) along sea coasts carry oceanic salts along with them in sufficient amount to cause salinization in coastal regions. The coastal regions are also exposed to the risk of progressive salinization of land due to natural disasters such as storms, cyclones, tidal surges, flooding etc.

Secondary salinization: (Anthropogenic activities of soil salinization):
Secondary salinization has been salinized by man-made causing factors. Mainly as a consequence of land clearing for cultivation, inappropriate irrigation, canal water seepage, overdosing of agro-chemicals and use of waste

effluents. Change of land use from natural forest vegetation to annual food crops decreases evapotranspiration and increases leaching. The presence of less permeable subsoil layers may intercept the percolating water passing through saline sediments resulting in lateral seepage, causing salinization in low lying areas (Doering and Sandoval, 1976).

Inappropriate use of brackish and saline irrigation water, poor drainage conditions, rising water tables etc., lead to secondary salinization of land and water resources (Rao et al., 2014). Recently,wide range of 310 million hectors (ha) area is irrigated, out of which 20–33% area is estimated to be affected by salt (Glick et al., 2007; Jamil et al., 2011; Shahid et al., 2018). Over extraction of groundwater transports salts to soil surface where they get precipitated when water evaporizes (Rao et al., 2014).Water logging and soil salinization in the Indira Gandhi NaharPriyojna (IGNP) in India is anexample ofcanal water seepage. Around 50% of the command area of IGNP has observed water logging area (Tewari et al., 1997).Use of untreated sewage effluent, dumping of industrial outlet onto the soil and water etc. may also cause the entry of heavy metals into soils.

The soil salinization has remarkable environmental, ecological, agricultural, and social impacts in terms of decreasing agricultural lands, low agricultural productivity, uncertain and unstable livelihood security, low economic returns, and poor quality of life. Excess salts effects the metabolism of soil flora and fauna, leading ultimately to the destruction of all soil life, altering fertile and productive lands into barren and desert lands. Soils are rendered useless agriculturally as well as for several other purposes like e.g., construction work.

Ecological effects:

Salinity of soil primarily affects ecological soil functions. The adverse impact of increased Electric conductivity (EC) on important soil processes like respiration, residue decomposition, nitrification, and de-nitrification through the decrease of soil biodiversity and microorganism activity is well known (Singh, 2015). Depending on its form and stage, soil salinity degrades fertile and productive land and reducing all vegetation (Chesworth, 2008; Jones et al., 2012; Trnka et al., 2013). Saline soils enter a negative feedback of Organic Carbon (OC) loss as decreased fertility and microbial and enzyme activities (Singh, 2015)leads to less biomass production which is badly effects distribution and stability of soil aggregates (Six et al., 2000) and promotes a higher portion of plant input in the accumulated organic matter. These changes increase distribution of clay particles and greater wind and water erosion rates (Paix et al., 2013) that further intensifyOC losses. Regarding Carbon, there is currently limited evidence on the Carbon stock trends in salt affected soil, whereas Carbon dynamics studies are contradictory (Wong et al., 2010). As a feedback of its effects on ecological functions, salinization impacts a series of environmental interactions thus undermining water infiltration and storage capacity of soil water resulting in increased water runoff and erosion.

Socio-economic effects

Although salinization has strong implications on socio-economic aspects, yet very few publications are presented in literature (Shahid et al., 2018). Social consequences of soil salinization include decline in agricultural harvest, low income, change of livelihood preferences and related social limits. The estimates show that the global annual cost of salt affected land degradation in irrigated areas could be US$ 27.3 billion in termsof lost crop production (Qadir et al., 2014).

The estimates based on 2012–14 average data suggested that, due to soil salinization in India loses annually 16.84 million tons of farm production (crops such as cereals, oilseeds, pulses) valued at Rs. 230.20 billion (Mandal et al., 2018). It has strong implications on the national economy. The Uttar Pradesh state is topped the list with 7.69 million tons production loss, followed by Gujarat state with 4.83 million tons production loss. Gujarat and Uttar Pradesh have the largest salinized area (>50% of cultivated area) in the country. These two states only share around 79% monetary losses in the country.

Peoples' living standard, regular life activities and socio-economic conditions are poorly affected. Farmers in response to salinity problem are forced to shift their livelihood strategies (ZiaulHaider and ZaberHossain, 2013) in coastal regions. Farmers in salineregions are generally resource inhibited and required financial and technical assistance to sustain their livelihood efforts (Oo et al., 2013).

Salinity effects on plant growth

Plants commonly faceenvironmental conditionse.g. abiotic stress such as drought, chilling, freezing, high temperaturesandhigher salinity of soils which can delay growth and development, reduce productivity, and, in extreme cases cause plant death (Krasensky and Jonak, 2012).Salinity affects almost all aspects of plant progress including germination, vegetative growth, and reproductive improvement(Machado and Serralheiro et al., 2017). Stress condition plants in saline environments experiences two types of stress, the osmotic stress and nutrient stress. Low osmotic potential of water in saline soils which adversely affects water absorption by plants is called as osmotic stress. Nutrient stress is a process of both 1) specific ion toxicity (sodium (Na), chloride(Cl),Boron(B) etc.) and 2) insufficiency of plant nutrients (N,K, P, Ca, Fe, Zn). It also results in nutritional imbalances(Munns and Tester, 2008). Salinity of soil significantly decreases phosphorus uptake by plants because phosphate ions precipitate with Ca ions (Bano and Fatima, 2009). The supplemented sodium(Na+) absorption in sodic soils reduces K+ absorption which poorly affects the enzymatic activities involved in metabolic processes like photosynthesis and protein synthesis (Hauser and Horie, 2010), which is damaging for plant growth (Katiyar-Agarwal et al., 2005).

Increased salinity is a severe problem and a foremost limiting factor for crop production around the globe (Wahid et al., 2007). Reduced leaf area, chlorophyll content and stomatal conductance in saline soils also affects photosynthesis.Salinity affects photosynthesis by decreasing CO_2 availability as a result of diffusion limitations and a reduction of the contents of photosynthetic pigmentscapacity of the plant through reduced leaf growth and inhibited photosynthesis, limiting its ability to grow(Netondo et al., 2004, Hauser and Horie, 2010).e.g. Salt accumulation in spinach inhibits photosynthesis, primarily by decreasing stomatal and mesophyll conductances to CO_2 and reducing chlorophyll content, which can affect light absorbance.

Apart from high nutrient deficiencies and toxicities, other restrictions for plant growth in saline-sodic soils includesphysicallypoor soil conditions, viz. low water and air permeability, high runoff, low water holding capacity (WHC), surface crusting, and hard setting. They effects plant root penetration, seedling, and tillage operations (Murtaza et al., 2006).

The salt stresses disturb acutely to the plant morphology, functioning and homeostasis and decrease the plant biomass (Parvaiz et al., 2014). High stages of soil salinity can significantly inhibit seed germination and seedling growthInfluence of Salinity on seed germination of many crops by creating an osmotic potential outside the seed inhibiting the absorption of water, or by the toxic effect of Sodium (Na^+)and Chloride (Cl^-) (Khajeh-Hosseini et al., 2003). Salt tolerance of the plants may vary according to the environmental conditions of plant and its growth stages. The excess amount of Sodium (Na^+)and Chloride (Cl^-) in the protoplasm show disturbance in the ionic balance and also show the ion-specific effects on enzyme proteins and membranes. Several researchers have reported plant growth reduction as a result of salinity stress, e.g. in onion (Chaudhry et al., 2020) tomato (Romero-Aranda et al., 2001), cotton (Meloni et al., 2001) and sugar beet (Ghoulam et al., 2002) and many more vegetables. However, there are changes in tolerance to salinity among species and cultivars as well as among the different plant growth parameters recorded. Shrivastava P. et al., 2014 presented review on the enhancement of productivity under stressed conditions and increased resistance of plants against salinity by application of plant growth promoting microorganisms.

Poor-Quality water use in agricultural production

In India nearly 85% fresh water resources are being utilized in agriculture and the balance, 15% in domestic and industrial sector. Quality and quantity of ground water are most important factors of high productivity and production. Maximum area over saline and brackish ground water occurs in the arid and semi-arid regions of Rajasthan, Haryana, Delhi, Punjab, Gujarat and Uttar Pradesh (Minhas and Tyagi,1998; Minhas and Sharma, 2003). Scarcity of good-quality water and extensive pumping of the ground water, areas which are being contaminated in several parts of the country.

Inappropriate use of poor-quality waters in the absence of suitable soil water crop livestock management practices poses a serious threat to environment health. Buildup of salt adversely affects lands and turning them in to non-productive lands.

Management strategies in agriculture

Saline lands can be converted to more productivecroplands by preventing the influx of saline water through proper farm management practices, correcting soil toxicities, nutrient deficiencies, and leaching the salts out of the root zone. The reclamation and managementpractices costs can be reduced by growing salt tolerant vegetation. These practices are discussed below.

Farm management practices

Salinity can be controlled by changing in farm management practices. Munns et al.2002 proposes that irrigated agriculture could be sustained by better irrigation practices such as adoption of partial root zone drying methodology, and drip or micro jet irrigation to optimize use of water. They suggested that salinity could also be contained by reducing the amount of water passing beyond the roots by reintroducing deep rooted perennial plants that continue to grow and use water during the seasons but it's not supports annual crop plants. This may restore the balance between rainfall and water use, thus preventing the movement of salt to the soil surface. Singh et al., 2003 reported the chemical amendment based technology has been developed to reclaim salt affected soils. By adopting this technology about 1.3 million hector (ha) area has been reclaimed in the states of Haryana, Punjab and Western Uttra Pradesh (Singh et al., 2007)

Leaching

Leaching soils to remove soluble salts is the most effective method known to reclamation of saline soils. This requires good permeability of the soil and good quality irrigation water. Removal of salts by leaching reduces soluble salt fromthe root zone, especially in shallow rooted crops but might cause permeability to decrease and pH to increase resulting in decomposition of roots as soil is changed from saline sodic to sodic (Dregne, 1976). Although the best long term solution to salinization is to provide adequate drainage, this process is costly(Toenniessen, 1984). The process of leaching was successful in the depth of 0-10 cm (Mahendran 2007).

The other management technologies use such as salt tolerant varieties in crops, use of mulch application, foliar application of fertilizers, fertilizer management as well as nutrient management, green manure and green leaf manure.

Uses of salt stress tolerant plants

According to United Nations Environment Program, about 20% of the agriculture land and 50% cropland around the world face salinity problems. The caloric and nutritional possibilities of agriculture outcome are limited by salt stress conditions of land (Deveshi Patel et al., 2020).Some areas have naturally occurring salinity and salt stress tolerant plants may provide a better or perhaps the only means of utilizing these resources for food production. Using of salt tolerance varieties in the efficient ways to solve the problem of soil salinity. Salinity can possibly also be managed through biologically manipulating the plants (Shannon, 1984). Great effort is, therefore, being directed toward the development of salt tolerant crop genotypes through the use of plant breeding strategies involving the introgression of the genetic background from salt tolerant wild species into cultivated plants (Shannon, 1984; Pitman and Laüchli, 2002). However, it should be borne in mind that there is also the risk that the availability of salt tolerant genotypes will result in less effort to recover saline areas or to prevent salinization. In the longer term this will be counterproductive.

Salt tolerance in crops will also allow the more effective use of poor quality irrigation water. (Niknam and McComb 2000) suggested that trees could be planted to take up some of the excess salt since they have high water use and can lower water tables to decrease salt discharge into streams and prevent secondary salinization of the surrounding areas.

Conclusion:-

The worldwide increasing salinization of arable land renders salinity one of the most harmful threats to modern agriculture and challenging food production and security in India. It is a dynamic process caused by several natural and anthropogenic processes, and quite often, the socio economic and political considerations become extremely important in speeding up the processes of soil salinization. Sometimes, such factors are beyond the control of individual farmers. Several on farm tested technologies are available for the reclamation and management of salt affected soils. The efforts put in by government agencies and farmers for the reclamation and restoration of saline soils in the country so far havebeen encouraging.Under the scenario where the productive lands are decrease due to increased urbanization, the restoration and management of salt affected soils in coastal regions. Furthermore, it is necessary requirement to investigate the nutrients and contents of saline soil for efficient use of fertilizers. Finally, the overall situation needed more essential approach to manage saline environment because this would include ecological, agricultural as well as socio-economic development aspects for sustainable management of soil salinity.

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