RESEARCH ARTICLE OPEN ACCESS

Review Paper on Soil Physics, Importance, Challenges and Threats

Dinesh Bhardwaj [1], Rishi [2]
Assistant Professor
Department of Computer Science
Department of Physics
GNDU College, Pathankot
Punjab – India

ABSTRACT

Soil physics deals with the dynamics of physical soil components and their phases as solid, liquids, and gases. It draws on the principles of physics, physical chemistry, engineering, and meteorology. It is especially important in this day and age because most farmers require an understanding of agro ecosystems. Nowadays, soil is increasingly under pressure as a limited resource for the production of food, energy and raw materials. In more recent years this list has grown to include anthropologists, economists, engineers, medical professionals, military professionals, sociologists, and even artists.

The central importance of soil for the functioning of terrestrial systems is increasingly recognized. Critically relevant for water quality, climate control, nutrient cycling and biodiversity, soil provides more functions than just the basis for agricultural production. This has led to an increasing demand for concepts assessing soil functions so that they can be adequately considered in decision-making aimed at sustainable soil management. The various soil science disciplines have progressively developed highly sophisticated methods to explore the multitude of physical, chemical and biological processes in soil.

This approach has been strengthened and reinforced as current research continues to use experts trained in both soil science and related fields and by the wide array of issues impacting the world that require an in-depth understanding of soils. Of fundamental importance amongst these issues are biodiversity, bio-fuels/energy security, climate change, ecosystem services, food security, human health, land degradation, and water security, each representing a critical challenge for Research.

The focus of soil physics research and that of soil science in general, has gradually broadened from mostly agricultural production issues to more comprehensive studies of Sub-surface water flow and chemical transport geared toward environmental issues.

Keywords:- Soil Physics, Biodiversity, Ecosystem, physical chemistry etc.

I. INTRODUCTION

Soil is a complex mixture of minerals, organic material, water, and various lifeforms. In its original state, soil was an uncontaminated substance covering the earth. But humans have intentionally and accidentally poured harmful products onto it in some areas. The waste can hurt the soil and possibly human, plant, and animal health. Soil physics may be defined as the application of the principles of physics to the characterization of soil properties and the understanding of soil processes, especially those involving the transport of matter or energy. This definition implies that soil physics is a sub discipline of both physics and soil science [1]. Soil physics deal with the study of soil physical properties (e.g., texture, structure, water retention, etc.) and processes (e.g., aeration, diffusion, etc.). It also consists of the study of soil components and phases, their interaction with one another and the environment, and their temporal and spatial variations in relation to natural and anthropogenic or management factors. Soil physics involves the application of principles of physics to understand interrelationship of mass and energy status of components and phases as dynamic entities. All four components are always changing in their relative mass, volume, spatial and energy status due both to natural and management factors [2].Most soils consist of four components and three phases. The four components include inorganic solids, organic solids, water, and air. Inorganic components are primary and secondary minerals derived from the parent material. Organic components are derived from plants and animals. The liquid component consists of a dilute aqueous solution of inorganic and organic compounds. The gaseous component includes soil air comprising a mixture of some major (e.g., nitrogen, oxygen) and trace gases (e.g., carbon dioxide, methane, nitrous oxide)[3].

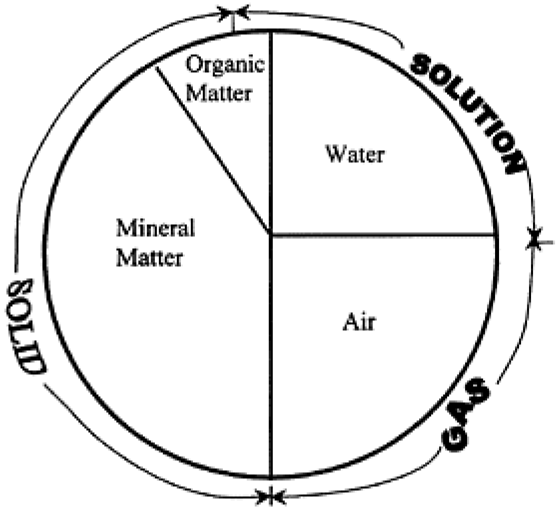


Fig1: Soil is made up of four components and three phases[3].

Properties and Phases and Components Table[3]

Phases	**Components**	**Composition**	**Properties**
solid	inorganic	Products of weathering; quartz, feldspar, magnetite, garnet, hornblonde, silicates, secondary minerals	Skeleton, matrix ρs=2.0–2.8 Mg/m3
	organic	Remains of plants and animals; living organisms, usually <5%	Large surface area, very active, affects CO2 in the atmosphere ρs=1.2– 1.5 Mg/m3
Liquid	Soil solution	Aqueous solution of ions (e.g., Na, K, Ca, Mg, Cl, NO3, PO4, SO4)	Heterogeneous, dynamic, discontinuous ρw=1.0 Mg/m3
Gas	Soil air	N2, O2, CO2, CH4, C2H6, H2S, N2O, NO	ρa=1–1.5 kg/m3 variable, dynamic

Much evidence exists of increased human-induced stresses on the earth's environment. Many of these stresses are, directly or indirectly, a consequence of pollutants generated by agricultural, industrial, and municipal activities. Pesticides and fertilizers used in farming operations continue to contaminate soil and groundwater systems worldwide. Soil erosion remains a problem in many areas. The accumulation of salts and toxic elements in irrigation agriculture is a worsening problem in many arid and semi-arid regions of the world. Acid rain is a cause of pollution in most or all continents. Chemicals migrating from municipal and
industrial disposal sites are similarly creating hazards to the environment. Contamination of the subsurface poses special challenges to soil scientists including soil physicists. Many or most subsurface pollution problems stem directly from activities involving the unsaturated (vadose) zone between the soil surface and the groundwater table. It is the unsaturated zone where management will offer the best opportunities for preventing or limiting pollution, or for remediating ongoing pollution problems. Solute residence times in groundwater aquifers can range from several years to millennia or **more.** Hence, once contaminants have entered groundwater, pollution is in many cases essentially irreversible, or can be remediated only with extreme costs. Consequently, soil and groundwater pollution problems are best dealt with, or prevented, through proper management of the unsaturated zone. Because of our expertise in the measurement and modeling of unsaturated zone flow and transport processes, soil physicists are in a unique position, and have special responsibilities, to contribute to the prevention or remediation of subsurface pollution problems[4].

This paper addresses some of the opportunities for soil physicists in the continuing effort to optimize agricultural production, while also contributing to the solution of environmental problems. It is critical that our research be part of comprehensive efforts involving other soil scientists, hydrologists, geologists, civil and environmental engineers, and (micro)climatologists.

II. HISTORY

Schübler, Schumacher, and Wollny were among the first to study soil physical properties for crop production in the nineteenth century. Schübler determined specific gravity, bulk density, water-holding capacity, swelling/shrinkage, hygroscopic water content, heat capacity, latent heat of wetting, and electrical conductivity of soils. Wollny did experiments to measure soil temperature, water and gaseous composition, how these properties were affected by soil management and earthworms, and how this affected crop productivity Schloesing and Van Bemmelen wrote about the ability of clay to hold water American scientists Hillgard studied the particle size of soils and laid the foundations for modern soil survey[5].

Johnson researched the effects of tillage on soil physical properties and capillary movement of water

King published a book 'Physics of Agriculture' in which he explained air porosity, water retension property of soil, different water-soil requirements for different crops , the effects of tillage on soil. Buckingham, in 1907, published 'Studies on the Movement of Soil Moisture', in which he recognizes that water flow in unsaturated soils is proportional to matric potential [6].

III. LITERATURES

In[7]Early studies of soil physics from the 1900s to the 1940s generally involved such issues as soil structure and soil aggregation, soil pore space, field soil water status, capillarity and soil water retention, evaporation, soil mechanics, soluble salts, soil salinity, diffusion, and heat content. Many of these early studies focused on the physical properties of soils as a medium for crop production, including the effects of tillage and compaction on root growth and plant water uptake. More comprehensive theoretical studies by soil physicists on water, heat and solute movement in soils started in the 1930s with the formulation of the Richards equation for transient unsaturated- water flow.

In[8] Similar differential equations were introduced for heat and solute movement, and subsequently applied in the 1950s and 1960s to a flurry of laboratory experiments involving mostly disturbed, homogeneous soil systems. Laboratory testing of convection-dispersion type solute transport models was especially popular at that time. Field-scale testing of flow/transport theories and models did not really start until the mid 1970s in part spurred by the development of better numerical models and the increased availability of mainframe and personal computers. Process-based simulation models were subsequently developed for the purpose of integrating available knowledge, and for formulating and evaluating alternative agricultural soil, crop, and water management practices. While most of these simulations initially focused primarily on water quantity issues (irrigation, drainage, soil erosion), they increasingly also involved agricultural water quality issues associated with pesticides, fertilizers, soil salinity, and sewage sludge.

In[9] soil physicists are increasingly becoming participants in global-scale hydrologic research. Especially needed (e.g., Wood, 1991) are improved models of land-surface hydrologic processes in general circulation models for predictions at regional, continental, and global scales, as well as appropriate field studies over a range of scales insofar as these scales impact hydrological processes at the larger scales. Soil physicists should be especially interested in the land surface component of global hydrological models, including the development of realistic physically based models for biosphere-atmosphere interactions to estimate the transfer of energy, mass, and momentum between the vegetated surface of the earth and the atmosphere.- With their traditional focus on soil water dynamics and microclimatology, soil physicists should be natural cooperators in research with hydrologists, climatologists and global climate modelers.

In[10] soil physicists must be interested in media other than the weathered and fragmented outer layer of the earth's terrestrial surface usually referred to as *soil (e.g.*, Hillel, 1980).

In[11] Development of realistic models for unsaturated flow and solute transport in fractured rock and other geologic materials is crucial for establishing suitable subsurface waste disposal sites. For example, much research in several countries has been, or is being, carried out in connection with the safe disposal of spent nuclear fuel and high-level radioactive waste in unsaturated fractured rock.

IV. THREATS AND THEIR IMPACTS

4.1.Soil erosion

4.1.1.Soil Erosion By water: **Soil erosion by water** is a problem wherever erodible soil is combined with sloping land, low soil cover and heavy rainfall. The Mediterranean region is particularly prone to water erosion because it is subject to long dry periods followed by heavy rainfall on steep slopes and fragile soils. Although the physics of the process are well understood, challenges remain because of large spatial and temporal variability and because of the need to combine remediation measures with agricultural activities[12].

IMPACTS:

- Loss of soil fertility from field affecting crop yields.
- Destruction of infrastructure, such as tracks and roads.
- Pollution of watering points for livestock.
- Flash floods down stream of the erosion site.
- Water pollution.
- Sedimentation of water reservoir.

4.1.2.Soil Erosion By wind: Wind erosion is a natural process that moves soil from one location to another by wind power. It can cause significant economic and environmental damage.Wind erosion can be caused by a light wind that rolls soil particles along the surface through to a strong wind that lifts a large volume of soil particles into the air to create dust storms. While wind erosion is most common in deserts and coastal sand dunes and beaches, certain land conditions will cause wind erosion in agricultural areas. **It occurs** usually as a consequence of cultivation when fields are left exposed for a period of time. **Impacts: human health**,**agricultural production** and **environment.**

The NSW Government provides further information for land managers who want to control wind erosion in Saving Soil – A landholder's guide to preventing and repairing soil erosion

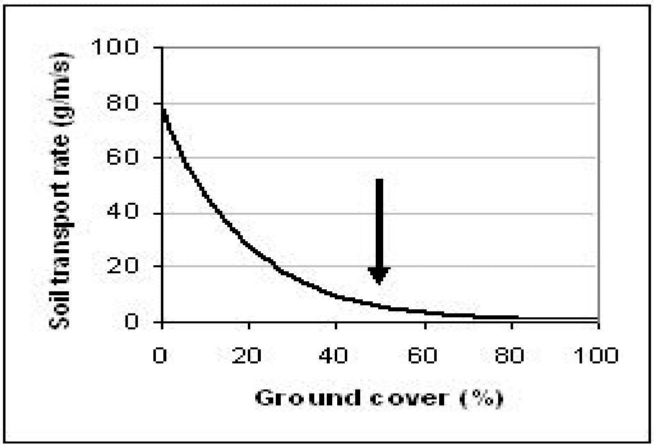


Fig4.1:Graph showing the relationship between ground cover and wind erosion. The arrow marks the level of ground cover required to control erosion[13].

4.2.Soil Salinization: Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil, and the area of land affected by it is increasing day by day. For all important crops, average yields are only a fraction – somewhere between 20% and 50% of record yields; these losses are mostly due to drought and high soil salinity, environmental conditions which will worsen in many regions because of global climate change. Salinization is the process involving an accumulation of salt in the topsoil. It is usually closely related to human action; in most cases either from inappropriate irrigation methods or overexploitation of coastal aquifers causing sea water intrusion[14].

Impacts: Salinity not only decreases the agricultural production of most crops, but also, effects soil physicochemical properties, and ecological balance of the area. The impacts of salinity include—low agricultural productivity, low economic returns and soil erosions, (Hu and Schmidhalter, 2002). Salinity effects are the results of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Akbarimoghaddam et al., 2011; Singh and Chatrath, 2001). Salinity affects almost all aspects of plant development including: germination, vegetative growth and reproductive development. Soil salinity imposes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants, and thus limits water uptake from soil. Soil salinity significantly reduces plant phosphorus (P) uptake because phosphate ions precipitate with Ca ions (Bano and Fatima, 2009). Some elements, such as sodium, chlorine, and boron, have specific toxic effects on plants. Excessive accumulation of sodium in cell walls can rapidly lead to osmotic stress and cell death (Munns, 2002). Plants sensitive to these elements may be affected at relatively low salt concentrations if the soil contains enough of the toxic element. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Blaylock et al., 1994)[15].

4.3.Acid rain: Acid rain removes minerals and nutrients from the soil that trees need to grow. At high elevations, acidic fog and clouds might strip nutrients from trees' foliage, leaving them with brown or dead leaves and needles. The trees are then less able to absorb sunlight, which makes them weak and less able to withstand freezing temperatures. Acid rain also contains nitrogen, and this can have an impact on some ecosystems. For example, nitrogen pollution in our coastal waters is partially responsible for declining fish and shellfish populations in some areas. In addition to agriculture and wastewater, much of the nitrogen produced by human activity that reaches coastal waters comes from the atmosphere. Many forests, streams, and lakes that experience acid rain don't suffer effects because the soil in those areas can ***buffer*** the acid rain by neutralizing the acidity in the rainwater flowing through it. This capacity depends on the thickness and composition of the soil and the type of bedrock underneath it. In areas such as mountainous parts of the Northeast United States, the soil is thin and lacks the ability to adequately neutralize the acid in the rain water. As a result, these areas are particularly vulnerable and the acid and aluminum can accumulate in the soil, streams, or lakes [16].

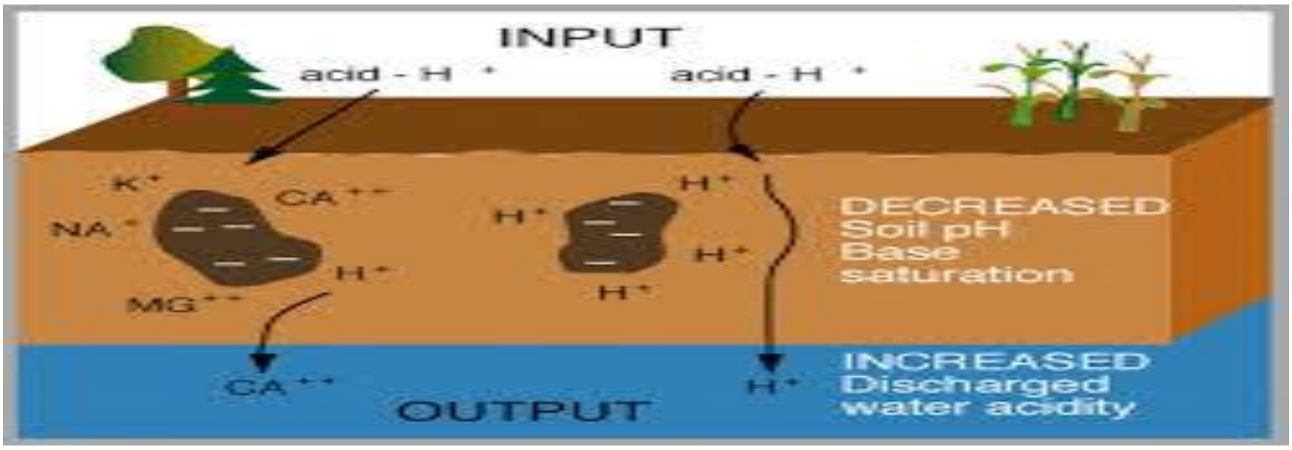


Fig4.2: Effect of Acid rain

4.4. Soil compaction: Compaction of soil is the compression of soil particles into a smaller volume, which reduces the size of pore space available for air and water. Most soils are composed of about 50 per cent solids (sand, silt, clay and organic matter) and about 50 per cent pore spaces. Soil compaction can impair water infiltration into soil, crop emergence, root penetration and crop nutrient and water uptake, all of which result in depressed crop yield. It limits soil exploration by roots and decreases the ability of crops to take up nutrients and water efficiently from soil and reduces crop yield potential. Reduced soil aeration can affect root growth and function, and lead to increased risk of crop disease.

Best Management Practices to Prevent Soil Compaction

Ideally, farmers should design their soil management and cropping practices to ensure the prevention of soil compaction:

- Use direct seeding practices to increase soil organic matter content, which will optimize soil structure.
- Reduce the potential for the development of compacted soils by eliminating cultivation and reducing traffic in fields, which will increase crop water use efficiency and increase crop yield potential.
- Take advantage of the natural soil processes of “wetting-drying” and “freeze-thaw” cycles to minimize the effects of soil compaction. For irrigated areas, fall irrigation may ensure sufficient water for the freeze-thaw effects[17].

4.5.Desertification: Desertification is defined as a process of land degradation in arid, semi-arid and sub-humid areas due to various factors including climatic variations and human activities.

4.5.1.Farming Practices,_Urbanization, Climate change, Farming practices,over grazing and Deforestation plays a huge role in desertification. If an area becomes a desert, then it’s almost impossible to grow substantial crops there without special technologies, the water quality is going to become a lot worse than it would have been otherwise. Without food and water, it becomes harder for people to thrive, and they take a lot of time to try and get the things that they need.

TREATMENTS: education is an incredibly important tool that needs to be utilized in order to help people to understand the best way to use the land that they are farming on. If people are using land to get natural resources or they are developing it for people to live on, then the policies that govern them should be ones that will help the land to thrive instead of allowing them to harm the land further[18].

4.5.2.desertification in developing countries

4.6.Floods and landslides: It is a temporary inundation of normally dry land with water, suspended matter and/or rubble caused by overflowing of rivers, precipitation, storm surge, tsunami, waves, mudflow, lahar, failure of water retaining structures, groundwater seepage and water backup in sewer systems.

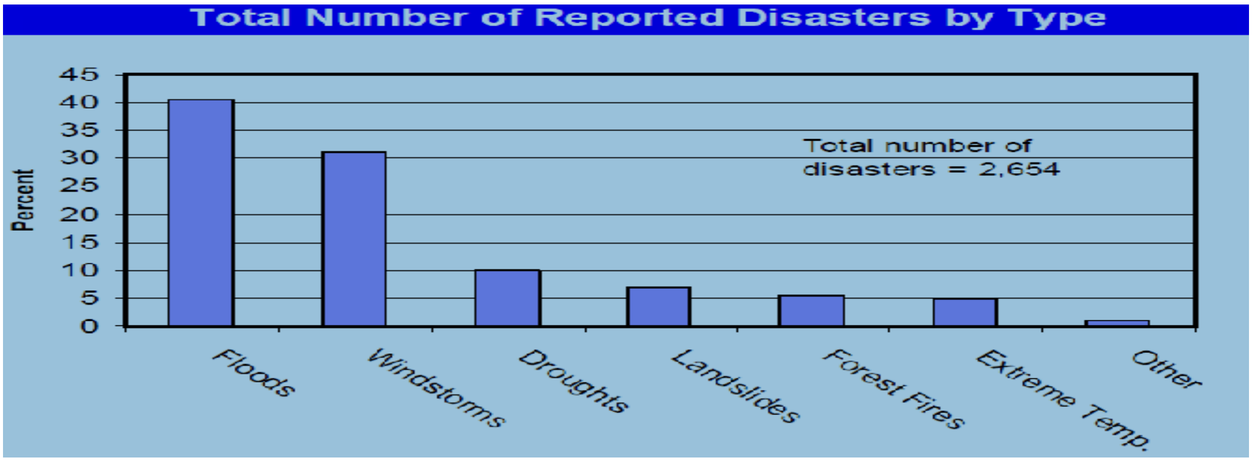


Fig 5.5: Reported disasters by type [19].

A landslide is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flow.Avalanche is the contributing factor to landslide, it is caused when a build up of snow is released down a slope, and is one of the major dangers faced in the mountains in winter. avalanche is a type of gravity current.

4.7.Loss of organic matter: Soil organic matter (SOM) can be defined as the total organic content of a soil after excluding non-decayed plant and animal remains. Carbon is the prime element present in SOM, comprising 48%-58% of the total weight and therefore soil is the second largest pool of carbon on earth, after the oceans and twice the size of the atmospheric carbon pool. Due to the importance of the carbon element, SOM is typically quantified as soil organic carbon Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides.

Organic matter influences the physical conditions of a soil in several ways. Plant residues that cover the soil surface protect the soil from sealing and crusting by raindrop impact, thereby enhancing rainwater infiltration and reducing runoff. Surface infiltration depends on a number of factors including aggregation and stability, pore continuity and stability, the existence of cracks, and the soil surface condition. Increased organic matter contributes indirectly to soil porosity (via increased soil faunal activity). Fresh organic matter stimulates the activity of macrofauna such as earthworms, which create burrows lined with the glue-like secretion from their bodies and are intermittently filled with worm cast material.

TREATMENTS: Practices that increase organic matter include: growing green manure crops or catch crops, perennial forage crops and cover crops; applying animal manure or compost; leaving crop residues in the field; applying reduced or conservation (minimum) or no tillage to minimize disruption of the soil's structure, composition and natural biodiversity and crop rotations with high residue plants with large amounts of roots and residue[20]. Table1:Measures

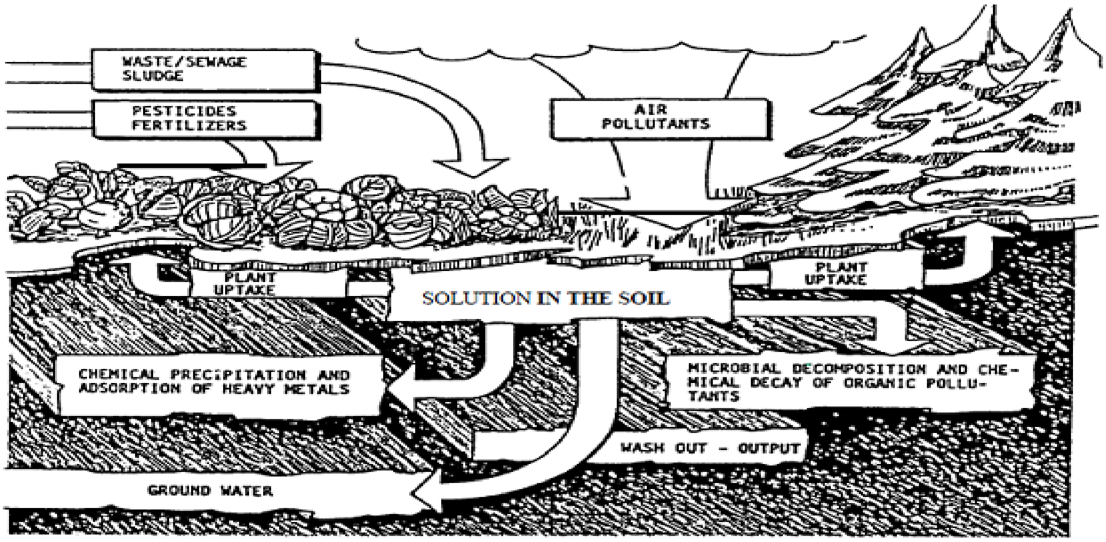
Measures	
Apply animal manures, compound fertiliser, trash, recycled waste	Inter-planting
Green manure crops	Reduce period of bare fallow
Cover crops with plant-based materials	Crop rotation
Retain crop residues	Retain crop residues

4.8.Soil contamination: Soil contamination or soil pollution as part of land degradation is caused by the presence of xenobiotic chemicals or other alteration in the natural soil environment. Common contaminants in urban soils include pesticides, petroleum products, radon, asbestos, lead, chromated copper arsenate, and creosote. In urban areas, soil contamination is largely caused by human activities. Some examples are manufacturing, industrial dumping, land development, local waste disposal, and excessive pesticide or fertilizer use.Humans can be exposed to soil contaminant in many ways. Some of them are:

- Breathing volatiles and dust
- Ingesting soil
- Absorbing through skin
- Eating food grown in contaminated soil[21]

4.9.Loss of Biodiversity

4.9.1. Pollutants: Waste compost and sewage sludge deposition on soil as well as intensive use of fertilizers and pesticides, in addition to the deposition of air pollutants (cf. Fig. 5), may have a negative impact on soil quality and especially the ground water and the food chain, by surpassing the natural capacity of soils for mechanical filtering, chemical buffering and biochemical transformation (Blum, 2000). In this context, it should be remembered that agriculture and forestry not only produce biomass above the ground, but also influence the quality and quantity of ground water generation underneath, because each drop of rain falling on the land has to pass the soil before it becomes ground water or drinking water[22].



SOIL CONTAMINATION BY FERTILIZERS, SEWAGE SLUDGE AND PLANT PROTECTION PRODUCTS

Fig4.9.Soil contamination by fertilizers, sewage sludge and plant protection products

4.10.**Urbanization**: Exclusive competition between the use of soil for infrastructure development, as a source of raw materials and as a geogenic and cultural heritage on the one hand and the use of soil for biomass production, filtering, buffering and transformation activities and as a gene reserve on the other hand. This becomes evident by sealing of soils through urban and industrial development, e.g. the construction of roads, houses, industrial premises, and sporting facilities or when soils are used for the dumping of refuse, all this being known as the process of urbanisation and industrialisation, thus excluding all other uses of soil and land[23].

4.11. Deforestation: Deforestation is the permanent destruction of forests in order to make the land available for other uses. An estimated 18 million acres (7.3 million hectares) of forest, which is roughly the size of the country of Panama, are lost each year, according to the United Nations' Food and Agriculture Organization (FAO).

Some other statistics:

- About half of the world's tropical forests have been cleared, according to the FAO.
- Forests currently cover about 30 percent of the world’s landmass, according to National Geographic.
- The Earth loses 18.7 million acres of forests per year, which is equal to 27 soccer fields every minute, according to the World Wildlife Fund (WWF).
- It is estimated that 15 percent of all greenhouse gas emissions come from deforestation, according to the WWF.

Reasons for Deforestation are:

- To make more land available for housing and urbanization
- To harvest timber to create commercial items such as paper, furniture and homes
- To create ingredients that are highly prized consumer items, such as the oil from palm trees
- To create room for cattle ranching

Common methods of deforestation are burning trees and clear cutting. These tactics leave the land completely barren and are controversial practices[24]. Deforestation is considered to be one of the contributing factors to global climate change. According to Michael Daley, an associate professor of environmental science at Lasell College in Newton, Massachusetts, the No. 1 problem caused by deforestation is the impact on the global carbon cycle. Gas molecules that absorb thermal infrared radiation are called greenhouse gases.

IMPACTS: Carbon isn't the only greenhouse gas that is affected by deforestation. Water vapor is also considered a greenhouse gas. "The impact of deforestation on the exchange of water vapor and carbon dioxide between the atmosphere and the terrestrial land surface is the biggest concern with regard to the climate system," said Daley. Changes in their atmospheric concentration will have a direct effect on climate. Deforestation has decreased global vapor flows from land by 4 percent, according to an article published by the journal National Academy of Sciences[25]. Some other effects of Deforestation are**: Soil erosion, Loss of species, disturbance of native people.**

4.12.Fertilizers: Fertilizer has been defi ned by soil science society of America as "any organic or inorganic material of natural or synthetic origin, other than liming materials that is added to soil to supply one or more plant nutrients essential to the growth of plants". In accordance with the rising food productions, chemical fertilizer supply has been continuously increasing with time. Global fertilizer consumption of arable and permanent crop area has increased from 79.29 tones/1000 Ha in 2002 to 98.20 tones/1000 Ha in 2010 and the demand for total fertilizer nutrients has been estimated to rise further at 1.9 % per annum from 2012 to 2016. China and India are the world's leading consumers of chemical fertilizers (N, P, K) while highest production of the same is reported in China, USA and India in that order (FAO 2012). So, fertilizers may be seen as an indispensable part of modern agriculture[26].
IMPACTS: Since fertilizers are meant to increase the nutrient content of the soil in order to improve the crop productivity they are bound to increase the SOC as a result of enhanced root turnover, rhizodeposition and crop residue fall thereby boosting microbial activity. It has been well established that functional diversity of the soil microbial community is primarily governed by the resource (N, P and C) availability (Cruz et al. 2009 ; Liu et al. 2010b ; Yang et al. 2011 ; Lupwayi et al. 2012). Thus, a signifi cant co-relation exists between SOC and microbial populations as well as microbial activities (Bohme et al. 2005). This directly indicates that the class and composition of fertilizer applied will certainly affect the microbial community structure of the cultivated lands. Another important aspect of organic fertilization is reduced bioavailability of pollutants like heavy metals and pesticides in soils. Another aspect of chemical fertilization is that it leads to generation of nutrient channels or patches thus creating nutrient gradients in the soil that affects the microbial populations. Li et al. (2013) studied the effect of N-gradient created by chemical fertilizers like ammonium sulfate or urea on nitrogen transformation, soil microbial biomass and microbial functional diversity[27].

V. TREATMENTS

Although there will be different prioritisations in different regions of the world, the "big issues" will surely include:
_ Climate change, especially its mitigation or exacerbation through soil
processes;
_ Pathways and impacts of pollutants at local and global scale;
_ Growing sufficient food, especially in the face of water shortage;
_ Nutrient enrichment and other human impacts on the functioning of
semi-natural ecosystems.

The resurgence in global agricultural research could be a well-coordinated effort to maximise production in regions of greatest potential and achieve at least some sustainable production in unpromising situations, whilst taking full account of environmental interactions. Unfortunately current actions, including forest clearance in South America, wasteful increases in agrochemical use in Asia, and inefficient water use almost everywhere, suggest it will include remediating problems caused by poorly-planned agricultural intensification. A wealth of new methods is becoming available – some potential tools for research on the details of soil functioning (e.g. various spectroscopies, molecular biology, imaging) have the power to initiate totally new areas of enquiry. Others are applicable to the collection and manipulation of soil data at a range of scales from field to global (e.g. proxy analyses, remote sensing, modelling) and thus valuable for monitoring, management and policy development. It is essential that some soil scientists are at the forefront of exploring new methodologies, in collaboration with appropriate specialist. But it is equally important that they, or other soil scientists, are active in testing the new approaches under realistic conditions and then applying them to significant questions, so they become valuable tools rather than minority art forms.
If there are to be soils scientists in the future it is essential to communicate the fascination of soils and their importance for humanity to school students and, most strategically, to teachers. At the University level, the decline in numbers of departments concentrating purely on soil science is not necessarily negative. Embedding of soil science in broadly based departments can lead to extra students receiving some teaching on soils. But there is also a need for soil science specialists, with implications for "critical mass" of expertise. The trend to deliver specialist training at post-graduate level may be beneficial, attracting students with varied backgrounds. For all students, teaching should obviously be rigorous and challenging. But for those teaching the broader groups I would encourage a rigorous yet "functional" approach, helping students to see what soils do within managed or natural ecosystems and equipping them to make management decisions. Most of all make it interesting! Although classification is important, those difficult words can wait until later[28].

VI. FUTURE SOIL

Soil is a life-sustaining, biologically active, porous and structured medium at the Earth's surface formed by mineral particles, organic matter, water, air and living organisms. Consisting of several horizons, soil regulates the supply of water and nutrients for the flora and microfauna and is therefore one of the basic compartments for ecosystems. Soil is of fundamental importance for the cycling of carbon, nitrogen and sulphur and determines the partitioning of water percolating to groundwater reservoirs or flowing to rivers and lakes. Soil acts as a living filter for numerous (in)organic wastes, immobilizes or detoxifies toxins, and renders pathogens harmless. Soil is a habitat and gene pool, serves as a platform for human activities, landscape and heritage and acts as a provider of raw materials. To enhance the soil's capacity to perform these functions, it is important to understand the factors and processes affecting soil quality under expanding and competing land use. Soil science developed from geology, biology and agricultural chemistry in the 18th and 19th century. In the 20th century, it has evolved to an independent discipline which was manifested by the foundation of the International Society of Soil Science in Rome in 1924. Soil science originally focussed on pedogenetic processes but soil scientists also study the water and matter dynamics in the soil-plant-aquifer-atmosphere system and quantify loss of soil particles through erosion by wind and water, losses of solutes through drainage water, and gaseous losses. It is a multidisciplinary science which interlinks knowledge of the atmosphere, the biosphere, the lithosphere and the hydrosphere[29].

Challenges for the 21st century Severe problems facing humanity in the 21st century are a present world population of 6.1 billion, increasing by 1.3%/yr, food-insecurity and malnutrition in most of Africa and parts of South America and Asia, excess fertilization with nitrogen and phosphorus in many other parts of the world leading to pollution of freshwaters, eutrophication and acidification of terrestrial and coastal ecosystems, decreasing biodiversity. Mean annual temperature will increases between 1°C and 6°C by 2100, causing sea level to rise by 90 cm and changes in weather patterns (droughts, floods, storms). The global per capita arable land area of 0.23 ha will decrease to 0.14 ha in 2050, fresh water supply will decrease to the scarcity level in many countries and extreme forms of degradation will affect more than 300 million ha of agricultural land, particularly in countries where farmers cannot invest in soil restoration.

Challenges directly related to soil science are given below, together with some priority research areas[30]:

6.1.Soil erosion: Analysis of the chain of processes between the driving forces of erosion and ecological and socio-economic effects; Influence of land use and climate change, management, desertification,savannah and forest fires and snow melt; Application of soil information and remote sensing for risk assessment on different scales; Development of new conservation and remediation methods.

6.2.Soil organic matter and biodiversity: Definition of SOM in relation to soil functions and the potential to sequester C and N under contrasting environments; Development of standardized methods characterizing soil biodiversity; Effects of climate change and related land use and management changes, Relationship between biodiversity and soil functioning; Use of different scales from whole organisms to the protein and the functional (mRNA) level; Identification of combined management practices to optimize SOM and soil biodiversity.

6.3.Excess fertilization: Identification of driving forces on excess fertilization with N and P and quantification of their ecological and economic effects; Definition of environmentally friendly levels of livestock densities; Optimization of methods for adapting the N and P fertilization to the crop nutrient demand; Combination of mineral and organic fertilizers in view of optimum SOM conditions.

6**.4.Soil contamination:**Identification and quantification of contamination sources (geogenic and anthropogenic);Improving methods for measurement of air-born contaminants,Investigation of the route of entry, the fate and the long-term behaviour and identification of potentially dangerous and new substances in the soil-plant-sediment-water system;Bioavailability of contaminants for humans, animals, plants and soil organisms; Risk assessment for outputs from soil; Improvement of techniques for remediation of contaminated soil.

6.5.Soil sealing:Effect on the water and matter flow in urban, suburban and rural areas; Impacts on local, landscape and global level;Establishment of a nomenclature to be applied for regions or countries; Establishment of methods to survey sealing with respect to area quality and quantity.

6.6.Soil compaction:Analyses of compaction effects on soil quality;Definition of soil conditions which are sensitive to compaction;Assessment of trends in agricultural machinery causing deep reaching compaction; Implementation of methods for predicting stress transmission and soil deformation; Development of management tools to reduce soil compaction.

_ 6.7.Soil alkalinisation: Assessment under different climate, soil management and irrigation water quality; Investigation of the factors which make a soil sensitive to salinization/ sodification; Influence of different water flow conditions (matrix and preferential flow) on alkalinization; Investigation of the (ir)reversibility of soil degradation processes caused by alkalinization; Identification of indicators for alkalinization and changes of soil structure and hydrology; Interrelationships between alkalinization and desertification and strategies for salt reclamation[31].

VII. CONCLUSION

Environmental deterioration can leave people as "environmental refugees"—people who are displaced due to environmental degradation, including deforestation, sea-level rise, expanding deserts, and catastrophic weather events. Red Cross research shows more people are now displaced by environmental disasters than by war.

Problems will aggravate with the rapidly increasing world population unless adequate measures of control are taken. Therefore, multidisciplinary cooperation of soil scientists with geological, biological, physical, toxicological, hydrological, geographical, geo-information, engineering, social, economic and political sciences is essential. Policy makers are finally requested to develop rational land use and management policies including anti-degradation measures. Several international documents are existing with respect to soil protection, e.g. the World Soil Charta of the FAO (1981), and the Agenda 21 (chapters 10 to 14) of the UN Conference in Rio de Janeiro (1992). The EU is currently developing a Thematic Strategy on Soil Protection as part of the 6th Environment Action Programme which is to be adopted in spring 2006 (European commission, 2004). However, as long as these texts are restricted to recommendation character, they will show limited success.

REFERENCES

[1] Sposito, G., and W. A. Jury. 1985. Inspectional analysis in the theory of water flow through soil. Soil Sci. Soc. Am. J. 49(4):791-797.

[2] *Rattan Lal,Manoj K.Shukla,"* Principles Of Soil Physics", *The Ohio State University Columbus, Ohio, U.S.A.,* **Isbn: 0-8247-5324-0.**

[3]BAKER, L., & ELLISON, D., 2008. Optimisation of pedotransfer functions using an artifi-cial neural network ensemble method. Geoderma. **144.** (1–2) 212–224.

[4] M. *Th. van Genuchten*, New Issues and Challenges in Soil Physics Research, Volume 1: Inaugural and State of the Art Conferences pp. 5-27.

[5]BABAEIAN, E., HOMAEE, M., MONTZKA, C., VEREECKEN, H. & NOROUZI, A. A., 2015. Towards retrieving soil hydraulic properties by hyperspectral remote sensing. Vadose Zone Journal. **14.** (3) doi: 10.2136/vzj2014.07.0080.

[6]BAKER, L., & ELLISON, D., 2008. Optimisation of pedotransfer functions using an artifi-cial neural network ensemble method. Geoderma. **144.** (1–2) 212–224.

[7] Richards, L. A. 1931. Capillary conduction of liquids in porous mediums. Physics 1:318- 333.

[8] Russo D., E. Bresler, U. Shani, and J. C. Parker. 1991. Analysis of infiltration events in relation to determining soil hydraulic properties by inverse problem methodology. Water Resour. Res. 27(6):1361-1373.

[9] Wood, E. F. 1991. Global scale hydrology: Advances in land surface modeling. Rev. of Geophys., Vol. 29, Supplement, pp. 193-201.

[10] Hillel, D. 1993. Unstable flow: A potentially significant mechanism of water and solute transport to groundwater. In: D. Russo and G. Dagan (cds.), Water Flow and Solute Transport in Soils, pp. 123-135, Springer Verlag, New York, NY.

[11] Nielsen, D. R., P. M. Tillotson, and S. R. Vieira. 1983. Analyzing field-measured soilwater properties. Agric. Water Manage. 6(1):93-109.

[12]https://www.epa.gov/acidrain/effects-acid-rain.

[13]https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex13331

[14]http://www.wamis.org/agm/meetings/anadia06/Sivakumar_Overview.pdfss.

[15]https://www.conserve-energy-future.com/causes-effects-solutions-of-desertification.php

[16] https://www.researchgate.net/publication/301542254.

[17] Gergely Tóth et.al,"**Threats to Soil Quality in Europe"2004.**

[18] Doran, John W., "Soil health and global sustainability: translating science into practice" (2002). Publications from USDA-ARS / UNL Faculty. 181.

[19] Doran, J.W., Sarrantonio, M., Liebig, M., 1996. Soil health and sustainability. In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 56, Academic Press, San Diego, CA, USA, pp. 1–54.

[20] Matson, P.A., Parton, W.J., Power, A.G., Swift, M.J., 1997. Agricultural intensification and ecosystem processes. Science 277, 504–509.

[20] Harris, R.F., Karlen, D.L., Mulla, D.J., 1996. A conceptual framework for assessment and management of soil quality and health. In: Doran, J.W., Jones, A.J. (Eds.), Methods for Assessing Soil Quality. Soil Sci. Soc. Am. Spec. Publ. # 49. SSSA, Madison, WI, USA, pp. 61–82.

[21] Power, J.F., 1996. Requirements for a sustainable agriculture for the next generation. In: Nath, B., et al. (Eds.), Proceedings of the International Conference on Environmental Pollution, Vol. 1. Held 15–19 April, 1996 in Budapest, Hungary. Publ., European Centre for Pollution Research, University of London,
London E1 4NS, UK, pp. 92–98.

[22] Romig, D.E., Garlynd, M.J., Harris, R.F., McSweeney, K., 1995. How farmers assess soil health and quality. J. Soil Water Conserv. 50, 229–236.

[23]Romig, D.E., Garlynd, M.J., Harris, R.F., 1996. Farmer-based assessment of soil quality: a soil health scorecard. In: Doran,
J.W., Jones, A.J. (Eds.), Methods for Assessing Soil Quality. Soil Sci. Soc. Am. Spec. Publ. # 49. SSSA, Madison, WI, USA, pp. 39–60.

[24] Vitousek, P.M., Aber, J.D., Howarth, R.W., Likens, G.E., Matson, P.A., Schindler, D.W., Schlesinger, W.H., Tilman, D.G., 1997. Human alteration of the global nitrogen cycle: sources and consequences. Ecol. Appl. 7, 737–750.

[25] Spangenberg, J. H., Görg, C., Truong, D. T., Tekken, V., Bustamante, J. V., and Settele, J.: Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies, International Journal of Biodiversity Science, Ecosystem Services & Management, 10, 40–53, 2014.

[26] McBratney, A. B., Santos, M. L. M., and Minasny, B.: On digital soil mapping, Geoderma, 117, 3–52, https://doi.org/10.1016/S0016-7061(03)00223-4, available at: http://www.sciencedirect.com/science/article/ B6V67-496FTGD 1/2/81065d61583bf2273a3e4deb685f6c61, 2003.

[27] Wall, D. H., Bardgett, R. D., and Kelly, E.: Biodiversity in the dark, Nat. Geosci., 3, 297–298, 2010.

[28]David S. Powlson Agriculture and Environment Division, Rothamsted Research, Harpenden, Herts. AL5 2JQ, United Kingdom,

[28] Rolf Nieder ,Institute of Geoecology, Braunschweig Technical University, Langer Kamp 19c, 38106 ,Braunschweig, Germany.

[29]Benbi, D.K. and R. Nieder (eds.), 2003. Handbook of processes and modeling in the soil-plant system. Haworth Press, New York, pp. 762. European Commission (eds. L. Van-Camp, B. Bujarrabal, A.R. Gentile,

[30]R.J.A. Jones, L. Monatanarella, C. Olazabal, S.K. Selvaradjou), 2004. Reports of the technical working groups established under the thematic strategy for soil protection, Volume I, Introduction and executive summary.

[31]Lal, R. (ed.), 2002. Encyclopedia of soil science. Marcel Dekker, New York. Sumner, M.E. (ed.), 2000. Handbook of soil science. CRC Press, Boca Raton.

[32]BAKER, L., & ELLISON, D., 2008. Optimisation of pedotransfer functions using an artifi-cial neural network ensemble method. Geoderma. **144.** (1–2) 212–224.

[33]AIMRUN, W., & AMIN, M. S. M., 2009. Pedo-transfer function for saturated hydraulic conductivity of lowland paddy soils. Paddy and Water Environment. **7.** (3) 217–225.