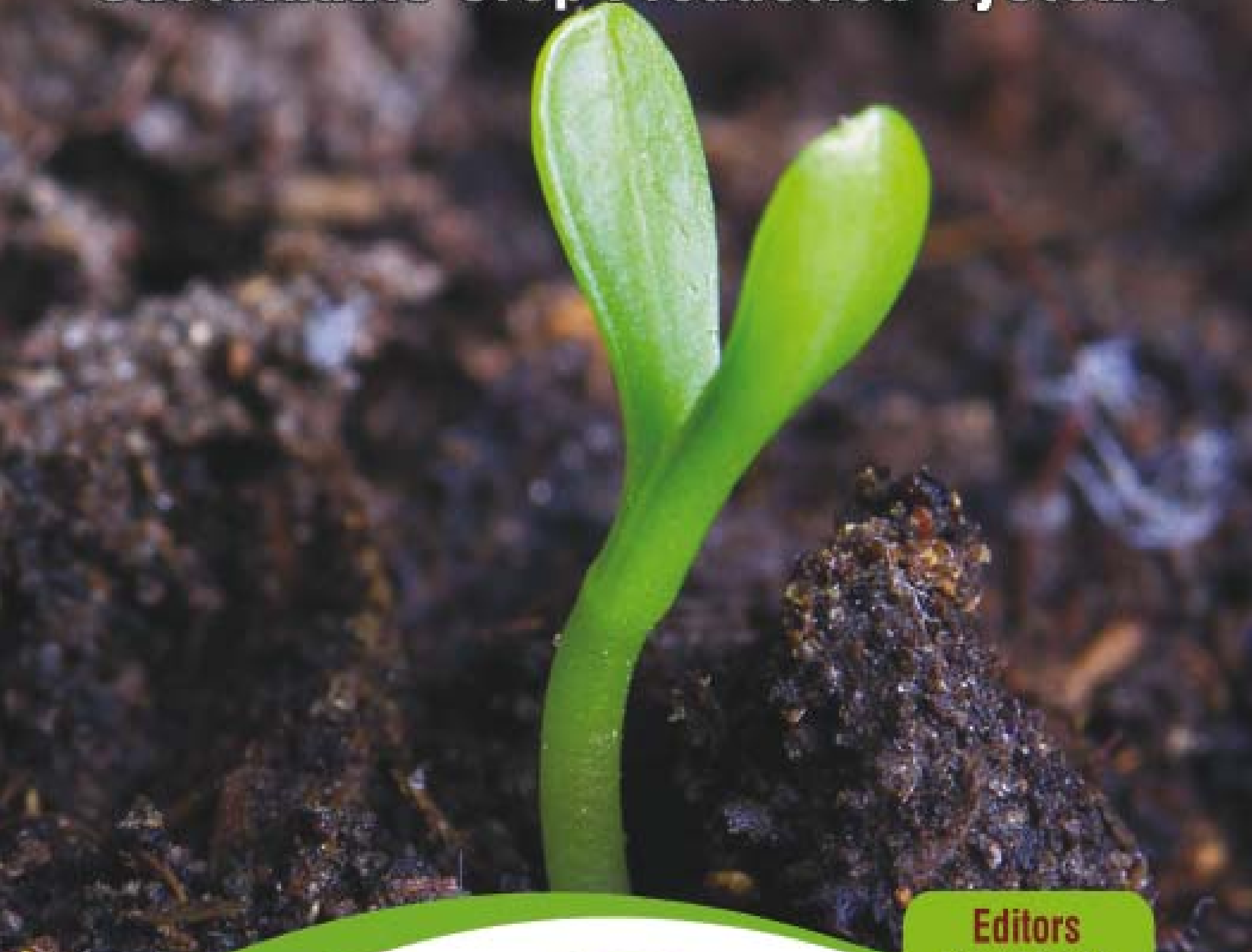
Soil Pollution Management for Sustainable Crop Production Systems



Editors

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SOIL

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Preface

Soil is a vital component for human existence. Going by the general rule, a healthy soil encompassing optimum physical, chemical and biological properties, can only contribute to sustained crop productivity and therein to a healthy society. Sustainable management of soil involves the improvement of productivity of soil by the alleviation of constraints involving site specific management practices and thereby contributing towards the enhancement of soil quality.

In the wake of the present day input intensive agriculture, more pressure is there on the soil to reap the maximum from the limited area. Conserving the soil health also include measures to alleviate the pollution hazards arising out of faulty agricultural practices, over usage of plant protection chemicals, indiscriminate use of fertilisers. These practices will deteriorate soil quality, decrease soil biodiversity and will ultimately affect the crop productivity. Moreover, the pollutants by way of the bio geo chemical cycling may enter into the food web and result in the bio accumulation of these compounds. Hence it is the need of the hour to formulate appropriate management strategies to combat soil pollution. Pollution mitigation strategies include agronomic methods, bioremediation techniques, utilization of beneficial microbes and imposition of suitable regulatory measures.

The compilation on 'Soil pollution management for sustainable production system' present an outline of the aspects such as our soil resources, various aspects of soil health management, causes, effects and management strategies of soil pollution, climate change, role of coconut based cropping systems on sustaining soil health and aspects related to pests and diseases.

We express our sincere gratitude to all the contributors of articles, stake holders of the project *"Enhancing economic viability of coconut based land use system for land use planning in Kerala"* and to the Kerala State Planning Board for funding the publication.

Editorial Team

SOIL HEALTH MANAGEMENT YESTERDAY, TODAY AND TOMORROW: A KERALA PERSPECTIVE

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Soil health can be defined in simplest form as the capacity of soil to meet its ecological functions in the environment it exists. So soil health can mean different qualities in different environments. It is beyond the scope of this short discourse to delve on global concerns of soil health. Hence the discussion is restricted to soil health in Kerala experiencing hot, humid tropical climate and ecosystem conditioned by tropical environment.

Land and soils of Kerala

Kerala, though a narrow strip of land along the sea coast on the south-west of Deccan Plateau, presents large diversity of landforms, soils and plant communities. The land mass of the state is flanked on the east by mountains and highland plateaus and on the south by Arabian sea. Between the sea and mountains we find nearly level sandy plain dotted with marshes and wetlands, laterite midlands and sloping foot hills reaching to highland plateau. The geomorphic surfaces of present day Kerala, formed after the uplift of Western Ghats, had been largely by peneplanation and head ward erosion by the numerous rivers formed to drain the enormous precipitation from monsoons. Whereas the ribbon valleys of midlands are formed by colluvial and alluvial deposits, the coastal alluvium and sandy plain are contributed by alluvio-marine sedimentation process.

Major types of soils found in the state are sandy soils of coastal plain, potential acid sulphate soils of coastal low lands, laterite soils of midlands, foothills and high lands, and limited areas of base rich Alfisols and Vertisols. Laterite soils cover ninety per cent of the upland area of the state. They are formed by intense physical, chemical and biological weathering of rocks and sediments, conditioned by the prevailing high temperatures and precipitation. Soil forming process is loss of bases and silica from primary minerals of acid, igneous rocks and residual enrichment with oxides of iron and aluminium and resistant minerals like quartz. The highly weathered laterite soils are depleted of much of the basic cations calcium, magnesium, and potassium and enriched with aluminium ions. Low activity kaolinite is the dominant clay mineral. When low in organic matter, these soils have abysmally low cation exchange capacity and low reserves of exchangeable cations. However, it is paradoxical that despite the soils being inherently very low in fertility, the state remains very green and the biomass productivity is substantially high compared to other parts of the country. This is made possible by the high temperatures, precipitation, intense biological activity and nutrient recycling by deep rooted natural vegetation which draw nutrient cations from deeper soil layers and efficiently accumulate and recycle through organic matter rich surface soil layers.

Agriculture in Kerala

Three general stages of land use and agriculture can be distinguished in the state.

1. Traditional agriculture, till 1960's.
2. Green revolution era
3. Post Green Revolution era.

Traditional agriculture started from pre-historic times in Paleolithic, Mesolithic and Neolithic ages, passed through metallic ages and culminated with settled agriculture and improvements thereon. Pre-historic and historic agriculture consisting mainly of hunting and gathering changed to settled agriculture, starting some 12000 years ago with the use of metallic tools and domestication of animals.

Hunting and gathering/Slash and burn agriculture/Plough Agriculture/ Oxen-plough agriculture/Class structured agriculture.

Cheran (Tamilakam) historical accounts of 4/5 century AD described settled, class structured agriculture in land area described by present Kerala State: land holders, lease holders, and tillers. The ecological conditions in the region lead to loosely organized and dispersed settlement patterns in difference to other parts of the country, and agrarian systems that resembled European Feudalism. Initial settlements were in coastal areas and fertile valleys along the river courses where low lands were cultivated to rice and uplands coconuts, fruit and tuber crops. Homesteads that meets that meet all food demands was an important aspect of traditional agriculture. Cash crops or plantation crops were rare until 1500 AD. Main commercial crop products and traded commodities were spices. European colonizers introduced many climatically suited crops from elsewhere in the world and many established well in Kerala. They included cashew, tapioca, tea and coffee. Bringing all the possible lands under rice could not meet the food demand of the growing population in the state. Extensive cultivation of tapioca and other root crops in uplands greatly helped meet the deficit and kept famines at bay. Plantations of cashew were established in mid lands and foot hills and coffee, tea, pepper and cardmom were established by British colonists in high lands during 16 to 19th century. Rubber plantations were established extensively in mid lands and foot hills from second half of 19th century into the 20th century, driven by industrial demand. Severe food deficit encouraged large scale migration of population from central Kerala to northern Kerala and high ranges to bring more area under agriculture and plantation crops. Before the introduction of Green Revolution model of agricultural technology the traditional agriculture relied on selection of seeds based on yield traits, use of plough and other tillage implements for land preparation and management and organic manures.

Era of Green Revolution

The Green revolution model of agriculture technology was ushered in the state in 1960's and continued till the end of twentieth century. The model is primarily based on the use of high yielding crop varieties, chemical fertilizers (mainly N, P and K), pesticides, irrigation and mechanization of farming operations. We have developed many high yielding varieties of crop plants and imported seeds of HYV's from elsewhere. Many irrigation projects were commissioned and used to enhance productivity. Substantial increase in fertilizer and pesticide use was recorded, so also yield levels of crops. Extension of the new agricultural technology and intensification of agriculture was substantial in eighties and nineties, of the last century.

By mid nineteen nineties crop yields plateaued and in many instances started declining. The rice yield increased from its pre–green revolution level of 1.5 tonnes per ha to just 2.5 tonnes per hectare only. The area under rice which reached the level of 8 lakh hectares in 1970's declined to just around 2 lakh hectares by the turn of the century, driven by escalating costs and poor profitability. Further improvements in crop genetics or increasing external inputs failed to reverse the trend. Green revolution, in short, failed to take off in the state, despite all out efforts by the political leadership, scientific establishment and extension agencies.

Post Green revolution

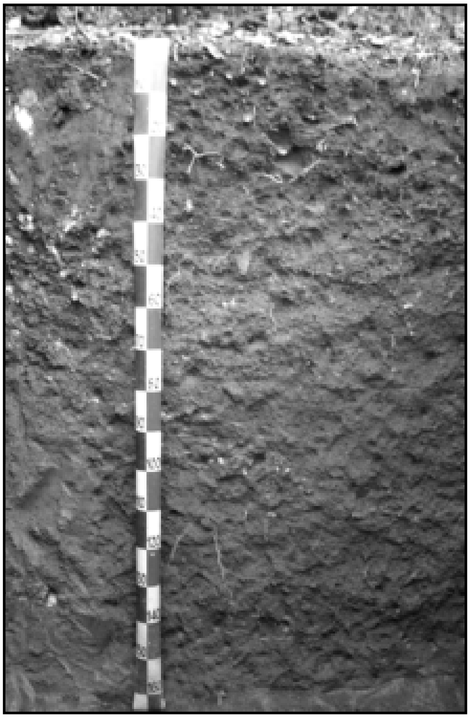
We can roughly reckon year 2000 as the start of post green revolution era. Disappointment with green revolution model, under achievement in many crop production systems and reported (or imagined) negative impact of on environment lead to either total negation of green revolution model or bringing in many changes: organic agriculture and integrated farming systems. However, very little effort was made in finding the real reasons for the failure the model in our state. Again, the socio-economic changes in the state and decline in dependence of agriculture as a means of livelihood reduced the impact of failure of green revolution model. The shift from green revolution model to INM practices, organic farming or zero budget farming etc too failed to make any dent in the agriculture scenario of the state: food shortages remained as it was and downward slide in productivity of most crops continue.

SOIL HEALTH

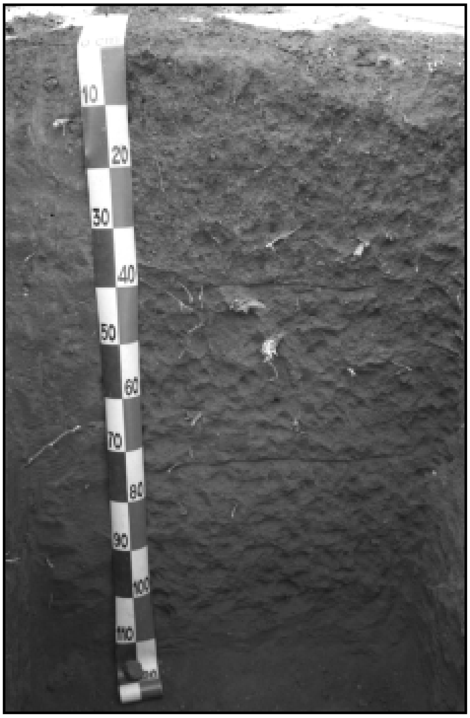
Soil health at its best, under humid tropical environment of the state, is realised in natural forests of the state. Soils under pristine forest lands with little or no anthropological interference are fertile, supporting large biomass production and very high biological activity. This is possible due to the high temperature and copious precipitation which encourages plant photosynthesis and biological activity through organic matter production. Deep rooted trees bring basic cations from deeper soil layers and retain them in the organic matter rich surface soils. The surface soil layers often contain around 5 per cent organic matter and therefore high cation exchange capacity and base saturation. The thick mass of surficial roots of tropical plant species absorb the nutrient minerals from percolating waters and prevent downward loss.

Any disturbance to the natural climax vegetation, conversion to managed forest plantations of single species, slash and burn agriculture, commercial plantations or tree or annual crop production can upset the system and degrade the soil. The changes that happen are loss of organic matter rich surface soil due to erosion or oxidation, loss of macro- and microbial bio diversity, leaching loss of basic cations, decline in cation exchange capacity of soil, soil acidification, development of toxic levels of Al in surface and subsoils, deficiency of plant nutrients and ultimately the decline in the capacity of soil to deliver eco-system functions. The expansion of agriculture in the state through traditional agricultural practice led to gradual decline in soil heath mainly through loss of fertile top soil. The green revolution model with focus soil management through NPK alone when adopted for use in the state did not take into consideration the inherently low fertility of laterite soils. Attention was focused only on input of NPK fertilizers with scant regard for addition of organic inputs or recycling of plant residues, and maintenance of adequate levels of organic matter in the low activity clay soils and input of liming materials to neutralise the acidity generated by inputs of nitrogenous fertilizers. Net result was rapid decline in soil health through acidification, loss of water and nutrient retention capacity, loss of bio-diversity and appearance absolute deficiencies of secondary nutrients calcium and magnesium and micronutrients boron and zinc. Development of strong surface and subsoil acidity meant soil environment favouring fungi to the detriment of beneficial bacterial strains. Acid soils are inhospitable to earthworms too. Suffice to say that decline in soil health was quite rapid in the green revolution era.

Can we regain the lost soil health? Though it is practically impossible to take the soil heath to the pristine condition, it can be regained to satisfactory levels through a combination of physical, chemical and biological means to enable soil meet its ecological functions. Physical restoration involves conservation of soil and water through appropriate means to retain whatever soil is remaining after the degradation process. Chemical methods are most important for the highly weathered laterite soils: amelioration of soil acidity, ensuring adequate availability of plant nutrients through external inputs (not only NPK, but secondary and micronutrients, in particular Ca, Mg, Zn and B), and amelioration of subsoil acidity through addition of gypsum. Biological means involve raising of crops that generate large biomass, recycling of all organic residues and thereby building organic carbon levels in the soil and zero or minimum tillage to reduce oxidation rate of organic matter. In short, simple solutions exist for maintenance of restoration of physical, chemical and biological heath of tropical highly weathered soils by virtue of good physical conditions offered by them.



Forest Soil



Cultivated soil

SOIL RESOURCES OF INDIA

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Introduction

India, blessed with a variety of geological formations, diversified climate, topography and relief have given rise to varied physiographic features. This extends from the snow clad mountainous peaks in the north, to the lengthy coasts in the Peninsula. The temperature varies from arctic cold to equatorial hot. This has resulted in a large variety of soils distinctly different from one another creating soil as a valuable resource of India (Fig.1). Many however think of tropical soils as the deep red and highly weathered soils, and are often thought are either agriculturally poor or virtually useless. Indian agriculture depends on the extent and quality of soils.

Different criteria have been applied to classify Indian soils, the outstanding being geology, relief, fertility, chemical composition and physical structure, etc. Any classification based on any one of the aforesaid criteria has its own inherent drawback. Even the most competent pedologist would find it difficult to present an accurate, complete, comprehensive and generalised account of the Indian soils.

Indian soils can be broadly classified into two main types geologically: (a) Soils of peninsular India and (b) Soils of extra-peninsular India. The soils that are formed directly from the underlying rocks, as a result of in situ decomposition are the soils of Peninsular India. These soils are transported and to a limited extend get re-deposited forming sedentary soils. The soils of the extra-peninsular India are found in the river valleys and deltas formed due to the depositional work of rivers and wind. These are very deep soils and constitute some of the most fertile tracts of the country. They are often referred to as transported or azonal soils.

The Indian Council of Agricultural Research (ICAR) set up an All India Soil Survey Committee in 1953 which divided the Indian soils into eight major groups. They are (1) Alluvial soils, (2) Black soils, (3) Red soils, (4) Laterite and Lateritic soils, (5) Forest and Mountain soils, (6) Arid and Desert soils, (7) Saline and Alkaline soils and (8) Peaty and Marshy soils. This is a very logical classification of Indian soils and has gained wide acceptance (Fig.2). A brief account of these eight soils is given as under:

1. Alluvial soils

These soils form the most important group of soils for agricultural production. Alluvial soils cover an area of 75 M ha, widely distributed in the Indo-Gangetic plains, and Brahmaputra valley. These are developed on alluvium, hence the name alluvial soils is given, irrespective of their place of occurrence and degree of profile development. The parent material of these soils is all of transported origin.

Alluvial soils occur mainly in the states of Punjab, Haryana, Delhi, Uttar Pradesh, Uttarakhand, Bihar, West Bengal, Assam and coastal regions of Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Gujarat.

Salient characteristics

- In general these soils are fertile, as these are inherently rich in plant nutrients. These contain sufficient P and K, whereas deficient in N and organic matter status.
- Variable in texture, as it depends on the source of parent material and their place of deposition.
- Some soils are fluvial in nature when derived from flood plain alluvium, classified under "Fluvisols"
- Soil reaction can be acidic or alkaline depending on the moisture and temperature regimes.
- Profile developments vary depending on the age of the alluvium and climatic conditions. These vary from least developed to well developed soils.

Great plain of India has both newer and younger alluvium called khadar and older called bhangar soils. The khadar soils are pale brown, sandy clays and loams, drier and leached, less calcareous and carbonaceous i.e. they are less kankary, are found in the low areas of valley bottom which are flooded almost every year. Bhangar, on the other hand, is found on the higher reaches about 30 metres above the flood level. It is of a more clayey composition and is generally dark coloured. A few metres below the surface of the bhangar are beds of lime nodules known as kankar. Alluvial fans with coarse, pebbly soils along the foothills of Shiwalik are known as Bhabar, to the south of which lies a long narrow strip of swampy lowland with silty soils known as Tarai, which are rich in nitrogen and organic matter but are deficient in phosphate.

In soil taxonomy, these soils are keyed out to either Entisols, Inceptisols, Alfisols, Mollisols, Ultisols and Aridisols.

2. Black (Cotton) soils

As the name suggests, these soils are very dark in colour and exhibit the properties of hard when dry and sticky and plastic on wetting. This imparts difficulty in cultivating these soils and their management. The occurrence of these soils is mainly in the central, western and southern states of India, covering an area of 72 M ha. These soils are comparable with the Grumusols of the USA. Their black colour is comparable with the Chernozems of Russia and Prairie soils of the USA, but, significantly different in their physico-chemical properties.

Typical black soils have characteristic shrink-swell nature and are developed on basaltic material (rock or alluvium) under different climatic conditions varying from semi-arid to sub-humid. These soils are rich in clay content, dominated by smectite contributing to the expansion and contraction resulting in a churning process in the pedon. This causes a vertical mixing in deep soils resulting in the development of deep (>50 cm) and wide (>1 cm) cracks, gilgai micro relief, pressure faces and/or closely intersecting slickensides.

Salient characteristics

- These soils are rich in clay content (ranging from 30 to 80 %). Smectitic clay dominates, ensuring higher CEC (30-60 cmol (+) kg-1 of soil) and swell-shrink properties.
- Soil reaction varies from 7.8 to 8.7, reaching 9.5 under sodic conditions and low in N, P and organic matter content. Potassium content varies and usually remains less than 0.5 percent.
- Better in water holding capacity and nutrient retention due to the higher clay content.
- Highly sticky and plastic nature poses problems in cultivation and inter cultural operations and makes it almost impossible to work on such soils.
- Dark colour could be attributed to clay-humus complexes and/or the presence of a small proportion of titaniferous magnetite or iron pyrites like black constituents of the parent rock.

These soils are called as Regur (derived from Telugu word Regudu), Karail in lower Gangetic Basin in U.P. and Bhal in Gujarat. These soils are mainly found in Maharashtra, Madhya Pradesh, parts of Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu. Black soils are reported also from Kerala, Jammu and Kashmir, Andaman and Nicobar Islands and Indo Gangetic Plains (Ray et al., 2006). The fluvial deposit by rivers contributes towards the occurrence of shrink–swell soils in Kerala. The presence of such soils in Jammu and Kashmir may be due to the presence of basic rocks in the complex rock system in the Himalayan regions (Bhattacharyya et al., 2013).

These soils were keyed out to order Vertisols and Inceptisols of vertic intergrades. However, recent studies showed that a group of soils to other soil orders show linear extensibility (LE) of 6.0 cm or more, which is a property of black soils due to the presence of smectitic clays allocating them to vertic sub-group (Soil Survey Staff, 2006). A few vertisols and vertic intergrades have red colour, indicating the use of Vertisols for all black soils as technically wrong (Bhattacharyya et al., 2013).

3. Red soils

These soils form the third most important group of soils in the world. In India, red soils occur mainly in the southern parts of the Indian peninsula, comprising the states of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Orissa and Goa and in northeastern states covering an area of 70 M ha. These soils have developed due to the weathering of crystalline and metamorphic rocks leaving the less mobile elements like silica, iron and alumina behind. These form sesqui-oxides under oxidized conditions forming Fe-oxides and Al-oxides imparting red colour to the soils, and hence the name Red soils. The climatic conditions favouring their development in India are hot semi arid to humid subtropical climate. In Andhra Pradesh, Telangana, Tamil Nadu, Madhya Pradesh and Karnataka, the red and the black soils occur under similar bioclimatic conditions, but on different parent materials and landforms. The red soils develop on igneous (acidic) rock and occupy higher topographic positions whereas the black soils develop on basalt (basic) rock or on alluvium derived from basalts, and occupy relatively-lower topographic positions on the landscape.

Salient characteristics

- These soils are red to yellowish in colour with hues 7.5 YR or redder in 25-150 cm depth of soil.
- Highly variable in texture, well to excessively drained, depending on the topographic position and texture, shallow to very deep, poor gravelly to fertile in the uplands to the plains and valleys.
- Soil reaction, in general, is neutral to acidic depending on the content of iron oxides and lower base saturation than black and alluvial soils.
- Soils are poor in N,P,K, lime and organic matter contents
- These soils dominate in Kaolinite (1:1) clay mineral
- Silica to sesqui-oxide ratio varies from 2.5 to 3.0, the amounts of iron and aluminium are very high (30-40 %)

These soils are keyed out to orders Alfisols and Ultisols (when the soils are well developed and with high and low base saturation, respectively) and Entisols (very shallow and crusty soils) or as Inceptisols (moderately developed soils).

4. Laterite and Lateritic soils

Laterite and lateritic soils cover an area of about 40 Mha. Laterite soils are formed mainly in tropical regions with heavy rainfall and high temperature experiencing alternate wet and dry seasons. These soils are found mainly on hill tops and plateau landforms of Orissa, Kerala, Tamil Nadu and cover an area of about 40 Mha. This term "Laterite" was initially used by Buchanan in 1807 for the ferruginous, vesicular and unstratified material found in the Malabar region of Kerala in the southern India. The process of formation of laterites takes place when the siliceous matter is leached away almost completely during the weathering on wetting the soil leaving behind the sesqui-oxides. On drying these are converted into irreversible iron and aluminium oxides. The soils thus formed are rich in sesqui-oxides but poor in base saturation and primary silicate minerals.

Lateritic soils do not require alternate wet and dry conditions for their formation and ground water level not very near the surface. These soils are mainly occurring in the states of Maharashtra, Andhra, Karnataka, Tamil Nadu and North-Eastern region.

Salient Characteristics Laterite soils

- Laterite soils are poor in base content with silica-sesquioxide ratio lesser than 2
- These possess hues 5 YR or redder with maximum intensity in the B-horizon
- Predominant in kaolin clay mineral
- Low in CEC (<16 cmol (p+) kg-1 soil) and base saturation (<40 %) Lateritic soils
- These soils have higher silica-sesqui-oxide ratio (>2) and high base saturation (>40 %)
- Kaolinite is the dominant clay mineral along with occasional presence of gibbsite

These soils are poor in their fertility status, with soil acidity and Al toxicity as major constraints hindering crop growth. Advantage of these soils is that it can be easily cut with a spade but hardens like iron when exposed to air contributing to its unique distinction of providing a valuable building material. As it is the end- product of weathering, it cannot be weathered much further and is indefinitely durable. Most of these soils key out in the order Ultisols (Chandran et al., 2005).

5. Desert (Arid) soils

These soils may be developed under cold or hot temperature regime. A large tract of hot arid region with length of growing period (LGP) < 60 days in a year or soils remaining dry more than 180 consecutive days is situated in the north western states of Gujarat, Haryana and Punjab covering an area of 29 M ha and pose desertic conditions of geologically recent origin. This is different from that of cold arid region such as those found in Leh, Ladakh regions in the North and from the tropical region of Andhra Pradesh and the south of Karnataka.

These soils are developed due to the aeolian deposition of sand resulting in poor profile development. The desert soils consist of aeolian sand (90 to 95 %) and clay (5 to 10 %).

Salient characteristics

- Desert soils are sandy to loamy fine sand in texture with very less clay content varying from 5 to 10 per cent.
- Soils, in general, are poor in nutrient and water holding capacity
- Soil reaction is alkaline due to its calcareous nature. In some cases, the soils are gypsiferrous forming a gypsic horizon

In the soil taxonomy, these soils qualify for Aridisols and Entisols.

6. Forest and Hill soils

Those soils developed under any forest cover are designated under this type of soils. In India, the total area under different forest species (tropical, deciduous, coniferous, tropical evergreen) is estimated to be 75 M ha and is observed dominantly in the states of Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh, Uttaranchal, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Kerala, Tamil Nadu, North-eastern states and Andaman Nicobar Islands. The topography and kind of forest control the nature of soils and their degree of profile development. Major soils under different forest areas include Brown forest and Podzolic (In northern Himalayas) and Red and lateritic (In Deccan Plateau). Brown forest soils are developed on sedimentary rocks and/or alluvium under sub-humid to humid climate and mixed vegetation. Podzolic soils are mainly found under coniferous vegetation in the presence of acid humus and low base status.

Salient characteristics Podzolic soils

- These soils are moderately to strongly acidic in reaction (pH 4.5-6.0).
- Rich in organic matter content but poor in base status (<50 %).
- Clay ranges between 20 and 30 per cent and low CEC (10-15 cmol (+) kg-1 of soil).

Brown forest soils

- These soils are neutral to slightly acidic in reaction (pH 6.0-7.0).
- Moderate to high in organic matter content and CEC (15-20 cmol (+) kg-1 of soil).
- Rich in bases (70-90 %).

These soils are keyed out as Inceptisols and Mollisols on stable landforms and as Entisols on steep slopes and eroded places. The north facing slopes develop into Alfisols and Inceptisols and the south facing slopes develop into Mollisols and Inceptisols (Sehgal, 2009).

7. Salt Affected Soils

Salt affected soils contain considerable amounts of soluble salts and/or sodium on the exchange complex. They occur in arid and semi-arid regions where potential evapotranspiration greatly exceeds precipitation.

According to the estimates of the Central Soil Salinity Research Institute (CSSRI), Karnal (Haryana), such soils occupy about 10 Mha, of which 7 Mha is sodic in nature and occurs in the Indo-Gangetic Plain, followed by black (cotton) soils in the Deccan (Peninsula) Plateau and the rest, largely occurring in the semi-arid and arid coastal regions, are saline. The worst affected states include Gujarat, Rajasthan, U.P., Haryana and Bihar (for sodicity), and the coastal region (for salinity).

8. Peaty and marshy soils

Peaty and marshy soils refer to the soils that have developed in the low-lying coastal marshy land or to the soils confined to depressions caused by dried lakes in the alluvial and coastal plain areas, formerly occupied by mangrove swamps. These soils are dominantly observed in the coastal inter-tropical lowlands. In India, they occur in localized pockets in the states of Kerala, Orissa, Sunderbans in West Bengal, Goa, South-Eastern Tamil Nadu and NE states where they are mostly associated with mangroves forest vegetation.

Peaty soils originate in humid regions as a result of accumulation of large amounts of organic matter in the soils. These soils contain considerable amount of soluble salts and 10-40 per cent of organic matter. Soils belonging to this group are found in Kottayam and Alappuzha districts of Kerala where it is called kari.

Marshy soils with a high proportion of vegetable matter also occur in the coastal areas of Orissa and Tamil Nadu, Sunderbans of West Bengal, in Bihar and Almora district of Uttaranchal. The peaty soils are black, heavy and highly acidic. They are deficient in potash and phosphate. Most of the peaty soils are under water during the rainy season but as soon the rains cease, they are put under paddy cultivation.

Soil orders

Based on soil classification, the major soil orders in India are Vertisols, Mollisols, Alfisols, Ultisols, Aridisols, Inceptisols and Entisols. Fig. 3 represents the major soil orders and their extent in India. Soils of India occur in five bio-climatic systems but only a few soil orders are found in more than one bio-climate.

Vertisols belong to arid hot, semi-arid, sub-humid and humid to per-humid climatic environments (Pal et al., 2009). Mollisols belong to sub-humid and also humid to per-humid climates (Bhattacharyya et al., 2006). Alfisols and Ultisols belong to humid to per-humid climates (Chandran et al., 2005). Both Entisols and Inceptisols belong to all the five categories of bio-climatic zones of India and Aridisols belong mainly to arid climatic environments (Bhattacharyya et al., 2008). This base line information indicates that except for the Ultisols and Aridisols, the rest five soil orders exist in more than one bio-climatic zones of India. The absence of Oxisols and Ultisols occupying only 2.56 per cent of total geographical area of the country, suggest that soil diversity in the geographic tropics in general and in India in particular, is at least as large as in the temperate zone (Eswaran et al., 1992).

Indian soils- Recent progress in knowledge

a) Alfisols

Presence of high altitude Alfisols in the humid tropical climate

The humid tropical climate characterized by the high temperature and adequate moisture resulted in Kaolinite/ oxidic mineral composition than the parent rock effect of Deccan Basalt, contributing to the development and persistence of ferruginous Alfisols in the climate (Bhattacharyya et al., 1999).

Alfisols/Ultisols in the humid tropical climate

These soils are dominantly clayey and clay skins are rarely identified in the field in the northeastern parts of India. Whereas, clay skins are noticed in the soils in the Western Ghats showing evidences of clay translocation and accumulation (Bhattacharyya et al., 1999).

Distribution of clay as a function of depth was noticed in the Ultisols of Arunachal Pradesh, emphasizing the formation of fairly well developed soils. There was an increase in clay with depth especially $>$20 per cent clay in the subsurface argillic hortizon than the surface horizon in these soils (Bhattacharyya et al., 1998).

Alfisols of Southern Peninsula

The physical and chemical properties of Alfisols occurring in the Peninsular and extra-Peninsular areas in India differ. The soils of Peninsular gneiss are formed on very old landscapes on old rock system of earth, hence represents ancient soils. These soils exhibit an increase in its clay content with depth ignoring the thin Ap horizon. These Alfisols possess a well developed argillic horion with >30 per cent clay. The illuviation of clay has resulted in such a clay deposition as a result of the humid past. This area presently has a semi-arid climate. However, the depth distribution of clay is a clear indication of truncation of soil profile developed in the past as a result of humid tropical climate (Pal et al., 1989 & 2012). This has resulted in a unique spatially associated red-black soil complex in many parts of southern and western India (Pal et al., 2012)

Alfisols in the Indo-Gangetic Plain(IGP)

Clay increases with depth in most of the Alfisols of the IGP indicating fairly well developed soils. However clay cutans are not seen in the field in IGP soils despite more than 30 per cent increase in clay in the Bt horizon. Difficulty in identifying clay skins in the clay-enriched Bt horizons is common in the IGP soils (Pal et al., 1994). However, thin sections of these soils do not show pure void argillans, but the presence of impure clay pedo-features provides incontrovertible evidences of clay illuviation in sodic environment (Pal et al., 1994 & 2003a & b).

b) Paddy soils

Hydromorphic paddy soils in HTC

Development of hydromorphic soils are resulted as a result of waterlogged flood plains due to the lower topographic positions. These soils are mainly paddy soils as seen in the valleys of Ganga, Brahmaputra and Tripura. In the regions of Godavari, Krishna and Cauvery delta, and certain command areas in black soil regions also have paddy as a crop, where it is grown in common black soils. These soils vary widely along and across the valley though the flood plains appear geomorphically alike. Due to the continuous or periodic submergence, these soils develop typical redoximorphic features (Soil Survey Staff, 2006) and are used for growing paddy.

Ganga Valley

These soils are alkaline in reaction, silty with some exceptions, high base saturation (100 % or more). This is due to the presence of Na-zeolite as in Itwa soils and Ca-zeolites as in Ekchari and Madhpur soils. The calculation of base saturation from the cation exchange capacity of soils and extractable bases (Ca and Mg by 1 N NaCl and Na and K by 1N ammonium acetate solution) provides clues for the presence of zeolites in soils. Most of these soils are in stable landscapes as evidenced by the clay illuviation in them (Bhattacharyya et al., 2013).

Brahmaputra Valley

These soils are almost neutral in reaction and have high ? pH, sandy in texture unlike soils of the Ganga valley (Bhattacharyya et al., 2004). This valley is covered by alluvium, which belongs to unconsolidated sediments of recent geologic age (Bloomn, 1979).

Tripura Valley

Typical hydromorphic clay-rich paddy soils occur in Tripura Valley (Aquepts: Inceptisols with aquic moisture regime). Paddy soils in Tripura are acidic in reaction due to the alpine to humid tropical climate of the northeastern region, low in clay, CEC and base saturation (Bhattacharyya et al., 2013).

Black soil region (BSR)

Paddy soils of this region are alkaline in reaction, rich in clay with high bases and CEC. This higher base saturation indicates presence of Ca-rich zeolites (Bhattacharyya et al., 1999). These soils are used for paddy in coastal Godavari region (Ray et al., 1997; Bhattacharyya et al., 2007b) and in Central India (Prasad et al., 2012) during rainy season. The presence of zeolites in these Vertisols make it suitable for paddy cultivation, and the non-zeolitic Vertisols of western and central India are kept fallow in the rainy season.

Soils in different zones of our country

India is divided into major zones, viz. northern, western, central, southern, eastern, north-eastern and islands (Bhattacharyya et al., 2013). The distribution of different soil orders in different climatic zones of India is represented in Fig.4.

Northern zone

This zone consists of six Indian states Uttar Pradesh (Undivided), Jammu and Kashmir, Himachal Pradesh, Punjab and Haryana) covering 20 per cent area of the country. Vertisols are reported only in UP among these six states, though shrink swell soils are reported in Jammu and Kashmir (Bhattacharyya et al., 2007a). Punjab and Haryana in the north western part showed the presence of a few Aridisols. Mollisols are reported from Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh (Undivided).

Western zone

The western zone consists of three states (Gujarat, Rajasthan and Goa) and covers 16.5 per cent area of the country. Aridisols dominate in Rajasthan. Interestingly, all the three states have Alfisols and Ultisols (later reported only in Goa). The present-day climate in Gujarat and Rajasthan does not permit the formation of these soils. The soils indicate a change of climate from wetter to dry regime.

Central Zone

The central zone consists of three states (Maharashtra, Madhya Pradesh including Chhattisgarh) and covers 23per cent area of the country. Madhya Pradesh (MP) has double the area under Vertisols compared to Maharashtra. Mollisols are reported from both MP and Maharashtra.

Southern Zone

The southern zone consists of five states (Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Puducherry & Karaikal) and covers 19.3 per cent area of the country. Occurrence of Vertisols in Kerala has been recently reported (Nair et al., 2006). Four southern states contain fertile Mollisols and support such occurrences in the humid tropical climate.

Eastern Zone

The eastern zone consists of five states (Bihar, Odisha, West Bengal, Sikkim and Jharkhand) covering 13 per cent area of the country. Vertisols have been reported from Bihar, Odisha and Mollisols from Sikkim. Occurrence of Vertisols and their intergrades have also been reported from West Bengal, Bihar and Odisha.

North-eastern Zone

The northeastern zone consists of seven states (Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya) and occupies 7 per cent area of the country. The northeastern zone is dominantly occupied by weathered soils like Alfisols and Ultisols. Expectedly higher elevation ranges of Arunachal Pradesh, Meghalaya and Manipur contain dominant proportions of Ultisols.

Islands

The islands consist of two Union Territories covering 0.2 per cent area of the country. Andaman and Nicobar islands have a considerable area under Mollisols other than the dominant Inceptisols and Entisols.

Indian tropical soils- The Potential

The tropical soils in India are well developed, deep soils that are highly weathered, red in colour and dominated by kaolinite and oxidic minerals usually.

In laterites of Kerala, keyed out to Ultisols possess mica, kaolin, gibbsite and hydroxy inter-layered vermiculite (HIV) too. These soils are similar to that of soils in the sub-humid northeastern states of India due to the presence of gibbsite indicating remnants of an earlier weathering cycle characterized by neutral to alkaline pedochemical environment (Bhattacharyya et al., 2000). Gibbsite has for a long time been considered an index mineral for advanced stage of soil weathering, as it was conceived to have formed from kaolinite. But such transformation appears improbable in acidic soil conditions because the desilication process is active only above pH 9 (Millet, 1970). However, presence of gibbsite in alkaline pedo environment is noticed in the Ultisols of the Shillong plateau in Meghalaya are formed in an alkaline pedo-environment (Bhattacharyya et al., 2000)

The model for understanding the formation of gibbsite, indicates two important points: (i) gibbsite is present as a remnant of an earlier alkaline pedochemical environment, and (ii) its formation even in the presence of a considerable amount of 2:1 minerals discounts the hypothesis of the anti-gibbsite effect (Jackson 1963 & 1964).

The presence of gibbsite in these soils should not, therefore, be considered as a conclusive proof of extreme weathering conditions of soils (Macias, 1981, Jenkins, 1985; Lowe, 1986). This fact assumes importance since Jackson's weathering index assigns gibbsite as a mineral with very high weathering index (WI 11). Because of the presence of gibbsite, Ultisols could belong to gibbsitic/allitic mineralogy class in soil taxonomy (Soil Survey Staff, 2006), but such classification fails to establish a legacy between the contemporary pedogenesis, mineralogy, use and management of these soils. The contemporary pedogenesis of Ultisols of Kerala (Considered to be international reference for laterite), does not include desilication and the transformation of 2:1 layer silicates to kaolinite and further to gibbsite. The study hints that the chemical transformation of Ultisols to Oxisols with time is difficult to reconcile as envisaged in the traditional model of tropical soil genesis (Chandran et al., 2005).

Conclusion

Soil is a non renewable resource with potentially rapid degradation rates and extremely slow formation and regeneration process. The variable factors influencing soil formation have resulted in a large variety of soils in India. The rich soil resources in India must be maintained and conserved in order to improve the agricultural production on a sustainable basis. Hence, conservation of our soil resources needs to be carried out besides improving soil health and soil quality. The focus must be on reclaiming the degraded lands and reducing the soil pollution to replenish and preserve resources for the generations to come. Thus Be the Solution to Soil Pollution.

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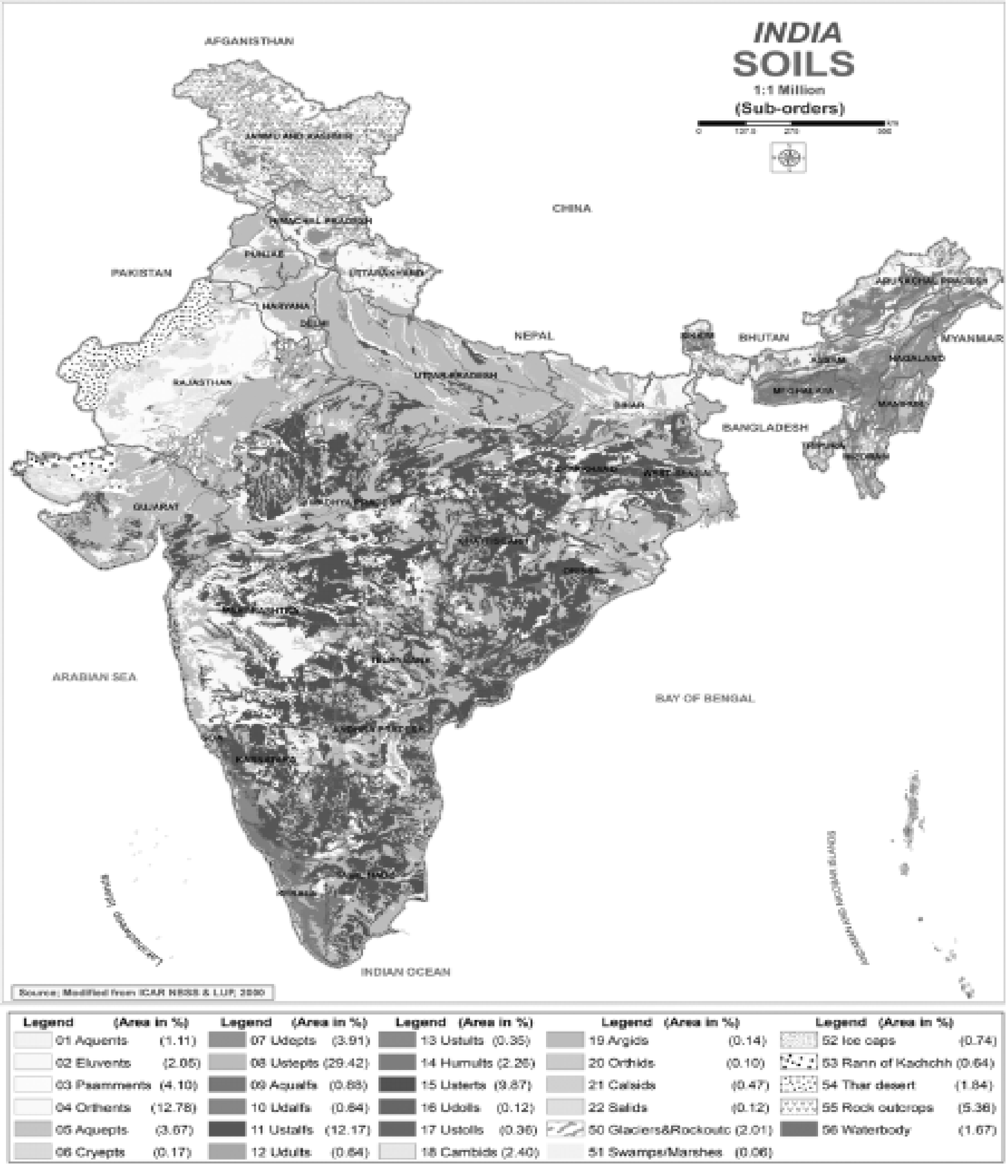

Fig.1 Soil map of India

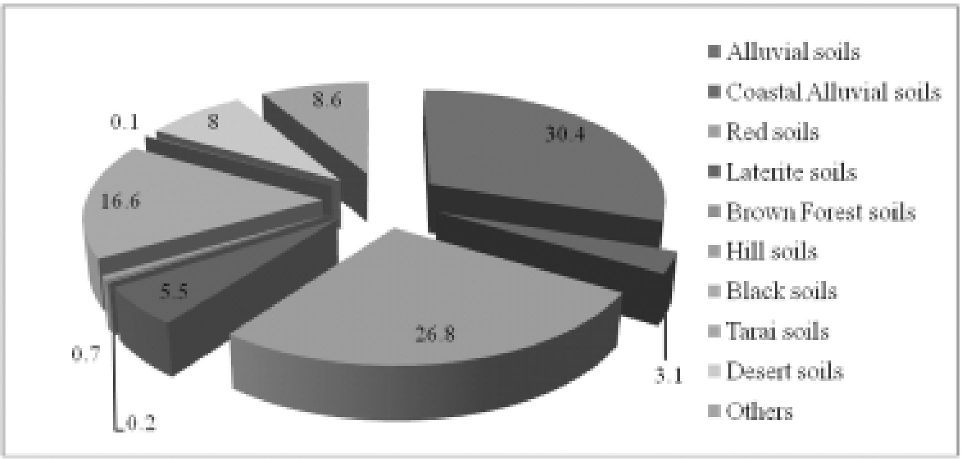

Fig.2 Major Soils of India (Value in %) (Bhattacharyya et al., 2013)

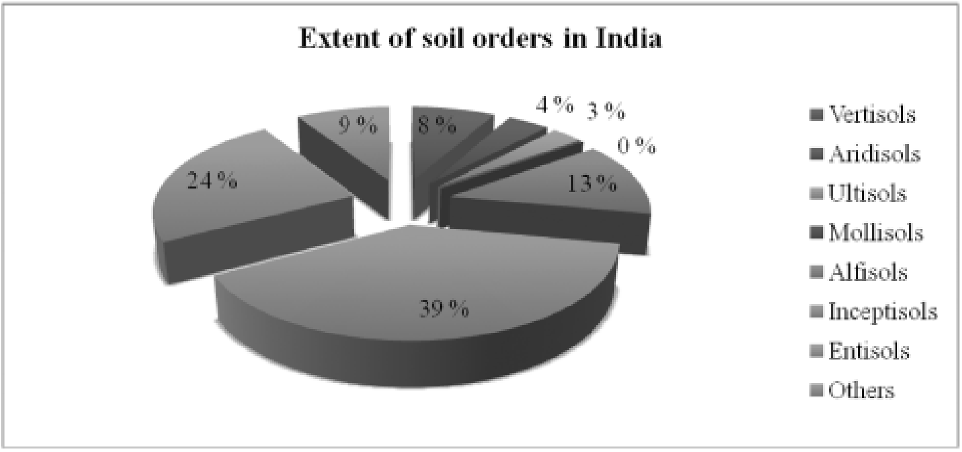

Fig.3 Major Soil orders and their extent in India (Bhattacharyya et al., 2013)

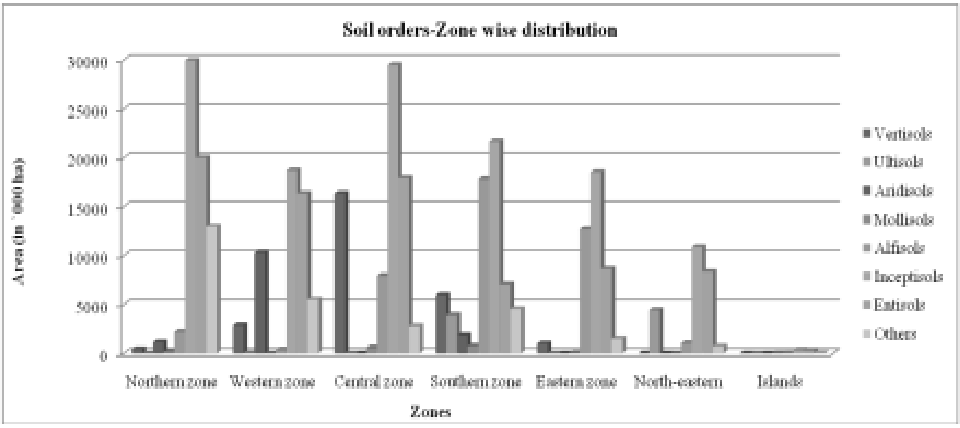

Fig.4 Climatic zone wise distribution of soil orders

SOIL POLLUTION, CAUSES, EFFECTS AND MANAGEMENT STRATEGIES

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Introduction

The present global population of 7.6 billion is expected to reach 9.2 billion by 2050, which owes approximately 32 per cent increase from the current population scenario. As per the reports from FAO, nearly all of this population expansion will occur in developing countries. Urbanization will continue at an accelerated pace, and about 70 percent of the world's population will be urban (compared to 49 percent today). Income levels will be many multiples of what they are now. In order to feed this larger, more urban and richer population, food production must increase by 70 percent. Hence growing population vis a vis, the challenges to maintain the food security to feed them is an alarming issue all through the globe. Food production from the limited land amidst urbanization and industrialization is hence becoming a handicap to sustainable agriculture.

One of the major amenities required for sustainable food production is a healthy soil with favorable physical, chemical and biological indicators. A farming system can be considered sustainable, if it ensures that "today's development is not at the expense of tomorrow's development prospects" (World Commission on Environment and Development, 1987). Soil forms the pivotal component of all farming systems. Hence soil resources have to be managed scientifically and systematically to meet the present and future needs.

But soil quality degradation is also occurring all over the world as a resultant of various anthropogenic factors as well as natural factors. The Status of the World's Soil Resources Report (SWSR) identified, soil pollution as one of the main soil threats affecting global soil productivity as well as to the ecosystems services provided by them.

Soil Pollution, a hidden danger under our feet

Soil pollution is an alarming issue as far as the sustenance of life on the planet earth. Soil pollution refers to the presence in the soil of a chemical or substance out of place and or present at a higher than normal concentration that has adverse effects on any non-targeted organism. As per the FAO report soil pollution is a dangerous phenomenon and should be of concern worldwide. The consequences of soil pollution have the potential to poison the food we eat, the water we drink and the air we breathe. The presence of certain pollutants may also produce nutrient imbalances and soil acidification. Soil pollutants can be those compounds which are naturally present or are being added to the soils by human interventions. Addition of pesticides and herbicides for agriculture, accidental leakage or spilling of chemicals such as gasoline and diesel, manufacturing processes, mining activities, chemical waste dumping and all are some of the man made activities contributing to soil pollution. However, the natural sources of pollution is due to the accumulation of compounds in soil due to imbalances between atmospheric deposition and leaching due to rainfall, or due to the natural production of certain compounds such as per chlorates. Hence we can see a diverse array of factors contributing to soil pollution and consequent degradation. This diversity, and the transformation of organic compounds in soils by biological activity into diverse metabolites, make soil surveys to identify the contaminants both difficult and expensive.

Types of soil pollution

Depending on the mode of entry of the pollutants to the soil, there are two types of soil pollution.

1. Point Source soil pollution
2. Diffuse soil pollution

Point Source soil Pollution

When the source of pollution emerges from a specific event or through a series of events within a particular area, in which the contaminants are released to the soil, and we can easily identify the source of pollution, it is referred as point source pollution. The pollutants dispensed out from the industrial units, over application of agrochemicals, mining and smelting activities, petroleum compound released from the oil and petroleum industries, all account for the point source pollution in soil. Pollutants from these sources can create risk to human health directly, apart from contaminating the soil.

Diffuse Pollution

If the pollution from the soil is spread over a wide area and is accumulated in soil and does not have a single and easily identified source, it is referred as diffuse pollution. Diffuse pollution occurs where emission, transformation and dilution of contaminants in other media have occurred prior to their transfer to soil (FAO and ITPS, 2015). As the diffuse pollution involves the transport of pollutants through air-soil-water systems, analysis of these components are necessary to assess the extent of pollution (Geissen et al., 2015). Some of the examples of diffuse pollution are sources from nuclear power and weapons activities, uncontrolled waste disposal and contaminated effluents released in and near catchments, land application of sewage sludge, the agricultural use of pesticides and fertilizers which also add heavy metals, persistent organic pollutants, excess nutrients and agrochemicals that are transported downstream by surface runoff, flood events and also atmospheric transport and deposition. Diffuse pollution has a significant impact on the environment and human health, although its severity and extent are generally unknown.

Sources of soil pollutants

The various sources of soil pollution either natural or manmade should be understood for evolving suitable management strategies to combat soil pollution.

1. Natural Sources of soil pollution

The parent material from which the soil is derived can be a source of soil pollution, as with the fact that volcanic releases are rich sources of arsenic (As). Also weathering of arsenic containing minerals and ores releases arsenic to the soil (Díez et al., 2009). Arsenic is slightly bioaccessible when coming from natural sources (Juhasz et al., 2007). Soils and rocks are also natural sources of the radioactive gas Radon (Rn). Radon diffusion from deeper layers to the surface is controlled, in part, by soil structure and its porosity (Hafez and Awad, 2016). High natural radioactivity is common in acidic igneous rocks, mainly in feldspar-rich rocks and illite-rich rocks (Blume et al., 2016).

Sometimes natural events such as forest fires and volcanic eruptions can cause natural pollution during which many toxic compounds such as dioxin like compounds (Deardorff, Karch and Holm, 2008) during which polycyclic aromatic hydrocarbons are released into the soil. Heavy metals such as mercury, chromium, copper, nickel and zinc are also released during volcanic activity. However, this natural pollution does not normally cause environmental problems due to the regenerative ability and the adaptation capacity of plants (Kim, Choi and Chang, 2011). The problems arise when the ecosystems are subject to external pressures, which alter their resilience and response ability. Polycyclic aromatic hydrocarbons (PAHs) can also occur naturally in soils originating cosmogenically or from the diagenetic alteration processes of waxes contained in soil organic matter. Biogenic production of PAHs is favoured under reducing conditions (Thiele and Brümmer, 2002). Naturally occurring asbestos (NOA) are fibrous minerals that occur in soils formed from ultramafic rock, especially serpentine and amphibole. The main risk associated with NOA is inhalation exposure of humans related to extraction activities, while its natural presence in soils poses a negligible risk to the environment. However, NOA can be easily dispersed by wind erosion, and their mobilization will depend on the characteristics of the asbestos-containing materials, soil properties, humidity, and local weather conditions (Swartjes and Tromp, 2008). The environmental issues caused by NOA arise when they are released from soils close to urban areas, because asbestos is a carcinogenic substance, posing a high risk to human health from inhalation (Lee et al., 2008).

2. Anthropogenic sources of soil pollutants

The main anthropogenic factors associated with soil pollution are the chemicals produced during industrial activities, domestic and municipal wastes, agrochemicals for plant protection operations, petroleum derived products. Heavy metals from anthropogenic activities are present in industrial sites (Alloway, 2013). Mining is another man made activity adding up to the woes of soil pollution. Mining and metal smelting activities add heavy metals and other toxic elements to the environment, which may persist for long periods (Ogundele et al., 2017). Toxic mining wastes are stocked up in tailings, mainly formed by fine particles that can have different concentrations of heavy metals. These polluted particles can be dispersed by wind and water erosion, sometimes reaching agricultural soils. Kumar and Maiti (2015) reported that toxic concentrations of chromium and nickel were also found in agricultural soils near an abandoned chromite-asbestos mine waste in India and in crops grown in those soils which may pose a high risk to human and livestock. In oil producing areas, spills of crude oil from well sites and from pipelines are a major source of soil pollution. One of the after effects of urbanization is the wide spread development of infrastructure such as housing, roads and railways which have contributed substantially towards environmental degradation resulting in soil sealing. By way of transportation activities, there will be emission of petrol and oil which will contaminate the environment. Soil pollution associated with roads and highways is especially important in urban and peri-urban soils, and can be a major threat when food production occurs in adjacent areas. Foliar deposition and root uptake and transfer to above-ground tissues of bioavailable heavy metals are the main processes observed in roadside soil (Hashim et al., 2017; Kim et al., 2017; Zhang et al., 2015b). Grazing in roadside soils is also quite common, and the ingestion of contaminated soil and plants constitutes potential dietary transfer of pollutants affecting animal and human health (Cruz et al., 2014).

Chemicals released as part of the routine house hold activities through deposition of sewage disposal, paints, cleansing agents, detergents and other miscellaneous articles have the potential for contaminating the soil environment. Vector control programmes particularly with regard to mosquitoes for the eradication of dengue, and malaria releases toxic and hazardous chemicals to the environment (Mansouri et al., 2017). Coupled with the above mentioned activities plastic pollution is an imminent threat for soil health. Plastics can accumulate heavy metals (Mato et al., 2001). They can reach the soil and aquatic systems and negatively affect the aquatic organisms as well as the soil activity. The presence and effects of plastic in aquatic organisms and ecosystems are well documented (Browne et al., 2008; Thompson, 2004).

Pollution via agricultural activities

Agriculture forms the basis for the sustenance of human existence on earth. Huge quantities of agrochemicals find its route to soil as a mandatory option to sustain crop productivity. Fertilizers, pesticides, herbicides, growth hormones etc are rich sources of heavy metals such as copper, lead, cadmium and mercury as well as that of persistent organic pollutants having the potential to impair crop metabolism and to impair crop productivity. Irrigation sources are also source of heavy metal contamination in soil especially when water driven from deep sub surface sources. Excess N and heavy metals are not only a source of soil pollution, but also a threat to food security, water quality and human health, when they enter the food chain (FAO and ITPS, 2015).

Livestock production can also be a source of pollution, especially if the waste is not properly managed and disposed of: the urine and faeces may contain parasites and medical substances that can persist and accumulate in the soil (Zhang et al., 2015a). Excessive application of fertilizers and manure or inefficient use of the main nutrients (N and P) in fertilizers are the main contributors to environmental issues linked to agriculture (Kanter, 2018). These two nutrients are a source of diffuse pollution. Excess N can also be lost to the atmosphere through greenhouse gas emissions, and excess P contributes to the eutrophication of neighboring sources of water. Excessive fertilizer usage can lead to soil salinity, heavy metal accumulation, water eutrophication and accumulation of nitrate, which can be a source of environmental pollution but also a threat to human health. The fertilizer industry is also considered to be a source of heavy metals such as Hg, Cd, As, Pb, Cu, Ni and Cu, and natural radionuclides. Proper handling and management of fertilizer is crucial to avoid polluting the soil (Stewart et al., 2005).

Major pollutants in soil

Soil pollutants are broadly categorized as

1. Inorganic pollutants
2. Organic Pollutants

Inorganic pollutants includes metals (cadmium, lead, copper and zinc) and non metals (cyanides, ammonium and sulphur) whereas organic pollutants include chlorinated and non chlorinated compounds (Swartjes, 2011).

Metals and heavy metals which are essentially required for the plants and animals may become toxic if the concentration exceeds a particular level, as they are non degradable and are bio accumulating. Through the bio geo chemical cycling, these compounds will accumulate in the soil and will persist in the food chain. They degrade the quality of atmosphere, water bodies and food crops apart from posing threats to human and animal health.

Over usage of fertilisers will cause the accumulation of nutrient elements which if reaches above the carrying capacity of soil will interact with other nutrient elements hindering their bio availability to plants. In the case of nitrogen and phosphorus, excess accumulation in the soil causes its leaching to the water bodies causing eutrophication and associated ill effects. This in turn will affect the aquatic biodiversity. Along with the direct effect, many heavy metals such as arsenic, cadmium, chromium, mercury, lead and zinc are also found in phosphatic and nitrogenous fertilisers (Brevik, 2013). Because of its effect on the diversity of microbial community, nitrogen pollution will affect the soil organic matter decomposition (Shen et al., 2010).

Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bio accumulate through the food chain, and have adverse effects on human health and the environment (UNEP, 2001). They enter the food chain by accumulating in the body fat of living organisms and becoming more concentrated as they move from one organism to another by the process of bio magnification. Having high mobility, they can easily penetrate water in its gaseous phase during warm weather and volatilize from soils into the atmosphere which will lead to their deposition many miles away from the release point as temperatures cool (Schmidt, 2010).

Persistent Organic Pollutants (POP) such as poly cyclic aromatic hydrocarbons and heavy metals are also released into the soil environment through the application of plant protection chemicals in the soil. Polycyclic aromatic hydrocarbons accumulate in the lipid tissues of plants and animals, but they do not tend to accumulate in plant tissues with high water content.

Effect of soil pollution

The ill effects of soil pollution are mainly reflected in three ways: 1. On food chain through crop uptake 2. On the ecosystem services 3. On the human health

1. Effect of soil pollution on food chain

Soil pollution reduces food security both by reducing crop yields due to toxic levels of contaminants and by causing the produced crops to be unsafe for consumption (FAO and ITPS, 2015). Those contaminants which are highly toxic to plants when they are not translocated to the fruits and shoots, may not enter the food chain. But when the translocation efficiency is high, it can readily enter the food chain and poses serious health hazards.

2. Effect of pollution on eco system services

Due to soil pollution, the inherent ability of soil to store water and nutrients is adversely affected and the soil microbial diversity and enrichment will also be affected. This causes imbalance in nutrient cycle and hence will adversely affect the uptake of water and nutrients by crop plants. Moreover over use of fertilizers may result in soil acidification and hence can inhibit nitrification and other microbial activities in soil. Intense acidification can also cause the mobilisation of toxic elements. Depending on the leaching movement of fertilisers to ground water as well as to the nearby water bodies, there will be loss of biodiversity and disfiguring of the food web. Negative impact of pesticides and plant protection chemicals on soil biota is well established. Along with the application of animal manures, lot of pathogen such as Salmonella, Campylobacter and Escherichia Coli may gain entry to the soil.

3. Effect of soil pollution on human health

The various soil pollutants describe in the previous section have got numerous ill effects on human health. Depending on the type of pollutant, the extent of hazard to human health varies. These contaminants enter into our body via inhalation, direct skin contact and through the food web. In the case of children sometimes soil eating/ geophagia is a common act and will pave the way for the direct entry of toxic contaminants into their body.

Heavy metals such as arsenic and lead are carcinogenic. Developmental abnormalities in children are associated with the exposure to lead. In addition to this, neurological disorders, damage to central nervous system, mis carriage, pre term/still birth are also associated with heavy metal contamination and human exposure.

Management of soil pollution

Soil pollution owing to the potential risk posing to the sustenance of life on the planet earth need to be effectively contained and managed so as to prevent further deterioration of the environment. On the basis of the mode of removal of the contaminants / pollutants remediation techniques can be divided into in situ remediation and ex situ remediation technique. The remediation techniques may be based on physical, chemical and biological treatments and they offer potential solutions to soil pollution (Scullion, 2006).

Bioremediation-A potential solution for the management of soil pollution

Bioremediation is a technique that relies on the microbial growth and activity for rendering the pollutants/contaminants ineffective to the environment. Since it is a microbial dependent activity, its effectiveness is highly relying on the applied environmental parameters that influence the microbial growth and degradation rate. According to Alexander, 1999 several conditions must be satisfied for bioremediation by microbial activity to take place in the soil. These include the following: 1) presence of organism in the soil containing pesticide 2) an organism must have the necessary enzymes to bring about the biodegradation 3) the pesticide must be accessible to the organism having the requisite enzymes 4) if the initial enzyme bringing about degradation is extracellular, the bonds acted upon by that enzyme must be exposed for the catalyst to function; 5) should the enzymes catalyzing the initial degradation be intracellular, that molecule must penetrate the surface of the cell to the internal sites where the enzyme acts; and 6) because the population or biomass of bacteria or fungi acting on many synthetic compounds is initially small, conditions in the soil must be conducive to allow proliferation of the potentially active microorganisms.

Addition of organic matter to the soil decreases the mobility of heavy metals and pollutants due to the presence of lignin and polyphenols which effectively polymerizes the heavy metals and contaminants. Biochar can also be used as a remediating agent for soil contamination.

Agronomic methods to manage soil pollution

Sustainable soil management options should form the essential component of all the management strategies for combating soil pollution. This encompasses the balanced application of fertilisers considering the soil fertility status as well as to the nutritional requirement of individual crops. Soil testing should be conducted regularly to avoid nutritional imbalances and to optimize the application of chemical fertilisers. Such practices can minimize the cost of cultivation, along with decreasing the environmental stress by way of pollution. Soil acidification is a consequence of over usage of chemical fertilisers, and hence application of ameliorants should essentially form the component of best management practices for crop production. Nutrient recommendations should consider the following parameters:

1. Native fertility status of the soil/soil reserve
2. Available nutrients in the added manures/compost/crop residues
3. Nutrient content in the fertilizers
4. Crop requirement of the nutrients
5. Quality of the produce

Possibility of nutrient addition through green manure/green leaf manure as well as through the incorporation of crop biomass should always be prioritized. Enrichment of soil organic matter content should be done so as to increase the exchange capacity of the soil and to act as a buffering agent towards major fluctuation in soil pH.

Exploring the potential of industrial by products which may be dumped at the factory premises causing severe environmental pollution as alternative to soil ameliorants. This include materials such as phosphogypsum, a byproduct of phosphatic fertiliser industry. Research works have shown that, it could ameliorate soil acidity in laterite soils as well as in soils where sub soil acidity is of concern. These findings open up the potential use of phosphogypsum as alternative to liming materials.

Plant protection activities should give prior consideration towards maintaining the ecological balance, enrich the population of natural enemies, enhancing the microbial diversity with regard to beneficial microbes, and Plant Growth Promoting Rhizobacteria. Use of chemical pesticides and fungicides should be resorted only at the most appropriate stage, rather the indiscriminate application of plant protection chemicals should be kept at bay. Adoption of environmental friendly techniques for pest and disease management should be done.

Cropping pattern can be shifted according to the preferential uptake of heavy metals. For example leafy vegetables have the greater potential to accumulate heavy metals that other fruit crops or grain crops. Within the cultivars itself, there will be variation in the rate and mode of uptake of heavy metals. Hence suitable crop rotation plan should be selected to tailor the soil conditions prevailing in the locality.

Phytoextraction of metals

Phytoextraction involves accumulation of heavy metals in the roots and shoots of higher plants which are later harvested and incinerated. These plants should have rapid growth rate, capacity to produce huge biomass, extensive root system and should have the ability to tolerate high amounts of heavy metals.

Phyto extraction can be done by the use of hyper accumulator plants with very high metal accumulating ability such as water hyacinth (Eichornia crassipes) and Brassica spp. Chinese ladder plant (Pteris vitata), a plant belonging to the species of ferns can accumulate large quantities of arsenic from contaminated fields. Spiny amaranths (Amaranthus spinosus) seen in the homesteads has the capacity to accumulate lead from the contaminated area. The ability to accumulate heavy metals can also be induced through the use of chelates which are having metal mobilizing capacity. Hyper accumulator plants have the capacity to exclude the metals through the compartmentalization of these metal ions in the vacuoles or in the cell wall and thus may not have access to cellular sites where vital functions such as respiration or cell division takes place. For a plant to be designated as hyper accumulator, the ratio of shoot to root concentration of the metal ion should be higher than one. The following table shows some of the common plant species present in our locality which are hyper accumulators of certain metals.

Common name	Scientific name	Heavy metal extracted by the plant
Sun hemp	Crotalaria juncea	nickel, chromium
Fat duck weed	Lemna gibba	arsenic
Bermuda grass	Cynodon dactylon	nickel and chromium
Brahmi	Baccoppa Monnieri	cadmium, chromium, lead and mercury
Spiny Amaranth/ Mullan Cheera	Amaranthus spinosus	cadmium, lead, chromium
Water hyacinth	Eichornia crassipes	chromium
Hydrangia	Hydrangia vulgare	aluminium
Sunflower	Helianthus annus	copper

Micro remediation of heavy metal pollution in soil

Certain microbes are able to produce metal complexing molecule such as siderophores as a mechanism for the amelioration of heavy metal toxicity in plants. Siderophores are low molecular weight, high affinity iron chelators that transport iron in the soil solution to the bacterial cells. Pseudomonas fluorescens produce fluorescent siderophores which sequester the iron compounds present in the soil. Heavy metals also under certain conditions stimulate the production of siderophores and consequently affect their bio availability in soil. Micromemdiation can also occur indirectly through the bio precipitation by the sulphate reducing bacteria viz., Desulphovibrio desulphuricans which can convert the soluble sulphates to the insoluble sulphides of cadmium and zinc. Microbes can also reduce the soluble mercuric ions (Hg2+) to the volatile Hg (0) or metallic mercury.

Through the methods of genetic engineering metal binding proteins from higher organisms can be introduced into the microbes which can sequester the contaminated metal ion in soil solution. Addition of organic amendments such as bio char produced by the process of pyrolysis of carbonaceous materials can stimulate the growth and activity of microbes and thereby accelerate the remediation process.

Conclusion

Soil pollution is invariably a malady affecting crop production, soil bio diversity and in the long run acting as a major challenge to human existence in this planet. As a means of survival, pollution in any form should be prevented at the first level itself, or should be managed suitably without allowing the large scale degradation of environment. Food crops and cultivars should as far as possible be grown in areas not under the threat of contaminations. Soil biodiversity should be considered while adopting any developmental activities above ground. As food security forms the key component of our sustainable existence in the planet, preserving the sanctity of soil, 'the soul of infinite life' should be our moto.

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COCONUT, AN IMMINENT SOLUTION FOR SOIL POLLUTION

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I. Introduction

Coconut, one the most important crops grown in the humid tropics, is very aptly called as 'Kalpavriksha', 'Tree of Life' 'Tree of Heaven' 'Nature's Super Market' etc. as each and every part of the palm finds one or other use in everyday life. Coconut also plays an important role in the ecological landscape of the country particularly in the hilly to mountainous areas planted to coconut.

People around the world are becoming aware and highly conscious about the need of preserving the nature and an increasing number of them are opting for environment friendly products. Apart from supporting the livelihood of millions of people, directly or indirectly, in more than 90 countries in the world that cultivates coconut, the versatile palm provides essential needs in every walks of human life viz. food and beverage, medicine, cosmetics, industrial raw material, construction material, cultural and religious functions, handicrafts etc. etc. A wide range of coir and coir products including the coir yarn, ropes, mats, mattings, rubberized coir products, mattresses, pillows, cushions, coir geo textiles, coir pith, rugs, carpets and curled coir etc. are now available.

The coconut is a very unique palm having a life span of many decades and provides many services to the preservation of ecosystem and if properly managed, can be an apt example for combating soil pollution. Some of the ecosystem services are listed below.

Socio-cultural services: From time immemorial, cultivation of coconut palm has deep rooted cultural and spiritual connections in India. In every Indian ritual and auspicious occasions like child birth, wedding, housewarming etc. coconut has an important role to play. The de-husked coconut is an important offering to the deities in Hindu temples across the country and many family and social festivities are incomplete without its offering. During temple festivals in Northern Kerala, where local folk dances are performed (e.g Theyyam), tender coconut leaves are used for dressing the performers. The coconut inflorescence and the leaves are used for decorative purpose for many social and cultural celebrations in different parts of Southern India.

Carbon sequestration: This is the long-term storage of carbon in oceans, soils, vegetation and geologic formations. When more photosynthesis takes place, more CO2 gets converted into biomass, thereby reducing carbon in the atmosphere and sequestering it in plant tissue as above and below ground biomass. In the case of coconut, the annual carbon sequestration in the above ground biomass is reported to vary from 15 to 35 Mg CO2/ha/year depending on cultivar, agro-climatic zone, soil type and management.

Soil conservation: Coconut as well as its companion crops provides sufficient ground cover, thereby, intercepting raindrops and reducing terminal velocity of raindrops to prevent loss of soil by runoff, or other removal processes. The fibrous mat of roots of coconut palms also helps in reducing soil loss through runoff.

Crop species diversity preservation: In a systematically planted coconut garden, an array of crops (vegetables, tubers, spices, fruits, medicinal and aromatic plants, ornamental plants, cereals, pulses, fodder, beverage crop etc.) could be grown with coconut depending on the growth stage of the main crop, enabling crop species diversity and ensuring year-round income.

Diversity of soil organisms: Coconut rhizosphere harbours a wide range of beneficial microorganisms which take part in improving the nutrient and fertility status of coconut gardens. The belowground microbial diversity (general as well as function specific) is found to be higher in multiple cropped coconut gardens, than mono-cropped ones.

Nutrient cycling: In some of the coconut gardens, plant parts like coconut water, husk, bunch waste, coconut frond etc. are left in the farm, though some of them are used as fuel and transformed into ashes. Coconut fronds, bunch waste etc. which are left in the garden itself undergoes slow decomposition and in turn supply back some of the nutrients removed from the soil. The understory vegetation could also provide significant biomass for nutrient recycling. Deep rooted companion crops could mine deeper soil layers and bring up nutrients.

II. Coconut- to combat pollution-the natural way

A. Use of coconut leaves

a. Mulching: Coconut leaves can be used for mulching the palm basins. This reduces the impact of falling rain drops on the ground and thereby prevents surface soil erosion. Addition of mulch can improve the organic matter status of soil as well as recycle soil nutrients. Organic matter can absorb moisture several times its weight and can serve as an effective moisture reserve for the cropping system.

b. Vermicomposting coconut leaves and other biomass: By using earthworm Eudrilus sp., all the fallen coconut leaves and other biomass in the coconut garden can be effectively converted into rich vermicompost. Vermicomposting can be done either in the coconut basin itself or cement tanks or in trenches prepared in the coconut garden at a suitable place. Such vermicomposting helps to reduce throwing away the biomass in the coconut garden and help combat environmental pollution.

c. Plaited coconut leaf: For houses, the plaited coconut leaf furnishes an alternative thatching sheet and supplies wall screens. Within the house, coconut leaf mats form part of the necessary furnishings. A coconut leaf mat is also used to sit out doors and during certain ceremonials. A variety of baskets is made to contain foods and stored clothing.

d. Ornamentation using coconut leaf: Coconut leaf based ornamentation is an indispensible item in almost all festive and religious functions. Usually tender leaves are used for decoration. Mature leaves are used for making traditional toys, paneling pillar, roof, walls etc. The coconut leaves can be woven to make fish traps, bags, hats, hand fan, table mats, sleeping mats, as well as many decorative items.

B. Use of coconut husk

a. Husk burial: The coconut is embedded in the husk, which forms 35 to 65% of the weight of the whole fruit, when ripe. The main use of coconut husk is to extract fibre and in India, only 15% of the husk is actually used for recovery of coir fibers. Burial of coconut husk can be done in coconut basins or in the interspaces to conserve soil moisture, thereby to overcome drought and button shedding due to moisture stress. The beneficial effect of husk burial will last for about 5-7 years.

b. Use of coir fibre: Coir is a 100% organic naturally occurring fiber derived from coconut husk. Coir fibers resemble the wood fibers in terms of physical properties and chemical composition. Naturally resistant to rot, moulds and moisture, it is not necessary to treat with any chemicals during its spinning process for converting it into yarn. It is very hard and the strongest among all natural fibers. The most popular uses for coir are door mats, agricultural twine and geo textiles (blankets that are laid on bare soil to control erosion and promote the growth of protective ground covers) because of its durability, eventual biodegradability, ability to hold water and hairy texture. The very strong global markets for coir fibre products and the increasing utility of coir fibre in new products – such as mattress, geo textiles and products for the automotive industry – means that coir fibre processing is an abundant activity in coir producing nations.

Novel method for retting coconut husk: The traditional method of coir fiber extraction from the coconut husk is retting, a laborious and time consuming process. This retting by soaking in backwaters requires 10-12 months. The continued and intensive exploitation of these backwaters for retting of coconut husk has polluted made several backwaters and caused deleterious effect on the fishery resources of the state. Retting activity has also led to the large-scale reclamation of the backwaters, resulting from the accumulation of coir pith, ret liquor and other coir products, thereby converting them into foul smelling, clogged canals. In order to solve this problem, the Central Coir Research Institute (Coir Board) has developed a novel method using biotechnological approach with selected strains of microbial cultures viz., 'Coirret'. This could reduce the period of retting from 11 months to 3 months.

c. Use of coir geotextiles: There is a rapid growth in the use of bio engineered soil erosion and sedimentation control designs especially in environmentally sensitive areas. Most of these designs incorporate coir products to provide the required initial structural stability until the establishment of sustainable vegetation. Coir Geotextiles protect land surface and promote quick vegetation. Geotextiles are a wonderful treasure of natural eco-friendly, erosion control blankets in woven and non-woven preparations. Being totally biodegradable, geotextiles help soil stabilization and renew vegetation in varying slopes.

C. Use of coir pith

a. Use of coir pith (cocopeat): It is the lignocellulosic agro-waste produced during coir fibre extraction, constituting about 70% of coconut husk. Coir pith degrades very slowly and it remains in the soil for a very long period of time. Coir pith is recalcitrant and accumulates in the environment forming hillocks posing environmental pollution in the areas close to coir fiber extracting units. As a result of its fluffy nature, its transportation will not be cost effective. Coir fiber extraction units contribute considerably to the problems of environmental pollution, both land and water pollution. In order to convert coir pith into a natural organic resource, it is processed and utilized as an economical input in agriculture as well as in horticulture. Processed coir pith is used as an excellent soil amendment due to its favourable physical properties in maintaining soil health.

It is used as a replacement for traditional peat in soil mixtures, or, as a soil-less substrate for plant cultivation. Coir waste from coir fiber industries is washed, heat treated, screened and graded before being processed into coco peat products of various granularity and denseness, which are then used for horticultural and agricultural applications and as industrial absorbent. Coir pith has very high moisture retention capacity of 600- 800 per cent and can be as high as 1100 per cent of dry weight. This eco-friendly material is said to be replacing peat moss (dug from the swampy area) and rock wool (used as cultivation medium in the developed countries) as an effective soil bed under green house conditions.

Some of the application fields of coir pith are: mulching to preserve the moisture and soil conditioning, organic manure (compost), briquetted fuel for chulas and furnaces, bricks and roofing sheets for building purposes etc., production of particle board, activated carbon, erosion control, bio-gas production, mushroom cultivation, potting mixture for seedling growth, extracting lignosulphonates, wetting agent, dispersing agent and adhesion compounds in pesticides, fertilizers etc.

b. Composting coir pith: Large scale composting can be done by the heap method in a shaded place by treating coir pith obtained from coir processing units with poultry manure, lime and rock phosphate. Spread it evenly after proper mixing. Keep the heap moist by regular watering and cover it using dry grass or other suitable material to prevent moisture loss. Turn the whole heap once in two weeks to enhance the speed of decomposition. The composting will be completed in 1½ to 2 months.

D. Use of coconut timber

a. Use of coconut timber: One of primary uses of coconut timber is for building construction. It is suitable for housing components like trusses, purlins, walls, joists, doors, window frames and jalousies. Coconut wood can be a promising material for the manufacture of furniture, novelties and other handicrafts due to its beautiful spotted grain pattern and attractive natural appearance. Use low density coconut wood materials (from the centre of the stem) only in non-load structures like walls and panels while high density coconut wood (from the perimeter of the stem) can be used as posts, power and telecommunication poles, for load-bearing structures like floor tiles (parquet), trusses and joints etc. Medium density boards can be effectively used for walling, horizontal studs, ceiling joists and door/window frames.

E. Use of other coconut parts

a. Value addition of tender coconut husks: Tender coconut husk becomes a waste material after consuming the tender coconut water and the soft kernel. Composting tender coconut husk is an environmentally sound and economically advantageous way to utilize waste for soil organic amendment. This Involves complete or partial degradation of variety of chemical compounds by consortium of microorganisms. This can be used as a natural soil conditioner.

b. Use as pulp for paper making: The waste husk of green / dry tender coconuts is to be chopped in to uniform size and made in to powder form which contains fibre, pith and outer skin. It is then pulped after mixing with the waste paper by organo-solv treatment using an organic solvent in the presence of mineral acid catalyst .This pulp from tender coconut husk is an excellent wood substitute in making paper.

j. Use of coconut water for value addition: Sizeable quantity of coconut water will be produced from various industries such as Desiccated powder, coconut milk, coconut oil etc. and if left un-utilized near the factory premises, will definitely cause environmental pollution. There are now technologies available for effective utilization of such coconut water to make coconut vinegar, soft drink etc.

k. Use of coconut shell: Every year billions of coconut shells are discarded as waste after their meat has been extracted. These discarded coconut shells can be used for making decorative items and eco friendly utensils (bowls, cutlery and tea sets etc.). These are 100% natural, lightweight, food safe and reusable.

Crushed coconut shells are suitable as substitute for conventional aggregates in lightweight concrete production. It is cost effective, eco friendly and resolves the issues related to shortage of conventional material. Coconut shell is hard in nature and does not deteriorate easily once bound in concrete and therefore, it does not contaminate or leach to produce toxic substances.

Coconut shells can be converted into charcoal and activated carbon and increase value to the product. Biochar from coconut byproducts like shell and pith, can improve carbon sequestration potential of soil, promotes microbial activity and improves physical properties and soil health, enabling ability to withstand erosion.

Preparation of COCOLAWN

COCOLAWN is a lush green instant lawn of grass developed by CCRI based on coir products viz coir geotextiles, coir fibre, coir pith and (C-POM) Coir Pith Organic Manure. The lawn is encased in a composite comprising a single layer of coir fibre embedded in coir netting or coir geotextiles. A layer of coir pith is placed on the fibre. Grass slips are planted on the coir pith bed so made and Coir Pith Organic Manure [CPOM] is applied on it to form a thin layer. The coir based lawn is lighter in weight and therefore, easy to handle in comparison to the grass turfs. It is easy to shift the material from one place to another and it can be rolled for transportation.

Gardening without Plastic

Coconut fibre, shells and wood can be used as containers for growing plants, especially for hanging purpose, replacing conventional plastic pots. Pots made of coconut fibre, which are bio degradable, can be used widely in gardening. Fibres from the coconut husk together are blended with a biodegradable plastic to produce a biodegradable plastic product that can be further made into other items. Plastics, thus, made from coconut husk fine fibre powder will return to the environment after disposal much more rapidly than those without coconut husk fine fibre powder.

Replacing plastics with coir-based products

Advantages of coir based containers are:

- Provides adequate aeration and drainage to the potted plants due to higher porosity
- Roots can easily pierce into the container walls avoiding root compression
- Enables direct planting of seedlings raised
- Avoids transplanting shock and provides better seedling vigour
- Holds moisture and hence higher water use efficiency
- Improved nutrient retention capacity
- Regulates the soil temperature

CLIMATE CHANGE AND SOIL POLLUTION

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Climate change is experienced from the time immemorial to the present. With progressing earth history, the parameters of climate such as temperatures and precipitation have globally, regionally and locally changed. We had ice ages and warmer periods, ice ages have occurred in a hundred thousand year cycle for the last 700 thousand years, and there have been previous periods that appear to have been warmer than the present despite CO_2 levels being lower than they are now. Climate change in Intergovernmental Panel on Climate Change (IPCC) usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change (FCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

A reduced water evaporation from agricultural land in contrast to natural forest, emissions of warmth and carbon dioxide especially in urban-industrial agglomerations and the release of methane and nitrous oxide in agriculture are the most important impacts. It is assumed that in the 21st century the global mean temperature will rise by another 2-3°C, mainly caused by a higher use of fossil fuels and an intensified conventional agriculture.

Geological reasons: The earth's climate is dynamic and always changing through a natural cycle. The climate changes are being studied by scientists all over the world who are finding evidence from tree rings, pollen samples, ice cores and sea sediments. There are a number of natural factors responsible for climate change. Some of the more prominent ones are continental drift, volcanoes, ocean currents, the earth's tilt, comets and meteorites.

Human causes: Apart from geological cycles, leading to climate change over the ages, human activities are a major contributor in the recent past, affecting climate. Human-caused global warming is often called anthropogenic climate change. Industrialization, deforestation and pollution have greatly increased atmospheric concentrations of water vapor, carbon dioxide, methane and nitrous oxide, all greenhouse gases that help trap heat near earth's surface. Humans are pouring carbon dioxide into the atmosphere much faster than plants and oceans can absorb it. These gases persist in the atmosphere for years, meaning that even if such emissions were eliminated today, it would not immediately stop global warming.

Our planet is made habitable by the presence of certain gases which trap long-wave radiation emitted from the earth's surface, giving a global mean temperature of 15°C as opposed to an estimated -18°C in the absence of an atmosphere (Rakshit et.al, 2009). This phenomenon is popularly known as the "Greenhouse" effect.

Effect of climate change on Soils:

Direct effects: Organic matter content, which is already quite low in Indian soils, would become still lower. Quality of soil organic matter may be affected. The residues of crops under the elevated CO_2 concentrations will have higher C:N ratio, and this may reduce their rate of decomposition and nutrient supply. Rise in soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes such as volatilization and denitrification. There may be a change in rainfall volume and frequency, and wind may alter the severity, frequency and extent of soil erosion. Rise in sea level may lead to salt-water ingression in the coastal lands, turning them less suitable for conventional agriculture

Indirect effects: Indirect effects are soil erosion, increased leaching of nutrients, insect-pest-pathogen, increased reproduction rate, severity of infestation, extension of geographical range, outbreak of new pests, salinization of fresh water, ground water depletion, land use change, deforestation, land degradation and shifting of cropping zone etc.

Soil contamination or soil pollution : It is a type of land degradation caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. Soil pollution due to climate change is manifested due to direct and indirect changes in natural soil environment.

Direct effects of climate change leading to soil pollution

Soil pollution refers to the presence of chemicals in soils that are either out of place or at higher-than-normal concentrations. Such contamination may be produced by mining and industrial activity or by sewer and waste mismanagement. In some cases, pollutants are spread over large areas by wind and rain. Agricultural inputs such as fertilizers, herbicides and pesticides and even antibiotics contained in animal manure are also major potential pollutants. Soil pollution is an insidious risk because it is harder to observe than some other soil degradation processes, such as erosion. The hazards posed depend on how soil properties affect the behaviour of chemicals and the speed with which they enter ecosystems. Excessive amount of nitrogen and trace metals such as arsenic, cadmium, lead and mercury can impair plant metabolism and reduce crop productivity. When they enter the food chain, these pollutants pose risk to food security, water resources, rural livelihoods and human health.

Sea-level rise will be a key issue for many coastal areas as rich agricultural lands may be submerged and taken out of production (Wassmann et al., 2009). Sea level rise will inundate low lying areas and will especially affect rice growing regions. Increases in floods and droughts will exacerbate rural poverty in parts of Asia due to negative impacts on the rice crop and resulting increases in food prices and the cost of living (IPCC, 2014). Sea-level rise threatens coastal and deltaic rice production areas in Asia, such as those in Bangladesh and the Mekong River Delta (Wassmann et al., 2009). Agriculturally fertile coastal regions with paddy fields are vulnerable to inundation and salinization. Threat due to coastal inundation is likely in Orissa state which normally produces around five million tonnes of rice each year. The rice crop on the coast contributes about 40 per cent to the total rice grown in the state.

Indirect changes leading to soil pollution

The most rapid processes of chemical or mineralogical change under changing external conditions would be loss of salts and nutrient cations where leaching increases and salinization where net upward water movement occurs because of increased evapotranspiration or decreased rainfall or irrigation water supply (Brinkman, and Sombroek, 1996)

Soil nutrient quantity is often affected by climatic factor. Change in temperature and precipitation could affect soil nutrient levels in numerous manners. Increasing temperatures could act to assert nutrients within the soil because of raised evaporative forces and abbreviate leaching (Dent., 1986). Moreover, decrease in rainfall may cause upward movements of nutrients and thus leads to Stalinization. Downward movement of water in soil leads to loss of soil nutrient; hence movement of water to a great extent affects the soil nutrient level. In tropical and subtropical countries, loss of soil nutrient is an increasing problem (Bullock et al., 1995, Smaling, 1990). Soil erosion threatens agricultural productivity and sustainability. There are several ways that soil erosion could increase in the future due to climate change. Wind and water erosion of agricultural soils are strongly tied to extreme climatic events, such as drought and flooding, which are commonly projected to increase as a result of climate change and land use change could exacerbate these impacts. Warmer winters may result in a decrease in protective snow cover, which would increase the exposure of soils to wind erosion, whereas an increase in the frequency of freeze-thaw cycles would enhance the breakdown of soil particles. The risk of soil erosion would also increase if producers respond to drought conditions through increased use of tillage summer fallow. Around one-third of the world’s soils are degraded due to unsustainable soil management practices. Tens of billions of tonnes of soil are lost to farming each year, which in some countries affects as much as one-fifth of all croplands. Erosion and deposition may result in soil pollution based on its severity.

Direct and indirect land-use change can lead to additional environmental pressures on land and water resources, habitat destruction and loss of biodiversity and thus contribute to further food insecurity through the competition for land and resulting increases in food prices (van der Velde et al., 2009; Tilman et al., 2009).

Land degradation due to increase in extreme events, such as flash floods and droughts threatening food and energy securityplacing more pressure on natural resources. Land degradation caused by inadequate communal land tenure systems and uneven distribution of water. Degradation of land quality (contamination of soil, groundwater and surface waters, loss of soil fertility) occurs due to industrialisation, urbanisation and unsustainable farming practices and causes soil erosion, soil infertility and reduced crop yields.

Land degradation is also a major problem in India. According to the State of India's Environment 2017, India's total geographical area of 328.72 million hectares 96.4mha is under desertification. In nine states, around 40 to 70 per cent of land has undergone desertification.Healthy soils are vital for food security. Of the 17 sustainable development goals (SDG) and 169 targets, four contain targets related to soils and sustainable soil management.

Climate change adaptation measures related to agricultural soils

- Decision making regarding the timing of agricultural operations, the type of operations used (e.g., minimum tillage) and by erosion control measures such as buffer strips could help reduce negative impacts on soil structure, erosion and runoff
- Soil moisture conservation measures such as mulching and minimum tillage could help minimise increased crop irrigation needs in summer. The possibilities and potential methods (technologies) for an efficient soil moisture control are summarized latter
- Careful planning of the amounts and timing of applications of fertilisers and pesticides
- Land management practices to increase SOM content (e.g., addition of cereal straw, animal manure, rotations etc.) could help maintain SOM contents and avoid increased CO_2 fluxes from soils. Correct farming techniques can sequester carbon into the soil and reverse the greenhouse gases created by Agriculture. The processes to increase soil carbon can be divided into three steps

Use plants for carbon sequestration : It is estimated that between 30-60% of the atmospheric carbon dioxide (CO_2) absorbed by plants is deposited into the soil as organic matter in the form of bud sheaths that protect the delicate root tips and as a range of other root excretions

Use microorganisms to convert soil carbon into stable forms: The stable forms of soil carbon such as humus and glomalin are manufactured by microorganisms. The continuous application of carbon as composts, manures, mulches and via plant growth will not increase soil carbon levels if farming practices destroy soil carbon. The following are some of the practices that result in a decline in carbon and alternatives that prevent this loss,

- *Reduce nitrogen applications:* Synthetic nitrogen fertilisers are one of the major causes of the decline of soil carbon. This is because it stimulates a range of bacteria that feed on nitrogen and carbon to form amino acids for their growth and reproduction. These bacteria have a carbon to nitrogen ratio of around 30-1. In other words every ton of nitrogen applied results in the bacteria consuming 30 t of carbon. The quick addition of these nitrogen fertilisers causes the nitrogen feeding bacteria to rapidly multiply, consuming the soil carbon to build their cells

- *Carbon eaters rather than carbon builders:* The use of synthetic nitrogen fertilisers changes the soil biota to favour microorganisms that consume carbon, rather than the species that build humus and other stable forms of carbon. By stimulating high levels of species that consume soil carbon, the carbon never gets to increase and usually continues to slowly decline

- *Reduce herbicides, pesticides and fungicides:* Research shows that the use of biocides (Herbicides, Pesticides and Fungicides) causes a decline in beneficial microorganisms. Dr Elaine Ingham has shown that these chemicals cause a significant decline in the beneficial microorganisms that build humus, suppress diseases and make nutrients available to plants. Many of the herbicides and fungicides have been shown to kill off beneficial soil fungi112

- *Use correct tillage methods:* Tillage is one of the oldest and most effective methods to prepare planting beds and to control weeds. Unfortunately it is also one of the most abused methods resulting in soil loss, damage to the soil structure and carbon loss through oxidation when used incorrectly

- *Control weeds without soil damage:* A large range of tillage methods can be used to control weeds in crops without damaging the soil and losing carbon. Various spring tynes, some types of harrows, star weeders, knives and brushes can be used to pull out young weeds with only minimal soil disturbance

- *Prevent Soil erosion:* Erosion is one significant ways that soil carbon is lost. The top few centimetres of soil is the area richest in carbon. When this thin layer of soil is lost due to rain or wind, the carbon is lost as well.
- *Avoid burning stubble:* Practices such as burning stubble should be avoided. Burning creates greenhouses gases as well as exposing the soil to damage from erosion and oxidation.
- *Encourage vegatative cover:* Vegatative cover is the best way to prevent soil and carbon loss. As stated in the previous section 'Managing weeds to increase soil Carbon', it is not always necessary to eradicate weeds. Effective management tools such as grazing or mowing can achieve better long term results.
- *Bare soils should be avoided as much as possible:* Research shows that bare soils lose organic matter through oxidation, the killing of micro organisms and through wind and rain erosion. Cultivated soils should be planted with a cover crop as quickly as possible. The cover crop will protect the soil from damage and add carbon and other nutrients as it grows. The correct choice of species can increase soil nitrogen, conserve soil moisture through mulching and suppress weeds by out competing them.
- Careful planning of land management (e.g., timing and application of fertiliser applications) could help minimize potential increases in trace gas fluxes from soils.
- Conservation measures to maintain peatland moisture could help avoid drying out of peatlands and associated CO_2 fluxes.
- Coastal management options should consider measures to protect aquifers from saline intrusion due to sea level rise where appropriate.
- Conservation measures for low-lying vulnerable coastal habitats need to be planned carefully with consideration of possible impacts on trace gas fluxes.

Conclusion

Changes due to climate change are expected to be relatively well buffered by the mineral composition, the organic matter content or the structural stability of many soils. As a matter of fact, the impact of climate change on soil system should be monitored in different agroecological regions on regular basis. Climate change and land degradation are closely linked issues and conservation farming has shown promise in minimizing land degradation.

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INTEGRATED NUTRIENT MANAGEMENT FOR COMBATING SOIL POLLUTION

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Introduction

"Soil pollution" refers to the presence of a chemical or substance out of place and/ or present at a higher than normal concentration that has adverse effects on any non-targeted organism (FAO and ITPS, 2015). Soil pollution can be due to the presence of man- made chemicals or other alteration in the natural soil environment. The man-made soil pollution is usually caused by various industrial activities, chemicals used in agricultural activities, or improper disposal of waste materials. The diversity of contaminants is constantly evolving due to agrochemical and industrial developments. Modern agricultural practices often lead to soil pollution to a large extent. The different agricultural sources of soil pollutants include agrochemical sources, such as fertilizers and animal manure, and pesticides. Trace metals from these agrochemicals, such as, Cu, Cd, Pb and Hg, are also considered soil pollutants as they can impair plant metabolism and decrease crop productivity. The misuse of organic and synthetic fertilizers leads to nutrient imbalances in soils, alters soil biodiversity, and produces changes in soil acidification which contributes to the mobilization and bioavailability of other contaminants. In addition, excess nitrogen inputs contribute to the release of N_2O into the atmosphere, a greenhouse gas with a higher potential warming effect than CO_2. Excess N and P cannot be absorbed by plants and soils, and consequently these macro elements contaminate surface and groundwater bodies. Water sources for irrigation can also cause soil pollution if they consist of waste water and urban sewage. Excess N and heavy metals are not only a source of soil pollution, but also a threat to food security, water quality and human health, when they enter the food chain.

Integrated Nutrient Management (INM)

Integrated Nutrient Management refers to the maintenance of soil fertility and plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner. Integrated nutrient management can play a great role in improving plant growth and productivity. Integrated Nutrient Managment (INM) plays a great role in maintaining organic carbon-rich soils, restoring and improving degraded agricultural lands and, in general terms, increasing the soil carbon content and play an important role in addressing the three-fold challenge of food security, adaptation of food systems and people to climate change, and the mitigation of anthropogenic emissions. The main components of INM include fertilizers, organic manures, legumes, green manures, crop residues and biofertilizers.

Role of Integrated Nutrient Management (INM) in combating Soil Pollution

Reducing chemical inputs is an important element of pollution prevention. The less a potentially harmful substance is used in agriculture, the less likely it is to affect other parts of the environment. This applies most directly to fertilizers, manures and pesticides. A good nutrient management is the practice of a pplying fertilizers and manures only in the amounts that can be taken up by a crop. Applications in excess of these needs have the potential to enter surface and ground water. In the past emphasis was on increased use of chemical fertilizers, but INM approach aim on educating farmers to optimize the use of organic, inorganic and biological fertilizers in an integrated way. As a result there will be regular supply for optimum crop growth and higher productivity, improvement and maintenance of soil fertility and zero adverse effect on agro-ecosystem quality. The increased use of chemical fertilizers alone is a great concern because of the following reasons:

a. Soils which receive plant nutrients only through chemical fertilizers are showing declining productivity regardless of being supplied with sufficient nutrients

b. The decline in productivity can be attributed to the appearance of deficiency of secondary and micronutrients

c. The physical condition of the soil is deteriorated as result of long term use of chemical fertilizers

d. Excess N and P may lead to ground water and environmental pollution

The components of INM are helping to reduce the soil pollution by reducing the use of chemical fertilizers. Applications of commercial fertilizers or animal manures often add more N than that is taken up by crops during a year in systems. In general the amount of N added for production of many field crops is the quantities of N expected to be taken up by the crop plus additional N to compensate for losses of N expected to occur. Hence, application of nutrients according to the crop demand and estimating available nutrients supply in the soil are very important steps in INM for reducing potential N leaching. To improve the efficiency of nitrogen fertilizers it is recommended to give as many split doses as possible to the crops and hence avoid the wastage and loss permanently. Inclusion of both shallow rooted and deep rooted crops in the cropping system is also one of the recommended practice to avoid loss of nutrients in the surface and deeper layers of soil. Site specific application is another important strategy to avoid the excess use of nutrients and lead to soil pollution. INM also advise to use slow/controlled release fertilizers and nitrification inhibitors for reducing the nitrogen loss by leaching and other ways and also helps to improve nitrogen use efficiency (NUE). Neem coated urea, sulfur coated urea, polymer coated urea, biochar coated urea are examples of slow/ controlled release nitrogen fertilizers. Also soil pH management through the addition of adequate lime/gypsum helps to avoid the loss of nitrogen by other means.

One of the most important components of INM is the legumes which fix atmospheric nitrogen and act as a nitrogen source in soil. This nitrogen supply helps to reduce the use of chemical nitrogen fertilizer application rates. This synergistic relationship between legumes and component crops are very much helpful in reducing the soil pollution by the use of nitrogenous fertilizers. Legume help in solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity, and restoring organic matter, and also has smothering effect on weed and help in disease and pest control. The carryover of N derived from legume grown, either in crop sequence or in intercropping system for succeeding crops, is also important.

Organic manures as INM components help to improve soil quality by altering chemical and physical properties, increase organic matter content, water holding capacity, overall diversity of microorganisms, provide essential macro and micronutrients to plants and suppress diseases. Organic manures aid to reduce the use of chemical fertilizers to crops and hence reduce the pollution due to fertilizer chemicals. Manure management is a very important step to avoid environmental pollution due to the emission of green house gas methane. Methane is emitted during the anaerobic decomposition of manure. The amount of methane produced from manure depends on i) the quantity of manure, which depends on the number of animals, the quantity of feed consumed, and the digestibility of the feed ii) animal type, the condition of the digestive tract, and the quality of the feed consumed iii) the manure handling method - liquid versus solid storage (Liquid manure management systems, such as ponds, lagoons, and holding tanks lead to anaerobic conditions, which can emit up to 80 per cent of manure based methane emissions, while solid manure emits little or no methane) and iv) environmental conditions (temperature and moisture).

The things to be ensured during manure handling are

- Avoid adding straw to manure because straw acts as a food source for anaerobic bacteria, resulting in higher methane emissions.
- Apply manure to soil as soon as possible because storing manure for long periods can encourage anaerobic decomposition and result in increased methane emissions.
- Avoid manure application when the soil is extremely wet, as this leads to anaerobic conditions and increased methane emissions.

- apply manure shortly before crop growth to allow for the maximum amount of available nitrogen to be used by the crop
- Avoid applying manure in the cool seasons because it lead to high emission of nitrous oxide and high nitrogen loss in the summer.
- Avoid applying manure when the weather is hot and windy, or before a storm, because these conditions can increase nitrogen oxide emissions.
- Implement soil and water management practices such as: improving drainage, avoiding soil compaction, increasing soil aeration, and using nitrification inhibitors for nitrogen gas production instead of nitrogen oxide.
- Spread manure evenly around the crop field.
- Maintain healthy pastures by implementing beneficial management grazing practices to help increase the quality of forages.
- Avoid applying excess amounts of manure because nutrients can be lost to the environment. Testing both the soil and the manure before application ensures the proper nutrient balance for plant needs and can help reduce the loss of nutrients as GHGs.

Composting is another option in INM which helps to convert the agricultural and other wastes to enriched manures hence alleviate the soil pollution due to wastes generated in the farm. Composting also helps to reduce the pest and disease by suppressing the pathogens. Value addition also takes place by this process and nutrients in the unavailable condition will convert to easily available and ready to use form.

Biofertilizers are essential component of INM, which are preparations containing living cells or latent cells of efficient strains of beneficial microorganisms that help crop plants' uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. Beneficial microbes helps to reduce the need for the use of chemical fertilizers and thereby reduce environmental pollution caused by chemical fertilizers. Beneficial microbes are very important in increasing crop productivity, profitability and sustainability by releasing growth promoting substances and vitamins to maintain soil tilth and fertility and also by suppressing the incidence of pathogens. There are nitrogenous biofertilizers, phosphatic biofertilizer, potassic biofertilizers and arbuscular mycorrhizal fungi. Applications of organic manures such as animal manure, poultry manure, green manure, composts, farm yard manure, biochar, and ash increase the beneficial microbes in the soil and improve soil health and overall sustainability (Amanullah, 2015).

Controlling erosion and runoff is an important management strategy. Practices such as strip-cropping, shelterbelts and use of cover crops prevent erosion and reduce the movement of nutrients and pesticides from agricultural land. Residue management through conservation tillage and continuous cropping is also effective in controlling erosion. A balance between erosion control and protection of water quality may have to be established to maximize conservation. Barriers and buffers can be planted to intercept and contain contaminants that are being carried from agricultural lands. In most cases, these are strips of vegetation that slow the velocity of runoff water enough for sediment to settle out, water to infiltrate into the ground and nutrients to be taken up by plants. Grassed waterways, vegetative strips and field borders are examples of buffers that can be used in annually cropped fields moving into the waterway from surrounding agricultural lands. The vegetation also stabilizes the banks and shores from the erosive action of the waterway itself.

Intercropping is another important option in INM which helps to reduce the loss of applied nutrients and increase the nutrient use efficiency within the system. The inclusion of annual and perennials in the system aid to explore the entire soil profile and utilizing the nutrients in surface and subsurface soil. This helps to reduce the excess retention of chemical fertilizers in the soil. Also the disease and pests will be suppressed by adding the trap crops as an intercrop. The pollution due to the application of pest control chemicals can be reduced by this way. The beneficial associations like mycorrhiza can be enhanced by including both tree spp as intercrop.

Crop residue management is a big problem when it is accumulated in the field. Proper management of residue ensures in INM and this may helps to reduce the pests and disease problems and also incorporation in the composting process helps to avoid loss of nutrients stored in the stubbles. Adequate measures to incorporate crop residues help to avoid leaching losses, help in improving water holding capacity, improve organic matter in the soil and help in microbial enrichment.

Conclusion

Sustainable agriculture requires that soil, water and air quality be maintained. Best management practice helps to reduce environmental pollution and retain more benefit to soil and crops. INM is one of the known and acceptable best management practice and if properly followed the INM approach can reduce the agricultural pollution to a great extent.

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SOIL AND WATER CONSERVATION FOR CLIMATE RESILIENCE

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Resource Degradation

Degradation of the primary natural resources viz. soil and water is major concern with respect to food production and other related activities at present. Soil degradation is defined as "a process which lowers the current and/or the potential capability of soil to produce (quantitatively and/or qualitatively) goods or services (FAO, 1979). In other terms it is the "decline in soil quality caused through its misuse by humans". It refers to decline in the soils' productivity through adverse changes in nutrient status and soil organic matter, structural attributes, and concentrations of electrolytes and toxic chemicals. For the holistic management of the natural resources integrated with sustainable production, the concept of watershed management is of much importance which is also relevant in terms of climate resilient agriculture.

Watershed management

As mentioned above, watershed is identified to be the ideal unit for implementing all the NRM programmes because

- Watershed, a geographical and hydrological unit draining to a common outlet point, is recognized an ideal unit for planning, conservation, and development of land, water and vegetation resources.
- Watershed concept is an integrated approach of harmonized use of natural resources like land, water, vegetation, livestock, fisheries and human resources.
- Watershed management is a single window, integrated, participatory and sustainable area development programme.
- Integration of technologies within the natural boundaries of a drainage area (from the highest point (ridge) to the outlet) for optimum development of land, water and biomass resources to meet the basic minimum needs of the people in a sustainable manner.

Here the major stress is on "WATER", as healthy development of other resources like plants, animals and humans revolves around water. A wide variety of programmes and institutions are involved and these cannot be successful without People's participation. Systematic and proper implementation of this concept allows accurate measurements and monitoring of hydrologic components.

Water is the most important natural resource today. That is why all NRM programmes undertaken by the Govt. revolve around water, in terms of 'watershed'. The major source of water on earth is precipitation by means of rainfall and snowmelt. Kerala receives an average annual rainfall of 3055 mm which is almost three times the national average of 1,170 mm. But owing to the steep terrains and improper land uses, the state is not able to conserve enough water to meet the drinking water and irrigation purposes throughout the year and often fall susceptible to drought.

Why the water shortage?

It does not matter how much rain we get. If we don't capture and manage it properly we can still be short of water. It is unbelievable but true that Chirapunji which gets 11,000 mm annual rainfall suffers from serious drinking water shortage during lean seasons. Even though Kerala receives an annual average rainfall of 3,055 mm, we still face water shortage in summer mainly because of the topography, improper management, and many anthropogenic factors.

Principles of soil and water conservation

Soil conservation and water conservation are mutually depended in such a way that without one the other could not be achieved. For conservation of soil and water, integration of biological and mechanical measures are required depending upon degree of the problems.

The essential interventions for soil and water conservation could be undertaken in four stages

I Between the sky and soil

- Vegetation cover
- Crop geometry/Plant population
- Improved crop varieties /planting materials and plant protection measures
- Cover cropping
- Mulching

II Maintenance of a healthy soil

- Tillage practices
- Soil fertility management: physical and chemical properties of soil

- Crop rotation
- Application of amendments
- Green manuring
- Crop residue management

III Measures against overland flow

- Erosion permitting and resisting crops/strip cropping
- Contour farming
- Vegetative barriers

IV. Drainage line treatment measures

- Diversion structures
- Temporary and semi-permanent check dams/grade stabilizers
- Permanent grade stabilization structures like check dams, drop structures, etc.
- Silt detention dams and water harvesting structures
- Slope stabilization measures like retaining walls, revetments etc.

Water resource of Kerala - threats and management issues

I. Deforestation - Land use changes:

- Conversion of watershed area has altered the hydrological regime while enhancing the silt movement – lowering water yield in the catchment affecting the groundwater recharge.
- Large-scale deforestation in the Western Ghats and introduction of plan tation crops in highlands replacing the natural vegetation reduced the storage capacity of soil and resulted in surface soil erosion in watersheds and sedimentation in rivers.
- This has affected summer flow in rivers and some perennial rivers and rivulets have become seasonal in the last few decades due to large scale land cover changes.

II. Sand Quarrying and River Bank Agriculture

Sand quarrying in rivers and watersheds are killing the rivers. Such activities lead to bank erosion, lowering of water table and create several environmental problems.

- Ground water level in some of the watersheds has gone down by nearly one meter in the last two decades.

- Agricultural practices in the riverbanks (and also inside the dry riverbeds) during non-rainy months also add to bank erosion and sedimentation in rivers.

III. Degradation of Water Resources

All 44 rivers in Kerala are highly polluted due to inflow of untreated domestic, industrial wastes and agriculture runoff.

- Most of the industries are near the thickly populated riversides, often near cities and towns. There is no efficient water treatment system in industries and city municipalities.
- Pollution level in some of the sites is far above permissible limits.

IV. Land Reclamation and Construction

Sand filling of ponds, farmlands, wetlands and other water bodies affects natural water flow and groundwater recharge

- Construction of new roads and buildings has blocked many canals, which were important for navigation and freshwater
- Vast areas of wetlands and paddy fields have been converted into settlement and industrial areas in the recent times.

V. Bacteriological Contamination in Drinking Water Source

Wide spread bacteriological contamination of fecal origin in sources of public drinking water supplies, viz. traditional open dug wells, bore wells and surface sources. These concerns for ground and surface water contamination relate to close proximity of increasing numbers of leach pit latrines under varying soil conditions, laterite (midland) and sandy soils (coastal area); Non point sources of pollution in the catchment area including possible agricultural and surface run off, especially during the rainy season etc.

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CAN THE CROP AND ITS NEED BASED NUTRIENT MANAGEMENT BE A SOLUTION TO ABATE SOIL POLLUTION ?: EXPERIENCE IN TROPICAL TUBER CROPS

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Introduction

Tropical tuber crops like cassava, sweet potato, yams and aroids (elephant foot yam, taro and tannia) and minor tuber crops (coleus and arrow root) constitute the subsidiary food for millions of people since time immemorial. These group of ethnic crops owing to its biological efficiency, adaptation to marginal environments both soil and climate, tolerance to pests and diseases, high starch content in tubers, better physico-chemical properties of tuber starch in making value added products gained much significance in the food, nutritional and social security of people in the recent times. Recent research conducted in these crops could reveal many of its nuetraceutical and medicinal properties which in turn also helped in promoting its consumption to some extent both as raw and as value added products. The industrial utility of tuber crops especially cassava deserves special mention as cassava starch can be used for making many products of commercial importance like biodegradable plastics, ethanol, super absorbent polymers, hard boards, films etc. Similarly, the antioxidants in sweet potato and yams (carotenoids and anthocyanins), phenols in coleus and elephant foot yam and the mucilage in taro and yams and fibres in all tuber crops are medicinally significant from the point of health benefits to the consumers. In addition, though the tubers of these crops are very low in protein, nature gifted their leaves with sufficient protein so that they can be consumed as leafy vegetables too.

The research experience in the plant nutrition of tropical tuber crops over half a century clearly revealed that, these crops as highly responsive to manures and fertilizers. Moreover, the long term fertilizer experiment in cassava since 1977 at ICAR-CTCRI also indicated cassava responds very strongly and positively to plant nutrition. However, the same experiment also showed cassava as a benign crop for continuous cultivation in the same field even without application of manures and fertilizers.

As regard to this year's World Soil Day theme 'BE THE SOLUTION TO SOIL POLLUTION', this article deals with how these group of crops and their plant nutrition can be a solution to soil pollution.

Coming to the topic per se, it implies that, we ourselves as well as our research specifically on nutrient management strategy and extension should become the vehicle to avoid the existing pollution of soil. Soil pollution can be in many ways and among the various modes, from the plant nutrition point of view, it can be mainly through soil and foliar application of manures and fertilizers. So, this paper will discuss the unique nature of cassava with respect to its sustainability for continuous cultivation without manures and fertilizers, climate resilience of cassava in terms of carbon sequestration, response of cassava to low input management and nutrient use efficiency of some genotypes of cassava and need based nutrient management practices like soil test based application of manures and fertilizers in cassava, best management practices in cassava and elephant foot yam, customized fertilizer formulations and use of NUE microbes in elephant foot yam in abating soil pollution. All these features will definitely imply the fact that, cassava, though responds positively to plant nutrients, it can also be suited to situations of no or low input of nutrients without adversely affecting the yield, thus can be a solution to soil pollution to some extent. This in turn appeal to the unique feature of the crop for being a solution to the problem of soil poisoning due to anthropogenic interventions like non judicious application of fertilizers.

a. Sustainability of cassava for long term cultivation without manures and fertilizers

At ICAR-CTCRI, under the long term fertilizer experiment (initiated in 1977) since 2005, the treatment 'absolute control' where there was no nutrient application either through manures and fertilizers revealed for the last 12 years that, it is a sustainable crop for continuous cultivation in the same field with an yield range of 6.583 to 17.999 t ha-1 and a mean tuber yield of 13. 943 t ha-1(Table 1).

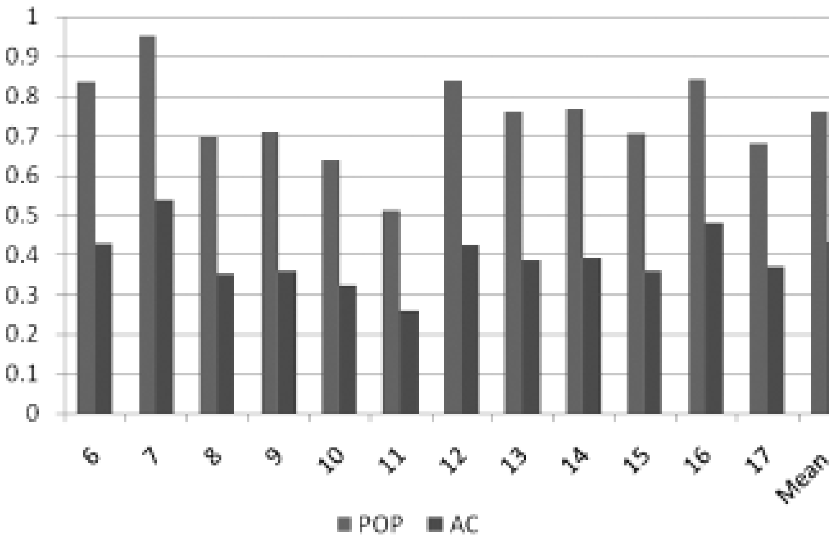
Table 1: Tuber yield of cassava under different treatments over a period of 12 years of continuous cultivation

Treat	Years												
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Pooled
T1	24.316	18.531	28.048	32.030	29.225	33.110	29.790	25.098	30.844	32.851	25.160	14.238	26.937
T2	23.795	12.624	30.965	31.020	32.571	32.130	24.700	24.901	25.173	27.615	23.060	11.425	24.998
T3	23.546	15.851	31.065	26.159	26.236	27.121	21.320	22.871	22.571	22.272	23.180	11.502	22.808
T4	17.015	6.583	17.999	13.975	15.926	11.027	17.280	12.140	17.933	15.171	14.270	8.002	13.943
CD	3.092	2.001	3.198	7.927	8.092	6.816	6.356	6.395	5.867	7.109	9.624	4.552	5.919

T1: NPK @ 125:50:125, T2: POP (NPK@ 100:50:10), T3: STBF (NPK @ 82:0:74 kg ha-1) , T4: AC (Absolute Control)

The reason can be attributed to the innate physiological mechanism of the crop to shed its leaves during the crop growth period as well the high leaf dry matter production to the tune of 1.515-5.426 t ha-1with an average value of 2.693 tha^{-1} under absolute control during this period. Moreover, cassava leaves are rich in all nutrients especially N. The content of nutrients viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn in cassava leaves accounts to the tune of 4.41, 0.28, 1.25, 0.21, 0.321, 0.016, 0.0008, 0.0154 and 0.0064 % respectively. Hence, the maintenance of soil fertility through improvement in both soil organic matter as well as other plant nutrients also is another factor sustaining soil productivity contributing to high crop productivity even without plant nutrition.

Table 2: A comparison of the Sustainable Yield Index (YSI) over 12 years (2006-2017) of continuous cultivation under POP and Absolute Control



The sustainable yield index worked during these years for package of practices (POP) and absolute control (AC) is presented in Fig.1 which too indicate without any plant nutrient application, cassava can sustain its yield and the factors contributing are discussed above.

b. Climate resilience of cassava in terms of carbon sequestration

Climate resilience of a crop denotes the ability of the crop to adapt and adjust to the adversities of climate change. Increasing CO2 concentration of the atmosphere is considered as the predominant cause of global warming and this indirectly indicates that, by decreasing the CO2 concentration of the air, global warming can be reduced. C sequestration is the removal of atmospheric CO2 by plants and storage of fixed carbon as soil organic matter. If the crop can absorb more CO_2 from the atmosphere and if the absorbed CO_2 can be converted to soil organic carbon, it can be designated as a high C sequestering crop and thereby reduce the atmospheric CO_2 and hence global warming.

Cassava because of its high leaf dry matter production (average 2.5-3 t ha^{-1}) absorbs more CO_2 from the atmosphere to produce more leaf dry matter and due to the innate physiological mechanism of leaf shedding especially during drought will result in incorporating the leaf dry matter into the soil and get converted into soil organic matter. The comparison made between recommended fertilizer practice (POP) and an absolute control (AC) with respect to change in soil organic carbon (SOC) through leaf dry matter addition over a period of 20 years (1990-2009) to highlight the C sequestering efficiency of cassava (Table 2) and thereby global warming is presented. Jian Ni (2004) accomplished the relation that, 1 g dry matter contains 0.45g carbon and hence estimated the carbon content in the leaf dry matter. According to Singh et al., (2007), to produce 1g dry matter, 1.69g CO_2 is absorbed from the atmosphere, thus the atmospheric CO_2 utilized to produce the leaf dry matter was arrived. The atmospheric CO_2 concentration during 1990 is taken as 360 ppm (Ramakrishna et al., 2006) and from this, the reduction in CO_2 content of the air through leaf production was calculated.

Table 2. Potential of cassava for carbon sequestration (Mean over 20 years)

Management practice	Leaf dry matter (t ha^{-1})	Leaf Carbon (t ha^{-1})	Atmospheric CO_2 absorbed (ppm)	Reduction in atmospheric CO_2 (ppm)	Soil organic carbon content (ppm)	Carbon sequestered (ppm)	Tuber yield (t ha^{-1})
Recommended fertilizer practice (POP)	3.726	1.677	62.96	297.04	10460	2460	31.02
Absolute Control (AC)	2.643	1.189	44.659	315.341	8360	1660	13.98

In the absolute control, the CO_2 acquisition and concomitant increase in SOC ranged from 25-50% of POP only. The ultimate effect of sequestering the atmospheric CO_2 through reduction in atmospheric CO_2 and increase in SOC was manifested as increase in tuber yield. Hence, it can be inferred that cassava can sequester atmospheric CO_2 into SOC and mitigate global warming to a great extent.

c. Response of cassava to low input management in cassava

Field experiments conducted for two years resulted in evolving a low input management strategy for cassava involving NUE genotypes viz., CI-905, CI-906, soil test based application of N, P, K, Mg and Zn, green manuring in situ with cowpea as low cost organic manure source and NUE microbial isolates viz., N fixers, P solubilizers and K solubilizers with tuber yield of 33.68 and 34.72 t ha^{-1} and B:C ratio of 4.43 and 4.57 respectively under the above genotypes including a saving of P, K, Mg and Zn to the tune of 100, 11.5, 62.5 and 80% respectively and the percentage increase in cost of inputs under the other high input practices over the low input practice varied significantly up to 55%. The saving of fertilizer inputs and even organic manure in the form of farm yard manure (FYM) can definitely abate soil pollution.

Under the LTFE, soil test based fertilizer cum manurial recommendation with NPK @ 82:0:74 kg ha^{-1} along with FYM @ 5 t ha^{-1} for the last 12 years could realize yield on par with POP (Table 1) linking cassava and its nutrient management through soil test based low input as best solutions to manage soil pollution. This type of need based application of chemical fertilizers and organic manures can avoid non judicious blanket fertilizer application and can definitely be a solution to abate soil pollution.

d. Nutrient use efficient (NUE) cassava genotypes

Research work conducted in fostering the significance of NUE genotypes since 2006 at ICAR-CTCRI resulted in releasing the first K efficient cassava variety 'Sree Pavithra' in 2005 which can yield at low levels of K due to the root architecture with more number of root hairs/ white roots in this variety which can mobilize the fixed K from lower layers to the surface resulting a saving of up to 50% K. Similarly, two N use efficient genotypes viz., W-19 and CR 43-8 were identified which can save N up to 50%. Moreover, three NPK use efficient genotypes viz., CI-905, CI-906 and 7 III E3-5 were screened after conducting field experiments continuously for three seasons for their efficacy to yield even up to 25% NPK for yield on par with 100% NPK, with yield as 32.032, 33.024, 34.292, 36.174 t ha^{-1} respectively at the above NPK levels indicating that, by using these NPK efficient genotypes, NPK fertilizers can be saved up to 75% (Table 3).

Table 3. Tuber yield at Levels of NPK (I,II &III seasons)

	Tuber yield (t/ha)			
	25%	50%	75%	100%
I Year	39.767	41.575	44.342	46.199
II Year	19.850	21.150	17.837	21.290
III Year	36.479	36.347	40.698	41.032
CD(0.05)	NS			
Mean	32.032	33.024	34.292	36.174

Hence, it can be well stated that, by using the NUE genotypes, the use of chemical fertilizers can be reduced and there by soil pollution to a great extent.

e. Best management practices for cassava and elephant foot yam under intercropping in coconut

The BMP evolved and validated for cassava and EFY after conducting 14 field trials for three years in AEU 3 and AEU 9 under intercropping in coconut comprised of organic manures viz., FYM as per POP for EFY @ 25 t ha^{-1} and soil test based application of FYM @7.5 t ha^{-1} for cassava, NPK fertilizers based on soil test @71:12.5:106.5 and 78:12.5:60 kg ha^{-1} for AEU 3 and AEU 9 respectively, lime as per surface soil pH @ @1t ha^{-1}, gypsum as per subsurface soil pH (below 5) @ 2 t ha^{-1}, Dolomite @ 1.5 t ha^{-1}, MgSO4 @80 kg ha^{-1}, ZnSO4 @ 25 kg ha^{-1} and borax @12.5 kg ha^{-1}. These type of need based application of nutrients based on soil test data can be the better means to abate soil pollution.

f. Customized fertilizer (CF) formulations for elephant foot yam under intercroppping in coconut

Customized fertilizer formulations developed based on soil nutrient status and plant nutrient requirement as the three CF's developed for EFY under intercropping in coconut for AEU 3 and AEU 9 with grades as N: P_2O_5: K_2O: Mg: Zn: B @8:11:21:3.5:1:0.3 (CF1), 7:12:24:2.5:1.25:0.4 (CF2), 7:3:25:3:1.25:0.4 % (CF3) is the best option to reduce soil pollution as it implies to need based nutrient management.

g. NUE microbes in reducing the chemical fertilizer use in elephant foot yam

NUE microbes viz., N fixers, P and K solubilizers viz., Bacillus cereus, Bacillus megaterium and Bacillus subtilis respectively as a component of the INM practice in EFY and sweet potato resulted in saving of 25% each of N and K and P up to 50-75%, thereby reducing the use of chemical fertilizers to manage soil pollution to a great extent.

Conclusion

This article highlights the significance of tuber crops and its need based integrated nutrient management strategy in managing the soil pollution to a great extent which can be regarded as the need of the present time where people are very much health conscious. Hence, this year's world soil day theme is very apt as we too are aware of the basic concept that, the composition of a human body is the ultimatum of the air, water and food he intakes. In this respect, the value of soil is immense as it is the foremost substrata for food production and incidentally it put forth the need to take care of the soil health by avoiding all sorts of pollution due to human interventions.

CROPPING SYSTEMS: AN ADAPTIVE STRATEGY FOR MITIGATING SOIL POLLUTION

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Cropping system refers to the crops, crop sequences and management techniques used on a particular agricultural field over a period of years. It aims at the sustainability of the production system aiming at maximum production along with preserving the natural resources and environment. In cropping systems, sometimes a number of crops are grown together or they are grown separately at short intervals in the same field.

Advantages of cropping system in mitigating soil pollution

- Improves soil productivity through soil and water conservation
- Efficient use of available soil resources
- Integrated nutrient management through nutrient recycling thereby reducing soil and environment pollution
- Integrated plant protection through crop rotation, timely planting of crops and ecological engineering
- Minimizes the spread of disease and pest
- Weed management through cover cropping or allelopathy to control weeds thus avoiding the use of herbicides

Systems of cropping

Cropping systems are classified based on the type of crops and cropping pattern

- Monocropping : In this system only a single crop is grown continuously over a period of time. This system reduces the soil fertility and damage the soil structure
- Mixed cropping: Growing two or more crops simultaneously with no distinct row arrangement. Eg; Sorghum, pearl millet and cowpea and broadcasted in rainfed conditions
- Row cropping: Growing two or more crops simultaneously where one or more crops are planted in rows. Eg; maize+greengram, groundnut+redgram

- Strip cropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically. Eg; groundnut+redgram (6:4) strip
- Relay cropping: Growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest
- Multiple cropping : Growing two or more crops on the same field in a year. It is type of polyculture eg: Tomatoes+onions+marigold
- Crop rotation
- Sequential cropping : growing two or more crops in sequence on the same field in a farming year. Eg : Marigold-Gomphrena cropping system
- Parallel Cropping: Under this cropping two crops are selected which have different growth habits and have a zero competition between each other and both of them express their full yield potential.

  E.g. Bindi or amaranthus with banana
- Companion Cropping: In companion cropping the yield of one crop is not affected by other, In other words, the yield of both the crops is equal to their pure crops.

  E.g.1) Mustard, wheat, potato, etc. with sugarcane

2) Marigold-vegetables in coconut garden

- Multistoried Cropping: Growing plants of different height in the same field at the same time is termed as multistoried cropping. It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density.

  E.g. 1)Coconut + Pineapple + Turmeric/Ginger.

2) Sugarcane + Mustard + Potato

- High density multi species cropping system: The practice of growing different crops of varying heights, rooting pattern and duration in a same piece of land. The objective of this system of cropping is to utilize the vertical space more effectively. In this system, the tallest components have foliage tolerant of strong light and high evaporative demand and the shorter component(s) with foliage requiring shade and or relatively high humidity.

  E.g. Coconut + black pepper + cocoa + pineapple.

Role of cropping system in maintaining soil quality

Soil quality is the ability of the soil to sustain productivity without affecting the environment. It is the efficiency of the soil to support crop growth without resulting in degradation. Decline in soil quality can occur due to soil erosion, loss in organic matter, soil compaction or desertification. The quality of soil can be improved by adopting restorative measures such as organic addition, conservation tillage, crop rotation etc. Cropping system is an effective strategy for improving the soil quality and mitigating its pollution. Soil and water conservation, soil fertility and soil problem management is possible through natural biological cycles in a cropping system. Component crops, frequency of a crop and crop sequence affects the productivity of the system. It helps in the optimum utilization of available natural resources and accelerates the soil chemical, physical and biological activities.

Soil chemical quality

It refers to the chemical properties and processes important to plant growth and environment. Maintenance of sufficient plant nutrient balance is critical to soil chemical quality. Adoption of high yielding varieties and intensive cropping enhanced the need of adequate fertilization. Inclusion of leguminous crops in the system promotes favourable soil chemical qualities in comparison to monoculture. The development of sustainable cropping system enhances the soil quality, maximizes the return of investment and minimizes the adverse effects associated with soil loss. Leguminous green crops have great potential as an alternative source for inorganic nitrogen. It contributes to the N content of soil through biological nitrogen fixation when grown as a sole crop in rotation or as an intercrop. Intercropping practices alleviate soil related constraints, enhance organic content and improve the physical quality. Continuous cropping with optimum level of fertilization can maintain or enhance the P status as well. In short, the chemical quality of soil can be maintained by adopting proper cropping systems.

Soil physical quality

The physical quality of the soil plays an important role in determining the movement of air, water, ions and root penetration. Decline in the quality of physical properties leads to crusting, compacting, drought, anaerobiosis, erosion and desertification of the soil. Soil physical properties become favourable in a mulch-based cropping system. Mulching reduces the erosion processes and maintains the colloid contents of the soil surface. Intensive monoculture adversely affects the soil structure which in turn affects hydrologic balance and water quality. Inclusion of suitable plant species in a cropping system and adopting appropriate agronomic methods are essential to enhance soil aggregation and other parameters of soil physical quality.

Cropping system refers to the system of cultivation in which different crops are managed on a particular piece of land for over a period of years. If only one crop is involved in the cropping system, it is called monocropping. Coconut, the major plantation crop of coastal ecosystem, is seldom remunerative as a monocrop. Inclusion of other components in the system helps in improving the farmer's income. The compatibility of the component crops is important for the success of the cropping system. In a cropping system, each crop should be provided with the recommended dose of nutrients. With the advance of technology chemical utilization increased in the field of agriculture with usage of chemical fertilizers and pesticides. The ecological balance gets damaged through the widespread contamination of the soil. Plants in the system Cropping system approach helps in mitigating the soil pollution through intensive agriculture. Crop residue recycling can be practiced for the effective utilization of soil nutrients there by reducing soil pollution. This can reduce the usage of chemical fertilizers and subsequent soil acidity. Acidic deposition in the soil slows down the ability of soil to buffer changes in soil pH. The reduced pH results in uncongenial conditions for effective absorption of plant nutrients from the soil. Fertilizer based soil pollution can also result in the leachage of nutrients into lakes or ponds causing algal bloom, stunted growth and mineral deficiencies. Growing crops with allelopathic effect helps in reducing the use of herbicides. Allelopathy is the effect of one plant species in inhibiting the growth of another plant species through release of chemical substances. Sequential cropping system- the practice of planting a second crop immediately following the harvest of first crop, thus harvesting two crops from the same field in one year- can be adopted in areas with specific soil problems.

Soil biological quality

Soil biota affects the nutrient transformations and alters soil fertility and structure. Cropping system approach helps in nurturing the soil invertebrates which are an important biological factor for mitigating soil pollution. It also influences the soil organic carbon content. Agricultural intensification results to increase in soil organic carbon content by supplying higher organic carbon through crop roots and residues. Type of crops in the cropping system influences the microbial growth and decomposition process in soil. A cropping system that conserves soil organic carbon content may provide agriculture from a carbon source to carbon sink. In low input agricultural systems, this plays an important role in retaining mineral nutrients in the soil and makes it adequately available to plants. Growing cover crops, crop rotations with legumes, addition of organic matter or mulching, intercropping and reduced tillage in cropping systems helps in preventing the loss of soil organic matter. The incorporation of plant residues and other plant wastes enhances the soil organic content of the system. Monocropping systems with low rate of fertilizer application can decrease the soil organic content where intensive cropping system with addition of fertlisers may enhance the organic content due to greater amount of residue returned to the soil. Such management systems help in increases sequestration of carbon in soil, and reduced fossil fuel consumption.

In general, using diverse crops and cropping systems with contrasting effects on soil physical ,chemical and biological quality. Designing suitable farming systems helps in optimizing the use of locally available resources and reducing the use of chemical inputs mitigating soil health.

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COCONUT VARIETIES: A PROMISING SOLUTION FOR SUSTAINING ENVIRONMENTAL EQUITY

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Cocos is a genus in the family Arecaceae, which includes 27 genera and 600 species. Coconut (*Cocos nucifera* L.), the only species in the genus, is an important perennial tropical plantation crop with no known truly wild forms. This palm grows in more than 90 countries which can be grouped into eight distinct coastal/oceanic regions on four continents.

There are two main categories of coconut palms. The Talls ('typica') are naturally cross-pollinating types, have more economic value, are vigorous growing, comparatively late flowering and the fruits are with intermediate colors of brown, green, yellow, orange among individual palms. The Talls flower at 6-10 years with an economic life span of 60-70 years. Dwarfs ('nana'), in contrast, are naturally self-pollinating types with reduced growth habitat, early flowering and produce large number of medium to small, distinctly colored (green or yellow or orange or brown) fruits. Dwarfs have a productive life span of 30-40 years but usually start flowering in the third year.

Information on genetic diversity is of relevance from the breeding point of view, especially in the context of hybrid variety development. Genetic diversity is usually thought of as the amount of genetic variability among individuals of a variety, or population of a species. It results from the many genetic differences between individuals and may manifest in differences in DNA sequence, in biochemical characteristics (e.g. in protein structure), in physiological properties (e.g. abiotic stress resistance) or in morphological characters such as flower colour or plant form. Conservation of coconut diversity in farmers gardens (original location) which is termed as In situ conservation is the best technique for enriching diversity.

Beside the Tall-Dwarf duality, there is considerable morphological variability between ecotypes including the characteristics of the fruit and vegetative organs. This variability is expressed in the size, shape and colour of the fruit and has been used to propose diversification model for the coconut palm based on a comparison between a wild type (Niu kafa) and a selected type (Niu vai). Many efforts are ongoing in coconut growing countries to conserve the rich natural diversity existing in coconut germplasm collections for further utilization in crop improvement programs so that it becomes a more profitable crop for small-farm holders, who constitute the vast majority of coconut growers. As a first step towards this goal, assessment of genetic diversity assumes significance for germplasm conservation and their subsequent utilization.

Collecting, conserving, evaluating and enhancing coconut germplasm of member countries, and locating and characterizing genetic diversity using morphometric and molecular biology techniques, have been some of COGENT's major concerns. ICAR-Central Plantation Crops Research Institute (CPCRI) is involved in collection and conservation of coconut germplasm in India. ICAR-CPCRI hosts the International Coconut Genebank for South Asia (ICG-SA). The field genebank in Kidu Farm, Karnataka, which is the ICG-SA field genebank, is supported technically by the laboratory facilities at ICAR-CPCRI, Kasaragod. CPCRI maintains the world's largest assemblage of germplasm by undertaking the planting and maintenance of the field gene bank and activities on embryo culture, assessment of diversity using molecular markers and disease indexing.

The establishment of gene pools and the conservation of genetic resources are basic to crop improvement. Hence, maintenance of large assemblage of genetic diversity is a vital aspect since crop improvement objectives change over time and it is difficult to predict the future needs accurately. Being a perennial crop with a persistent capacity for sexual reproduction, coconut gene pools serve in two ways; as a collection for breeder's work and as a base collection for conservation. Despite the necessity, it is very important to the country because there are original populations native to areas, which has not being subjected for any artificial selection. Initially the information regarding diversity in coconut ecotypes in collected during exploratory visits undertaken to different coconut growing regions (within India and abroad). Coconut farmers recognize varieties mainly based on colour, shape and size of nuts. The colour of nut varies from dark green to deep orange or brick red. The shape of nuts may be globular, while others may be spindle shaped or even distinctly triangular.

- Kaitha thali: Among the tall palms of the West Coast there is a variety called kaitha thali which is rare. It has soft fleshy edible husk. In the tender nut, the fibres are poorly developed that the husk sometimes eaten raw and is said to be a very good antidote against sea sickness

- Spikeless or spicata: this is quite distinct from ordinary coconut palm in having no branches or spikes in the inflorescence. In the variety, femaleness is most and maleness is least expressed, because of the number of male flowers is as low as 50. It is found that about 50 per cent of the progeny of this variety breed true to type.

- San Ramon: this is a very high yielding type with large nuts mearly twice as large as the ordinary. It requires about 3270 nuts to produce a ton of copra whereas ordinary tall palms require about 6000 nuts.

- Caumanis: sweet tender husk which is eaten like artichoke which it resembles much in flavor
- Thairu thengai: There are certain palms among tall type of the West Coast, which is locally known as thairu thengai (curd coconut). In the nut there is no milk, but is completely filled with a jelly of the consistency of thick curd from which the name is derived. The kernel is not hard to make copra but it is good for eating. These nuts do not germinate but a few in every bunch produced in such trees are quite normal and when planted may give rise to trees of this type.
- Klapawangi: Fragrant endosperm
- Kappadam: this is grouped along with ordinary tall type, but is more robust in all characters particularly in the size of nut which is one of the largest on record.
- Laccadive micro: the nuts are very small and yield is about 160 nuts per palm per year. Average copra content is about 80 to 95 g per nut with oil content of 75 per cent.

Rare traits such as plicata, late flowering, bispatheate (spadix covered by two spathes instead of one) and secondary spikelets (further branching of spikelets) have been reported in Talls. Dwarfs possess other rare traits such as polyembryony, vivipary (general observation) and variegation (pigment variation in leaf / nuts). There are other morphological variants (Menon and Pandalai 1960) such as albinism (lack of chlorophyll), aromatica (fragrant endosperm), change in sex expression and plicata (fused leaflets), bulbils (emergence of shoots from the normal inflorescence with a green spathe covering in the leaf axil), midget palm (flowering in early infant stage), pink husked palm, horned coconut. The variations in such traits could be either genetic or physiological in nature. These unexploited traits have lot of scope for use in the breeding program and they are not been used to their potential.

Varieties developed through selection

Selection and evaluation of promising accessions conserved at CPCRI, coordination centres at All India Coordinated research Project on Palms and the State Agricultural universities have resulted in the development and release of 27 high yielding varieties of coconut, suitable for different agro climatic zones through application of mass selection. Breeding efforts in the country in addition to development of high yielding varieties suitable for copra/oil/ tender nut have also focused on development of disease resistance, especially to root (wilt) disease of coconut. Chowghat orange Dwarf (COD) is recommended as the best tender nut variety.

Sl. No.	Variety	Important trait	Nut yield (nuts/ha/ year)	Copra yield (t/ha)	Agency responsible for release
Tall					
1	Chandra Kalpa	Drought tolerant, high copra oil content, suitable for neera	17700	3.12	CPCRI
2	Kerachandra	High yield, dual purpose	19470	3.86	CPCRI
3	Kalpa Prathibha	High nut, oil yield , dual purpose	16107	4.12	CPCRI
4	Kalpa Mitra	High nut, oil yield, drought tolerant	15222	3.68	CPCRI
5	Kalpa Dhenu	High nut, oil yield, drought tolerant	14160	3.41	CPCRI
6	Kalpa Haritha	Dual purpose, less eriophyid mite damage	20886	3.70	CPCRI
7	Kalpatharu	Drought tolerant, ball copra, high yield, coir fibre amenable for dyeing	20709	3.64	UAS, Karnataka
8	Pratap	High yield	26727	4.01	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Maharashtra
9	Kamrupa	High yield	17877	2.90	AAU,Assam
10	ALR (CN) 1	High yield	22303	3.50	TNAU
11	Kera Bastar	High yield	19470	3.18	Indira Gandhi Agricultural University, Chhatisgarh
12	Kalyani coconut 1	High yield	14160	3.84	Bidhan Chandra Krishi Viswavidyalaya, West Bengal
13	Kera Keralam	High yield, drought tolerant, suitable for neera	26019	3.53	TNAU
14	ALR (CN) 2	High yield	21240	2.89	TNAU
15	VPM 3	High yield, drought tolerant	14868	3.41	TNAU
16	Kera Sagara	High yield	17523	3.64	KAU

Dwarf/ semi tall					
17	Chowghat Orange dwarf	Tender nut purpose, orange nuts	19824	2.78	CPCRI
18	Kalparaksha	Semi tall, green colour	13260 (17748)	2.85 (3.34)	CPCRI
19	Gauthami Ganga	Tender nut pupose , green colour fruit	11505	1.80	ANGRAU
20	Kalpasree	Early flowering, green fruit, recommended for root (wilt) tract	15930	1.54	CPCRI
21	Kalpa Jyothi	Tender nut purpose, yellow color fruit	20178	2.86	CPCRI
22	Kalpa Surya	Tender nut purpose, orange color fruit	21771	4.07	CPCRI
23	Kera Madhura	Semi tall, dual purpose	24480	4.80	KAU
24	CARI-C1 (Annapurna)	High copra content, tender nut purpose, green fruit	9133	2.20	CARI, Andamans
25	CARI- C2 (Surya)	Ornamental purpose, orange color fruit	20231	1.41	CARI, Andamans
26	CARI- C3 (Omkar)	Ornamental purpose, yellow color fruit	24072	1.77	CARI, Andamans
27	CARI- C4 (Chandan)	Ornamental purpose, orange color fruit	16373	1.67	CARI, Andamans

Hybrid development:

Among the several breeding methods, exploitation of heterosis has the maximum impact on improvement of cross-pollinated crops. Since the desired characters such as high yield, precocity in bearing, better quality, high copra and oil content, drought tolerance and disease resistance are distributed among different varieties or different individuals of the same variety, hybridisation is by far the most useful method to bring together the desirable traits. Harland advocated the exploitation of hybrid vigour to increase the productivity of coconut. A new dimension to coconut improvement was added with the discovery that the hybrids made by Dr. J S Patel (1937) between Tall and Dwarf cultivars showed enormous vigour, enhanced production potential and early bearing tendency.During 1970-1990 production of T x D hybrids was common throughout India. However, efforts to evaluate D x T hybrids started simultaneously and the first D x T (Chandra Sankara) was released during 1985. Nowadays, D x T is more common due to the ease with which it can be produced compared to T x D hybrids. Efforts are also for evaluation of precocious and high yielding D x D hybrids. For carrying out hybridization (D x T or T x D) in coconut, knowledge about the floral biology and the hybridisation technique is essential. So far, 19 hybrids, including eight superior Dwarfs x Tall hybrid varieties and 11 Tall x Dwarf varieties have been developed in India for commercial cultivation in different regions.

Sl No.	Hybrid	Parents	Important trait	Nut yield (nuts/ha /year)	Copra yield t/ha)	Agency
1	Chandra Sankara	COD x WCT	High yield	20532	4.27	CPCRI
2	Chandra Laksha	LCT x COD	High yield, drought tolerant	19293	3.76	CPCRI
3	Kera Sankara	WCT x COD	High yield, drought tolerant	19116	3.78	CPCRI
4	Kalpa Samruthi	MYD x WCT	Dual purpose, drought tolerant	20744	4.35	CPCRI
5	Kalpa Sankara	CGD x WCT	Tolerant to root (wilt) disease	14868	3.20	CPCRI
6	Kalpa Sreshta	MYD x TPT	Dual purpose, high yield	29227	6.28	CPCRI
7	Laksha Ganga	LCT x GBGD	High yield	19116	3.73	KAU
8	Ananda Ganga	ADOT x GBGD	High yield	16815	3.63	KAU
9	Kera Ganga	WCT x GBGD	High yield	17700	3.56	KAU
10	Kera Sree	WCT x MYD	High yield	23364	5.05	KAU
11	Kera Sowbhagya	WCT x SSAT	High yield	23010	4.49	KAU

12	VHC-1	ECT x MGD	High yield	21240	2.87	TNAU
13	VHC-2	ECT x MYD	High yield	25134	3.74	TNAU
14	VHC-3	ECT x MOD	High yield	27612	4.47	TNAU
15	Godavari Ganga	ECT x GBGD	High yield	18585	2.79	ANGRAU
16	Konkan Bhatye Coconut Hybrid 1	CGD x WCT	High yield	20532	3.47	Dr. SSKKV
17	Kalpa Ganga	GBGD x FJT	High yield, suitable for ball copra	21417	3.38	UHS
18	Vasista Ganga	GBGD x PHOT	High yield	22125	3.88	Dr. YSR Horticultural Univ.
19	Ananta Ganga	GBGD x LCT	High yield	22656	3.85	Dr. YSR Horticultural Univ.

Conclusion

Although the large standard collection of coconut germplasm has been used for development of many varieties, there is an urgent need to utilize the special types such as aromatic coconut and sweet coconut in breeding programs to diversify the coconut cultivation. Considering the achievements made and opportunities available, the strategies suggested for future breeding programs include in situ conservation of unique types and those with rare traits have lot of relevance in the present situation wherein climate resilient varieties are the need of the hour. Climate resilient varieties will evolve and adapt only in diverse environment. Such evolution is curtailed in gene banks where we promote uniform environment and the best management practices. In situ conversation and on-farm conservation techniques which will conserve the unique environment and soil microbiome are to be promoted. Efforts in this direction for germplasm conservation will pay rich dividends in the coming years as we can expect evolution of climate resilient varieties.

EMERGING THREATS ON ENVIRONMENTAL SUSTAINABILITY

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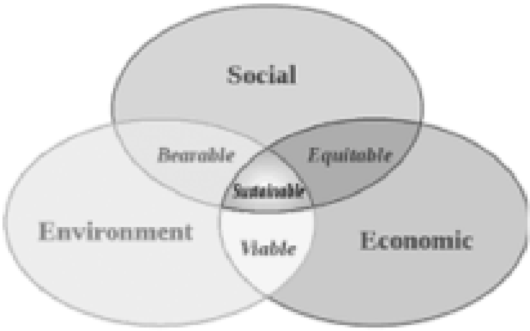
Environmental sustainability is defined as responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs. When we look at the natural environment, we see that it has a rather remarkable ability to rejuvenate itself and sustain its viability. For example, when a tree falls, it decomposes, adding nutrients to the soil. These nutrients help to sustain suitable conditions for the growth of future saplings. When nature is left alone, it has a tremendous ability to care for itself. However, when man enters the picture and uses many of the natural resources provided by the environment, things change. Human actions can deplete natural resources, and without the application of environmental sustainability methods, long-term viability can be compromised.



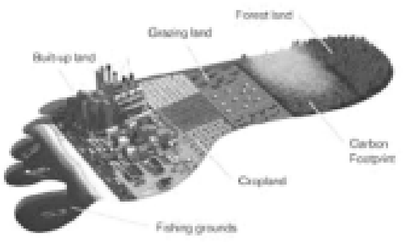
The goal of environmental sustainability is to conserve natural resources and to develop alternate sources of power while reducing pollution and harm to the environment. Sustainability should lead to social development, economic growth and environmental protection. Social development is about improving the well-being of every individual in society so they can reach their full potential. The success of society is linked to the well-being of each and every citizen. Social development means investing in people. It requires the removal of barriers so that all citizens can journey toward their dreams with confidence and dignity. Economic growth is the increase in market value of goods and services produced by an economy over time. It is conventionally measured as the percent rate of increase in real gross domestic product, or real GDP. Environmental protection is practiced for protecting the natural environment on individual, organization controlled by governmental levels, for the benefit of both the environment and humans.

Earth Overshoot Day

Earth Overshoot Day (EOD), previously known as Ecological Debt Day (EDD), is the calculated illustrative calendar date on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year. Earth Overshoot Day is calculated by dividing the world bio-capacity (the amount of natural resources generated by Earth that year), by the world ecological footprint (humanity's consumption of Earth's natural resources for that year), and multiplying by 365, the number of days in one Gregorian common calendar year:

(World Bio-capacity/World Ecological Footprint) x 365

Andrew Simms of UK think tank New Economics Foundation originally developed the concept of Earth Overshoot Day. When viewed through an economic perspective, EOD represents the day in which humanity enters an ecological deficit spending. In ecology the term Earth Overshoot Day illustrates the level by which human population overshoots its environment. In 2018, Earth Overshoot Day is on August 1. Earth Overshoot Day is calculated by Global Footprint Network and is a campaign supported by dozens of other nonprofit organizations.



There are two great emerging threats in environmental sustainability viz., Biodiversity loss and Invasion by Alien Invasive Species

Biodiversity

Biodiversity refers to the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes including diversity within species, between species and of ecosystem. There are 1,435,662 identified species all over the world which includes 751,000 species of insects, 250,000 of flowering plants, 281,000 of animals, 68,000 of fungi, 30,000 of protists, 26,900 of algae, 4800 of bacteria and 1000 viruses. Approximately 27,000 species become extinct every year. Majority of them are small tropical organisms. Extinction of species leads to further destruction of fragile ecosystems. If this trend of biodiversity depletion continues, one-fourth of the world species may be lost by the year 2050.

The term biodiversity was coined by Walter G. Rosen in 1985 during the first planning meeting of the National Forum on Biodiversity held in Washington DC in September 1986, the proceedings of which brought the notion of biodiversity to the attention of wide field of scientists. However, the credit of popularising this word goes to E.O. Wilson, who is called as Father of Biodiversity. Of the 20 hot spots of the world reported so far, two of them belong to India. The Eastern Himalayas and Western Ghats are the two hot spots of biodiversity in India encompassing rich floral and faunal wealth.

Genetic erosion

The twentieth century has witnessed a loss of 75% of the genetic diversity of crop plants. High yielding varieties have occupied more than 60% area of wheat and rice lands. Out of 3000 food plant species only 150 were commercialized. Agriculture is dominated by only 12 species out of which four yields more than 50% of the total production (Rice, wheat, Maize and Potato). Genetic erosion is a matter of serious concern which could hamper the crop improvement programmes. The maintenance of a diversity of crops with different characteristics gives the community a buffer stock of food in case of droughts, floods, pest attack or disease outbreak.

The major factors leading to extinction of a species and consequent loss of biodiversity are a) habitat loss and fragmentation, b) Introduction of exotic species, c) Invasion by alien species, d) Over exploitation, e) Soil, water and atmospheric pollution, f) Intensive agriculture and monocultures.

Bio-security issues in coconut

Biological invasions, the routine importation (both accidental and deliberate) of harmful non-native organisms occur daily, and are estimated to cost more than $100 billion loss per year world-wide. Nonetheless, the scientists, policy makers and public over the whole world including India are paying considerably less attention and spending far fewer resources than needed to identify and address bio-invasions and their manifold impacts that include chronic damage to societal infrastructure, agro-ecology, fisheries, the environment and human health. Economic losses due to bio-invasions are substantial in many parts of the world including India. Twenty-five percentages of costs of food consumables accessible to customers are attributed to invasive weeds, pests and diseases. Invasive species are second only to habitat destruction as the major cause of biodiversity loss. In the globalized era, goods and services produced in one part of the world are increasingly available in other parts of the world and people around the globe are more connected to each other than ever before paving way for accidental introduction of invasive pests. International travel is more frequent resulting in several biosecurity threats. Establishing risk-based biosecurity systems in different countries is vital to safeguard the food supply chain.

Quarantine

The word “Quarantine” took shape from the Venetian dialect form of the Italian quaranta giorni, meaning 'forty days', which is the minimum number of days ships were required to be isolated before passengers and crew could disembark during the pandemics of Black Death. In Old Testament the book of Leviticus 13: 46, stated that anyone with leprosy remains unclean as long as they have the disease and that they must live outside the camp away from others (Paul, 2002) indicating the influence of quarantine suppressing disease spread from time immemorial and its impact that is likely to bring forth benefits in the larger interest of the human well-being.

Plant quarantine is a government endeavour enforced through legislative measures to regulate the introduction of planting materials, plant products, soil, living organisms etc., in order to prevent inadvertent introduction of pests (including fungi, bacteria, viruses, nematodes, insects and weeds) harmful to agriculture of a country/state/region, and if they are introduced, to prevent their establishment and further spread. After the Second World War, FAO convened an International Plant Protection Convention (IPPC) in 1951 to which India became a party in 1956. Currently it has 179 signatory countries.

Invasive pests on coconut already reported in the country

a) Coconut eriophyid mite: The exotic pest, coconut eriophyid mite, Aceria guerreronis Keifer was reported from all coconut growing regions ranging from 0.2% in Bay Islands to 57.3% in Karnataka. Ever since the pest was first reported in the country from Kochi, Kerala during 1998, it had spread like a wild fire affecting all coconut plantations in key south Indian states.

b) Asian grey weevil: Myllocerus undatus Marshall (Curculionidae ; Coleoptera), a pest of quarantine importance was registered from root (wilt) diseased tracts of coconut in Kerala. Mild to medium level of infestation damaging 5-10% of leaf area of un-split leaves with typical notching-like symptom along the leaf margins was noticed on majority of the coconut seedlings in root (wilt) endemic zones. In the nursery area with nearly 10,000 coconut seedlings, more than 40% seedlings were found infested by the weevil affecting the marketing potential of seedlings. The characteristic feature of this weevil is the presence of three-spined hind femur and is considered as an invasive pest from Sri Lanka.

c) Inflorescence moth: Occurrence of non-native inflorescence moth, Batrachedra arenosella (nuciferae) was observed from Port Blair-Bay Island, Minicoy-Lakshadweep Island, Kasaragod-Kerala, Ambajipeta-Andhra Pradesh, Jagdalpur-Chhattisgarh and parts of Karnataka. The pest incidence was quite higher in Niu Leka Green Dwarf at World Coconut Germplasm Centre, Port Blair when compared to other Pacific Ocean collections maintained there.

d) Spiraling whitefly: Sporadic incidence of spiraling whitefly, Aleurodicus dispersus Russel recorded from Minicoy Island, Kerala and Tamil Nadu was effectively bio-suppressed by natural enemies. As the name suggests, adults of A. dispersus has a typical spiralling fashion of egg-laying and found in mild to moderate levels during March-May. It is highly polyphagous pest infesting a wide array of crops in coconut plantations.

e) Rugose spiraling whitefly: The latest entry in this series is Aleurodicus rugioperculatus Martin introduced from Belize, Central America during 2016 in Pollachi and Palakkad area. It was found to feed and breed profusely from the under surface of the palm leaves, numbering more than 10 live colonies in a leaflet. As rugose spiralling whitefly (RSW) is a highly polyphagous invasive species, a biosecurity alarm was sounded to monitor its spread and extent of damage caused. Though RSW initially created panic by its expansive mode of ovipositional damage in different crops including banana, bird of paradise, custard apple, jack, Heliconia sp., etc., it could not sustain feeding on other crops successfully compared to coconut and relatively to some extent, on banana, which are its most favoured host plants. Encarsia guadeloupae Viggiani, an aphelinid parasitoid of spiralling whitefly (Aleurodicus disperses Russell) fortuitously introduced in India in the late 1990s and well established in South India, turned out to be a very effective parasitoid of A. rugioperculatus as well. It parasitized A. rugioperculatus to an extent of 60% and kept the pest under check not allowing it to flare up in any of the South Indian States from where RSW has been recorded so far. Extensive deposits of sooty mould, Leptoxyphium sp. was found on the upper surface of palm leaves and other intercrops, which forms one of the identification features of pest attack. Of late, scavenging associated novel discovery of a Leiochrini beetle, Leiochrinus nilgirianus Kaszab could be identified feeding on the sooty mould and cleansing the palms as Swachh palm Abhiyan.

Impending biosecurity risks

Coconut leaf beetle, Brontispa longissima Gestro and the armoured scale insect, Aspidiotus rigidus ravaging Maldives and Philippines, respectively though could not be encountered so far in our survey, but are impending dangers at our door steps.

a) Brontispa longissima (Chrysomelidae : Coleoptera)

The outbreak of the B. longissima in Myanmar and Maldives in recent years poses a great threat and concern to the nearby countries such as India, Sri Lanka and Bangladesh. It is feared that the pest will find its way from Maldives to Sri Lanka and Southern parts of India to derail the economy of these important coconut growing regions of the world. Since invasive pests fail to restrict along political / agro-ecological boundaries countries like India, Bangladesh and Sri Lanka are ever in red alert zones. For all those countries, where coconut and coconut based industries support millions of people, the pest incursion would be catastrophic. Coconut leaf beetle (CLB) was originally described in 1885 from Aru Islands in Indonesia and from Papua New Guinea.

b) Wallacea jarawa (Chrysomelidae : Coleoptera)

A close relative of the chrysomelid beetle, B. longissima, viz., Wallacea jarawa feeding on the spear leaf region of coconut seedlings was recently recorded from South and Little Andaman. The feeding niche of Wallacea jarawa confining on coconut spindle is a matter of concern, however, the pest was not observed from any adult palm during the snap survey conducted during October 2014. Though 80-90% of seedlings were infested by the pest damaging about 40% of leaf area, there was no seedling mortality. It is a matter of domestic quarantine.

c) Aspidiotus rigidus (Diaspididae : Hemiptera)

Hard scale, A. rigidus, is a close relative of Aspidiotus destructor, a minor pest reported from Kerala, Tamil Nadu and other coconut growing tracts of the country. Gradient outbreak of coconut scale insect, A. destructor was observed at Chingoli near Kayamkulam, Kerala during August-September 2012. A. rigidus is reported to be a ravaging pest in The Philippines incurring huge loss to coconut growers in that country. It is also reported as an emerging invasive threat in our country. The mobile stage being the crawlers and males are easily drifted away by wind or passively carried through any inert packaging materials, nuts, leaflets, dried spathes, etc.

d) Red ring disease in coconut

It is caused by the nematode, Bursaphelenchus cocophilus (Cobb) Goodey and transmitted by the palm weevil, Rhynchophorus palmarum. Juvenile nematodes are transmitted especially during oviposition and other activities. Young palms between 30 months and 10 years old are susceptible. Yellowing followed by browning and drying of older leaves and premature nut fall are the external symptoms in affected palms. The cross sections of the affected palms show diagnostically, The presence of a reddish brown ring of 2-4 cm width about 2-5 cm inside from the stem periphery is the characteristic diagnostic internal symptom of the disease. This extends throughout the stem but is clearest about 1 m above ground level. Red streaks may appear in the petioles, and the roots become orange to faint red, dry and flaky. The key sign is the presence of the nematode in the reddened tissues and gradually the affected palms die. The disease is distributed in Caribbean area (Grenada, St. Vincent and the Grenadines, and Trinidad & Tobago), Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), North America(Mexico), South America (Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, and Venezuela).

Sustainable Agriculture

One way environmental sustainability is being applied through sustainable agriculture. This is defined as the use of farming techniques that protect the environment. Sustainable agriculture has grown out of concerns over the industrialization of agriculture that began in the 20th century. Although industrial agriculture has the ability to produce abundant amounts of food at affordable prices, the method of farming can be detrimental to the environment. Industrial agricultural methods are heavily reliant on chemical fertilizers and pesticides and put high demands on soil and water resources. Also, industrial crops are often monocrops, which involves growing a single crop year after year. These methods can lead to water pollution when chemicals run off into waterways, deplete the water resources due to overuse, and soil erosion and poor soil quality due to aggressive planting. With sustainable agriculture, farmers minimize water use and lower the dependence on chemical pesticides and fertilizers. They also minimize tillage of the soil and rotate crop planting each year to ensure higher soil quality.

A crop habitat based pest regression module has been developed at ICAR-CPCRI with Kalpasankara coconut hybrid and intercrops such as nutmeg, rambuttan, banana, curry leaf, jack, marigold, custard apple etc for framing farming to fullness. Pest incidence was comparatively low in the ecological engineering plot compared to that of mono-cropped coconut garden wherein two to four folds increase in pest incidence could be observed. Admixture of volatile cues due to crop pluralism including eco-feast crops disoriented pests away from ecological engineering garden and ensuring a high population of pest defenders and pollinators as well. A significant attraction of honey bees on coconut and coral vines is indicated in ecological engineering plot. Reduction in pest incidence and systematic crop care could boost up the coconut yield averaging 161 nuts per palm per year after five years of planting. A crop pluralism based distraction of pests could thus be accomplished. In addition to pest regression, a sustained income and employment through complementary utilization of resources was the star attraction of this module that would de-risk farmers who generally adopt for intensive mono-cropping by suppressing diversity.

A holistic approach of crop care, nutrition, water and intercropping is therefore the need of the hour as part of technology integration for inclusive development and doubling income. The yield is faster and fatter in ecological engineering system and accumulation of organic wealth is quite profound. Sustainability mode and ecological viability is well realized in this concept of functional diversity coupled with generation of continuous income and employment making farming lucrative and to reduce risk from eventualities. Such module needs better attention at policy level to augment income and maintain the ecosystem. Not only pests are reduced in the system, the spectrum of pollinators, scavengers and defenders dominate the niche making biotic system well balanced and sustaining the fragile ecosystem as well.

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AN INSIGHT INTO THE REGIME OF SOIL BORNE PLANT PATHOGENS

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Introduction

The diseases that are caused by pathogens which persist (survive) in the soil matrix and in residues on the soil surface are defined as soil borne disease. Thus the soil is a reservoir of inoculum of these pathogens, the majority of which are widely distributed in agricultural soils. However, some species show localised distribution patterns. Most often they cause damage to root and crown tissues of the plant that is hidden in the soil. Thus these diseases may not be noticed until the above-ground (foliar) parts of the plant are affected severely showing symptoms such as stunting, wilting, chlorosis and finally death.

Soil borne diseases are difficult to control because they are caused by pathogens which can survive for long period of time in the absence of the normal crop host and often have a wide host range including weeds. These diseases are often very difficult to diagnose accurately. Because of their microscopic size and non-specific symptoms of an infection, soil borne organisms live out of sight and, generally out of mind of the growers and plant protection workers. The effective control of the soil borne diseases is possible only through detailed study on survival, dissemination of soil borne pathogens and effect of environmental conditions. Cultural practices and host resistance and susceptibility can play a major role in disease management.

Biology of soil borne pathogens Survival

Soil borne pathogens survive as soil inhabitants (survive in soil for relatively longer periods), soil invaders or soil transients (survive in the soil for relatively shorter periods). Soil borne pathogens also survive as non-pathogenic and generally in the form of saprobes (organisms that live on decaying organic matter). Under certain congenial conditions these saprobes will turn into pathogenic form.

Distribution of pathogens in the soil

The horizontal and vertical distribution of soil borne pathogens depends on production practices, cropping history, and a variety of other factors. Along a vertical axis, the inoculum of most root pathogens lies within the top 10 inches of the soil profile, the layers where host roots and tissues and other organic substrates are found. On the horizontal plane, distribution of inoculum in a field is usually aggregated in areas where a susceptible crop has been grown.

Factors that influence the distribution

Many factors in the soil influence the activity of soil borne pathogens and diseases. Soil type, texture, pH, moisture, temperature, and nutrient levels are among them. Soils that drain poorly, however, tend to favour the survival and distribution of soil borne pathogens such as Pythium, Phytophthora, and Aphanomyces. Similarly, Fusarium and Verticillium wilts can also be more severe in wet soils than in dry soils. Only a few root diseases are favoured by drier soils (for example, common scab of potato caused by Streptomyces scabies).

Predominant Soil borne Pathogens

Fungi: *Sclerotium rolfsii, Rhizoctonia solani, Fusarium sp, Pythium, Phytophthora* etc.

Bacteria: *Erwinia, Raltsonia, Rhizomonas, Agrobacterium, Streptomyces* etc.

Different types of diseases caused by soil borne plant pathogens

Root rots

Soil borne diseases are caused by a diverse group of fungi and related organisms. The most important genera include Pythium and Phytophthora, Rhizoctonia, Cylindrocladium and Armillaria which causes root rots. These diseases are characterized by a decay of the true root system; some pathogens are generally confined to the juvenile roots whilst others are capable of attacking older parts of the root system. Symptoms that are observable include wilting, leaf death and leaf fall, death of branches and limbs and in severe cases death of the whole plant. Some examples of these diseases are shown below.

Rhizoctonia Root Rot Disease

Known as damping-off, wire stem, head rot or crown rot. In older seedling the invasion of the fungus is limited to the outer cortical tissues which develop elongate tan to reddish – brown lesion. The region may increase in length and width until they finally girdle the stem and the plant may die. The fungus is responsible for brown patch of turf grass, damping off of pulses, black scurf of potatoes, bare patch of cereals, root rot of sugarbeet, belly rot of cucumber, sheath blight of rice etc.

Stem, collar and head rots

These diseases are also caused by a diverse group of pathogens like Phytophthora, Sclerotium, Rhizoctonia, Sclerotinia, Fusarium and occasionally by Aspergillus niger. The most obvious symptom of these diseases is the decay of the stem at ground level. Quite often this decay can lead to symptoms of wilting, death of leaves and to death of the plant. Phytophthora for example, can cause diseases such as heart rot of pineapple, blight of potato and tomato and some fruit rots in these conditions. Similarly Rhizoctonia can cause leaf blight in maize and head rot of cabbage in warm wet weather.

Wilts

The main species of fungi that cause these diseases are Fusarium oxysporum and Verticillium spp. The symptoms of these diseases include wilting of the foliage and internal necrosis of the vascular tissue in the stem of the plant. Some species of bacteria can also cause similar types of diseases.

Seedling blights and damping off diseases

Fungi that commonly cause seedling death include Pythium, Phytophthora, Rhizoctonia, Sclerotium and less commonly Fusarium sp. These fungi can infect seedli8ng during the germination, pre-emergence or post emergence phases of seedling establishment. Pythium, Rhizoctonia and Sclerotium are commonly associated with seedling death of vegetables such as beans, cucurbits, tomato, cabbages and other cruciferous crops.

Pythium Damping –off Disease

The species most often encountered are Pythium debaryanum, P. ultimum, P. aphanidermatum, and *P. graminicola*. The disease often occurs in a roughly circular pattern. This is because of the tendency of fungi to grow radically from the point of origin, which is one of the field markers to distinguish the diseases between other factors that cause the same symptoms.

Phytophthora damping-off

Phytophthora species belong to class Oomycetes, family Pythiaceae. *P. cactorum, P. fragaria, P. palmivora, and P. syringae* cause primarily stem rot, damping off of vegetables, forest trees, and ornamentals. Unlike Pythium, Phytophthora is aggressive in warmer soil temperatures (15-23° C), but still cooler condition; flooding, along with warm temperature. Initially affected tissue develops a soft, watery brown rot. Within several days, the affected plant parts may dry.

Management of soil borne diseases

Management of soil borne diseases depends on a thorough knowledge of the pathogen, the host plant, and the environmental conditions that favours the infection. In order to develop a disease, all three factors must be present. The pathogen (a virulent, infectious agent) must have viable inoculum, such as zoospores, available to infect the host. The host (a susceptible plant) must be exposed to the pathogen's inoculum, and be physiologically susceptible to infection. Finally, the environmental conditions must be favourable for the infection of the plant and growth of the pathogen. For example, the soil must be saturated with water for a certain period of time which facilitates water moulds to develop and infect the roots. An understanding of these pathogen-host-environment dynamics will help you devise a disease management strategy. An effective disease management option must be economical: that is, the value of the crop saved must exceed the cost of control. For this reason, assessments of disease incidence, disease severity, and potential crop loss are key factors when considering control strategies. The careful, regular monitoring of fields and the thorough examination of symptomatic plants are essential steps. The timing of control measures is also critical. Management of a destructive disease such as Phytophthora root rot may require early implementation of appropriate management measures. Besides being economically sound, a management strategy should also be simple, safe, inexpensive to apply, and sufficiently effective to reduce diseases to acceptable levels. Few management options possess all of these desirable qualities, however, it is usually best to integrate multiple management options (e.g., planting resistant varieties, following beneficial cultural practices, and applying disease-control materials).

Cultural control

Fertilizer application:

- Application of fertilizers along with irrigation improves the overall plant health and thereby reduces the impact of severity of diseases.
- Application of ammonium bicarbonate reduce the viability of sclerotial bodies of S. rolfsii
- Application of phosphatic fertilizers also influences the host resistance by

increasing the production of phytoalexins

- Management of Pythium and Phytophthora by application of phosphoric acid.
- Application of gypsum reduces the incidence of Macrophomina in groundnut.

Providing good soil drainage and good air circulation among plants

Good soil drainage reduces the number and activity of certain oomycetes pathogens (eg.,Pythium) and nematodes. Flooding fields for long periods or dry fallowing may also reduce Fusarium, Sclerotinia sclerotiorum, and nematodes. Irrigation also helps to reduce the soil borne disease charcoal rot caused by M. phaseolina.

Crop rotation

Generally soil borne pathogens survive in the soil and plant debris up to several years. Crop rotation will be helpful to control the soil borne inoculum as it will be reduced due to non availability of the host. Satisfactory control through crop rotation is possible with pathogens that are soil invaders, i.e., survive only on living plants or only as long as the host residue persists as a substrate for their saprophytic existence. When the pathogen is a soil inhabitant, however, i.e., produces long-lived spores or can live as a saprophyte for more than 5 or 6 years, crop rotation becomes less effective or impractical. In the latter cases, crop rotation can still reduce populations of the pathogen in the soil (e.g., Verticillium) and appreciable yields from the susceptible crop can be obtained every third or fourth year of the rotation. In some cropping systems the field is tilled and left fallow for a year or part of the year.

Soil amendments

Application of organic amendments like saw dust, straw, oil cake, etc., will effectively manage the diseases caused by Pythium, Phytophthora, Verticillium, Macrophomina, Phymatotrichum and Aphanomyces. Population of beneficial microorganisms will increase in the soil which in turn will help in suppression of pathogenic microbes. For example, application of lime (2500 Kg/ha) reduces the club root of cabbage by increasing soil pH to 8.5. Similarly application of sulphur (900 Kg/ha) to soil brings the soil pH to 5.2 and reduces the incidence of common scab of potato cause by Streptomyces scabies. Application of castor cake and neem leaves helps to reduce the foot rot of wheat.

Soil Solarization

When clear polyethylene is placed over moist soil during sunny summer days, the temperature at the top 5 centimetres of soil may reach as high as 52°C compared to a maximum of 37°C in un-mulched soil. If sunny weather continues for several days or weeks, the increased soil temperature from solar heat, known as solarization, inactivates (kills) many soil borne pathogens such as fungi, nematodes, and bacteria near the soil surface, thereby reducing the inoculum and the potential for disease. Verticillium wilt, Fusarial wilt can be controlled by soil solarization. Bacterial canker of tomato, caused by Clavibacter michiganense, can also be reduced by this method. Sub-lethal doses of temperatures due to soil solarization also make the pathogen propagules more susceptible to attack of biocontrol agents.

Biological control

Biological control of pathogens, i.e., the total or partial destruction of pathogen populations by other organisms, occurs routinely in nature. There are, for example, several diseases in which the pathogen cannot develop in certain areas either because the soil, called suppressive soil, contains microorganisms antagonistic to the pathogen or because the plant that is attacked by a pathogen has also been inoculated naturally with antagonistic microorganisms before or after the pathogen attack. Sometimes, the antagonistic microorganisms may consist of avirulent strains of the same pathogen that destroy or inhibit the development of the pathogen, as in case of hypovirulence and cross protection. In some cases, even higher plants reduce the amount of inoculum either by trapping available pathogens (trap plants) or by releasing into the soil substances toxic to the pathogen. Researchers have increased their efforts to take advantage of such natural biological antagonisms and to develop strategies by which biological control can be used effectively against several plant diseases.

Suppressive Soils

Several soil borne pathogens, such as Fusarium oxysporum (the cause of vascular wilts), Gaeumannomyces graminis (the cause of take-all of wheat), Phytophthora cinnamomi (the cause of root rots of many fruit and forest trees), and Pythium spp. (a cause of damping-off) develop well and cause severe diseases in some soils, known as conducive soils, whereas they develop much less and cause much milder diseases in other soils, known as suppressive soils. The mechanisms by which soils are suppressive to different pathogens are not always clear but may involve biotic and/or abiotic factors and may vary with the pathogen. In most cases, however, it appears that they operate primarily by the presence of one or several microorganisms antagonistic to the pathogen. Such antagonists, through the antibiotics they produce, through lytic enzymes, through competition for food, or through direct parasitizing of the pathogen, or do not allow the pathogen to reach high enough populations to cause severe disease. Numerous kinds of antagonistic microorganisms have been found to increase in suppressive soils; most commonly, however, pathogen and disease suppression has been shown to be caused by fungi, such as Trichoderma, Penicillium, and Sporidesmium, or by bacteria of the genera Pseudomonas, Bacillus, and Streptomyces. Suppressive soil added to conductive soil can reduce the amount of disease by introducing microorganisms antagonistic to the pathogen. For example, soil amended with soil containing a strain of a Streptomyces sp. antagonistic to S. scabies, the cause of potato scab, resulted in potato tubers significantly free from potato scab. Suppressive, virgin soil has been used, for example, to control Phytophthora root rot of papaya by planting papaya seedlings in suppressive soil placed in holes in the orchard soil, which was infested with the root rot Phytophthora palmivora.

Chemical Control

Chemical pesticides are generally used to protect plant surfaces from infection or to eradicate a pathogen that has already infected a plant. A few chemical treatments, however, are aimed at eradicating or greatly reducing the inoculum before it comes in contact with the plant. They include soil treatments (such as fumigation), disinfestation of warehouses, sanitation of handling equipment, and control of insect vectors of pathogens.

Host Plant Resistance

Growing of resistance plants is one of the most effective and economical method. Host plant resistance not only reduces the crop losses but lessens the expenditure incurred on disease control as well as reduces the pollution hazards.

Monogenic (Vertical)

It is also known as race specific or major gene resistance. It is complete and is stable for pathogens having a few pathotypes but breakdown easily in others. In case of cabbage yellows (F. Oxysporum f.sp. conglutinans) monogenic resistance is permanent in nature.

Polygenic (Horizontal)

Also known as race non-specific or quantitative resistance. Polygenic resistance is less effective but generally lasts longer.Host resistance is most effective when combined with cultural and chemical methods.

Transgenic Approaches

Modern DNA technology has made it possible to engineer transgenic plants that are transformed with genes for tolerance of adverse environmental factors, for resistance against specific diseases, or with genes coding for enzymes such as chitinases and glucanases directed against certain groups of pathogens, such as fungi, viruses, and bacteria, or with nucleic acid sequences that lead to gene silencing of pathogens.

Resistance conferred through specific plant genes

There are numerous crops in which plant genes for specific pathogens have been isolated from resistant plants, transferred into susceptible plants, and expressed in these plants. Provided that all the necessary supporting genes are also transferred and expressed in the new host, some of the formerly susceptible plants now behave as resistant ones. Such resistant plants are subsequently cloned and multiplied, each producing a distinctive line or variety of plant that is resistant to the specific pathogen. When the resistance gene DRR206 from pea was transferred into canola, the transgenic canola plants exhibited resistance to blackleg disease, caused by the fungus Leptosphaeria maculans, decreased seedling mortality caused by the root pathogen R. solani, and resulted in smaller leaf lesions caused by Sclerotinia sclerotiorum.

Transgenic Plants Transformed with Genes Coding for Anti-pathogen Compounds

Genes coding for several pathogenesis-related (PR) proteins, such as chitinases and some glucanases, have been isolated, cloned, and expressed in plants, thereby interfering with the development of certain groups of pathogens and providing resistance to affected plants. Examples of plants transformed with genes coding for anti-pathogenic compounds include peanut plants transformed with antifungal genes that reduced the incidence of Sclerotinia blight, caused by Sclerotinia minor significantly compared to susceptible non-transgenic plants.

Management through Remote Sensing

Remote sensing is a science/art that permits us to obtain information about an object/a phenomenon through analysis of data obtained through sensory devices without being in physical contact with that object.

Aerial photography

Aerial photography can detect objects on land over a larger area. Colwell first used remote sensing technique for monitoring stem rust of wheat. He showed that panchromatic colour and especially infrared aerial photography could be used to detect rusts and viral diseases of small grains and certain diseases of citrus. Later, infrared photography was used in England for late blight of potato. The key to distinguish diseased and healthy parts of a crop is to use appropriate film or filter combinations. The main film types used are panchromatic, infrared, normal colour and colour infrared. The infrared films are preferred because of their superior sensitivity to visible light and to near infrared wavelengths of radiation (700-900 mμ The healthy foliage is highly reflective to the infrared wavelengths and appears red on this film whereas blighted or diseased foliage has low infrared reflectance and does not appear red in the photograph.

Satellite Imaging

Weather satellites

Often cyclones create heavy clouds with rains and an anti-cyclone creates a cloudless sky. All these can be effectively monitored by weather satellites. Sequential pictures show the movement of these systems before they arrive in an area. Therefore by monitoring epidemic favouring systems using a satellite, the disease occurrence on the field can be monitored. Ex: The spread and deposition of stem rust pathogen of wheat is influenced by definite synoptic weather conditions called Indian stem rust rules.

Conclusion

Management of soil borne diseases is most successful and economical when all the required information pertaining to the crop, disease affecting it, history of these in the previous years, resistant levels of the host and environmental conditions to prevail is available. Combination of disease management practices may have additive or synergistic effects and such an approach is especially desirable in the case of soil borne diseases which are entirely different epidemiologically. Hopefully, the present situation, which emphasizes the use of integrated disease management practices, will stimulate the development of non-chemical methods of disease management to better manage the soil borne pathogens.

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COMMUNITY EXTENSION SERVICES FOR SUSTAINING SOIL BIODIVERSITY

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Introduction

Soil biodiversity represents the variety of life below ground, which plays many fundamental roles in delivering key ecosystem goods and services. Maintenance of soil biodiversity is essential to both the environment and to agricultural industries. A teaspoon of topsoil typically contains a vast range of different species and up to 6 billion microorganisms. Soil biodiversity reflects the variability among living organisms in the soil - ranging from the myriad of invisible microbes, bacteria and fungi to the more familiar macro-fauna such as earthworms and termites. The activity of soil biodiversity can be stimulated by improving soil living conditions, such as aeration, temperature, moisture, and nutrient quantity and quality (Nadia, 2000). Soil organisms are essential for nutrient cycling, modifying soil physical structure and water regimes, suppressing pests and diseases, soil carbon sequestration and greenhouse gas emission and break down of organic matter. Soil biodiversity is increasingly recognized as providing benefits to human health because it can suppress disease-causing soil organisms and provide clean air, water and food.

Soils that support natural, non-agricultural ecosystems usually have the greatest soil biodiversity. soils that receive less manufactured inputs (e.g. chemical fertilisers and pesticides) generally have higher soil biodiversity. Cropping systems generally have low soil biodiversity, unless they increase inputs of carbon and nitrogen to the soil, which will increase soil microbial populations. Soil biodiversity can be maintained and partially restored if managed sustainably. Application of organic matter to the soil, such as crop stubble, supports greater soil biodiversity.

As the agricultural production is becoming more intensive, effective management of available limited resources, viz., land, water, sunlight and crop residues is critical in improving production and productivity. Among these, the use of crop/farm wastes for mass multiplication of beneficial microbes is one of the important tools for sustainable production. On-farm management of agricultural wastes not only improves the soil health but increases the farmer's profit also. One of the practical ways to manage agricultural waste is to recycle it for the mass multiplication of beneficial microbes. The availability of waste biomass from a well managed coconut garden with 175 trees/ha has been estimated as 14 tonnes /ha/year in the form of leaves, spathe, bunch waste and husk (Subramanian et al., 2005). These organic wastes can be utilized as mulch or converted to composts by employing earthworms or microbial cultures. The organic inputs produced by recycling farm wastes may be efficiently utilized for soil biodiversity conservation, thereby boosting crop diversification and income from farming systems. Community level production of organic inputs from crop residues can be a potential source of income for farmers' groups.

CPCRI has standardized several agro techniques viz., soil moisture conservation practices using husk/coir pith for growing different crops, green manuring, basin management with leguminous crops, direct utilization of coconut wastes for soil conservation measures, vermicomposting of coconut plantation wastes and irrigation for increasing the yield of coconut palm. In a research study conducted at CPCRI by Thomas and Shantaram (1984), it was found that promising legume crops grown during a period of 140-150 days generated 15-28 kg of biomass and 102-197g of nitrogen in the basin of a coconut palm. By adopting such agro techniques, the soil biodiversity can be enhanced so as to achieve sustainable production and income from farming systems. However, the importance of bioresource management and conservation of soil biodiversity are yet to be exploited by the farming community on a larger scale in their farm holdings. Hence, it is imperative to enhance the knowledge level of farmers and other stakeholders on these aspects to ensure sustainable production and livelihood security.

In addition, bioresource management through production and utilization of organic inputs will generate employment and contribute to economic upliftment and livelihood security of the farmers/rural youth/farm women. In addition to the benefit of ensuring income to the entrepreneurs, this will ensure quality bio-inputs to the farmers, thereby contributing to sustainable production and productivity. Efficient utilization of the bioresources coupled with other technological interventions will enhance the income from coconut, intercrops and other allied enterprises to the tune of 25-50%. However, thorough awareness creation on the importance of bioresource management and effective use of bio-formulations at a wider level is very much essential in obtaining desired outcome. Decentralized production and utilization of bio-inputs on a community basis can result in proper utilization of bioresources, thereby contributing to protection of environment and promotion of sustainable agriculture.

Issues related to Bio-resource Management

1. Lack of clarity on the utilization of crop residues – burning for ash / utilization as mulch or green manure / recycled as compost.
2. Low awareness on environmental issues and potential benefits of agricultural wastes
3. Inadequate knowledge on composting techniques.

4. Lack of knowledge on the quality, storage and availability of bioformulations.
5. Inadequate knowledge on the effective utilization of bioformulations – ideal substrates to be used for multiplication, moisture level to be maintained and mode of application.
6. Lack of proper knowledge on problem-based application of bioformulations.

Community level Integration of Bioresource Management for Sustaining Soil Biodiversity

Community responsibility needs to be imbibed by creating awareness on the needs and benefits of recycling bio-wastes viz., importance of plant waste recycling in maintaining soil and plant health, benefits in terms of soil and water conservation, protection of environment by way of reduced use of chemical fertilizers etc., which all can lead to enhanced biodiversity in soil.

USDA Natural Resources Conservation Service (1998), in their Soil Quality Information Sheet described the good agricultural practices for conserving soil biodiversity as follows:

Cultivation

Tilling to greater depths and more frequent cultivations has an increased negative impact on all soil organisms. No-till, ridge tillage, and strip tillage are the most compatible tillage systems that physically maintain soil organism habitat and biological diversity in crop production.

Compaction

Soil compaction reduces the larger pores and pathways, thus reducing the amount of suitable habitat for soil organisms. It also can move the soil toward anaerobic conditions, which change the types and distribution of soil organisms in the food web. Gaps in the food web induce nutrient deficiencies to plants and reduce root growth.

Pest control

Pesticides that kill insects also kill the organisms carried by them. If important organisms die, consider replacing them. Plant-damaging organisms usually increase when beneficial soil organisms decrease. Beneficial predator organisms serve to check and balance various pest species. Herbicides and foliar insecticides applied at recommended rates have a small impact on soil organisms. Fungicides and fumigants have a much greater impact on soil organisms.

Fertility

Fertility and nutrient balances in the soil promote biological diversity. Typically, carbon is the limiting resource to biological activity. Plant residue, compost, and manure provide carbon. Compost also provides a mix of organisms, so the compost should be matched to the cropping system.

Cover crops and crop rotations

The type of crops that are used as cover or in crop rotations can affect the mix of organisms that are in the soil. They can assist in the control of plant pests or serve as hosts to increase the number of pests.

Crop residue management

Mixing crop residue into the soil generally destroys fungal hyphae and favors the growth of bacteria. Since bacteria hold less carbon than fungi, mixing often releases a large amount of carbon as carbon dioxide (CO2). The net result is loss of organic matter from the soil. When crop residue is left on the soil surface, primary decomposition is by arthropod shredding and fungal decomposition. The hyphae of fungi can extend from below the soil surface to the surface litter and connect the nitrogen in the soil to the carbon at the surface. Fungi maintain a high C:N ratio and hold carbon in the soil. The net result is toward building the carbon and organic matter level of the soil. In cropping systems that return residue, macro-organisms are extremely important. Manage the soil to increase their diversity and numbers.

Massive sensitization of farmers and social groups on the above bioresource management concerns can reduce the rate of soil biodiversity erosion to a great extent, which can be achieved at community level by coordinating grass root level farmer organizations (FOs).

Steps in Community level Integration of Bioresource Management for Sustaining Soil Biodiversity

i. Awareness creation and capacity building :

To begin with, thorough awareness creation should be done at all levels, which may ensure the involvement of all stakeholders in the programme by way of involvement in effectively utilizing bioresources through recycling of biowastes and enrichment with microbial agents. and also in creating demand for the product. Farming community should be educated on the production of various bio-inputs, quality parameters and regulations to be followed, benefits and specific use of the bioformulations, mode of application and ideal conditions for mass multiplication and field maintenance.

- Awareness campaigns on the importance of Bio-resource management for Officers of State Department of Agriculture, farmer groups and farmers

- Capacity building for the members of Bioagent production unit - Culturing and multiplication in coconut water media, preparation of talc based formulations & production of organics from locally available resources and enrichment using bioagents

- Capacity building for farm women/youth on mass multiplication of bioagents in crop waste

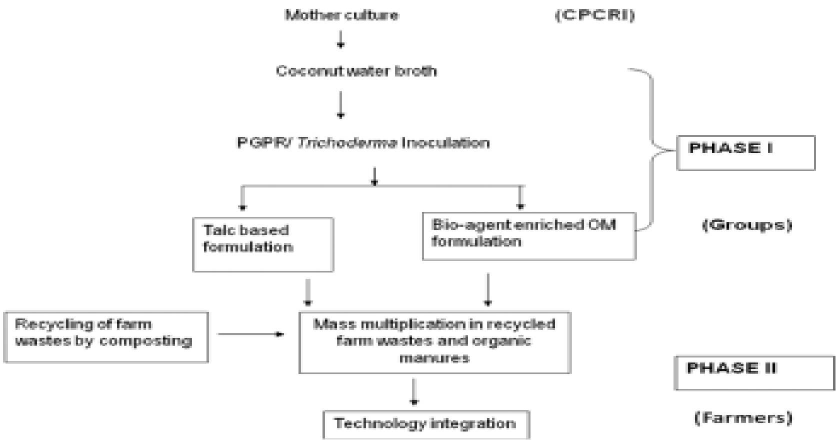
- Capacity building for farmers on production of organics, enrichment using bioagents and utilization for soil and plant health management

ii. Establishment of bioagent units at district level involving 3-4 members for culturing, multiplication in liquid media and decentralized production of formulations of beneficial microbes. Training should be imparted on handling of microbial cultures, inoculation, culturing, mass multiplication of bioagents in locally available and cheap media like coconut water and production of talc based formulations.

iii. Small scale organic input production units at block level involving 5-6 members each can be identified for production of organics (composts) from locally available resources and enrichment of compost/ farmyard manure/ neem cake with talc based formulations of bioagents. This can be linked with selected Coconut Producer Societies (CPS) as an income generation activity.

iv. Farm level technology integration involving production of organics from crop residues, enrichment using bioagents, utilization of enriched organics for soil and plant health management and production of bio-primed planting materials. Organic recycling along with soil moisture conservation measures in Coconut Based Farming System can be integrated by CPSs/FOs. Growing and incorporation of green manure crop and soil test based nutrient application if integrated can ensure higher and sustained production in Coconut Based Farming Systems.

Activity Flow Chart



Community based Bio-resource Management: Success story from Kanjikuzhy Block of Kerala

Kanjikuzhy Block being a known organic tract of Kerala, the farmers widely use several microbial formulations for plant growth promotion and disease suppression. Most of the farmers were using talc based or liquid formulations without having a thorough knowledge on their effective utilization. As the talc based formulations are costly, the farmers were educated on the technique of mass multiplication of the bioagents on organic substrates. This could help the farmers in reducing the cost of application by 50%. Mass multiplication of bioagents depends largely on the substrate used for mass multiplication and the method of culturing. The farmers of Kanjikuzhy were found to use the bioagents, mainly Trichoderma sp. in soil along with different organic substrates and hence the locally available substrates used by the farmers of Kanjikuzhy Block area were evaluated for their suitability. The results revealed coir pith compost, neem cake, vermicompost and cow dung as well as their combinations as ideal substrates and poultry manure and goat manure as poor substrates for mass multiplication of bioagents. Poutry manure and Goat manure in small quantities upto 20% with other substrates favoured the growth of microbes.

Under a trial with chillies, Growth rates of two isolates of Trichoderma (CPCRITD 28- CPCRI culture and KKT-6 from Kanjikuzhy) were found to be highest in Coir pith compost + Neem cake (4:1) combination, but on soil application, the highest growth rate was observed in Cowdung + Neem cake (4:1) treatment. However, highest and sustained yields were obtained from the plants treated with Cowdung + Neem cake (4:1), which was on par with Coir pith compost + Neem cake + Poultry Manure + Cowdung (2:1:1:1). Higher yield in the above two medium can be attributed to the optimum levels of microbial population in the enriched organic mix as well as soil coupled with higher nutrient levels in the treated plants. Correlation analysis also revealed that the population of Trichoderma harzianum in soil and Nitrogen content of the soil were found to be significantly associated with the yield of chillies. Wachira et al. (2014) observed that the efficacy of bio-inoculants, especially when combined with manure and fertilizers, had a positive and synergistic effect on yield in maize. Okoth et al. (2011) recommended that repeated application of the bio-inoculants should be encouraged to build up their numbers in the soil.

Hence, it was inferred that while enriching organics with microbial agents, the population count in the enriched manure alone should not be the only factor to be considered, but also the soil microbial population and nutrient status after application. Application of the two enriched substrate combinations, viz., Coir pith compost + Neem cake + Poultry Manure + Cowdung (2:1:1:1) and Cowdung + Neem cake (4:1) were found to be ideal in ensuring disease suppression, improved growth and sustained yield from crops like vegetables, ginger, turmeric, pepper etc.

Apart from the utilization of ideal microbial enriched organic mixtures, the farmers were also educated on preparation different composting techniques like vermicomposting, coir pith composting with and without urea, hillock composting for large scale on-site composting, biofertilizers and biopriming of coconut seedlings. Biopriming of coconut seedlings with Trichoderma sp. was proved to enhance the growth of coconut seedlings - higher collar girth, height and number of leaves, apart from inducing systemic resistance.

By integrating bioresource management as a component of soil test based management coupled with soil moisture conservation, the income from CBFS was enhanced by 62% , the details of which is provided below:

Components	Income (Rs. /ha)	
	2014-15	2015-16
Coconut	24,475	28,539
Intercrops		
Banana	15,104	36,768
Vegetables	26,123	55,821
Tuber crops	9914	15,509
Spices	2699	3,562
Others	9529	18,147
Total	63,369	1,29,807
Livestock/other enterprises	41,412	54,202
Total Farm income	1,29,256	2,10,099

The higher net income from holdings were mainly due to improved soil health and reduction in cost of cultivation through proper utilization of available local bioresources coupled with adoption of moisture conservation techniques.

Conclusion

Lack of awareness, knowledge, and understanding of soil biodiversity has been identified as the major constraint on sustainable ecosystem management and crop production. As soil organisms are the primary agents of nutrient cycling and modification of the soil structure, agricultural activities that promote their population in the soil should be promoted for crop production. However, with increasing demand for land, crop intensification has become the major challenge in the conservation of soil biota. Hence , it is the need of the hour to educate the farmers on the importance of conserving the biodiversity of soil through good agricultural practices. Community level adoption of bioresource management for enhancing soil biodiversity can be strengthened by building the community capacity for the utilization of all possible biota viz., Rhizobium bacteria, Mycorrhiza, earthworms, nematodes and other microbial population for decomposition process, plant growth promotion, biological suppression of pests and diseases and in eliminating environmental hazards resulting from accumulations of toxic chemicals or other hazardous wastes. Community based production and utilization of bio-formulations and organic inputs at local level can ensure the availability of quality bio-inputs for repeated application so as to build up required population necessary for soil biological activities and sustainable crop production. In addition to the improvement in production and income from farming systems, community based production of organic inputs will generate more employment opportunities and income to rural youth / farm women. Community level efforts to manage bioresources can contribute to improvement in livelihood opportunities of the small and marginal coconut farmers coupled with conservation of natural resources and protection of environment.

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NEMATODES AND SOIL HEALTH

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Introduction

Nematodes are numerically the most abundant metazoans on earth and second only to insects, in terms of diversity of forms (species) is concerned. Nematodes dwell in all types of habitats on the earth, from ocean depths to tops of mountains, from hot water springs to icy Arctic and Antarctic, from barren lands to cultivated fields, and from meadows to tropical forests. Most of the nematodes are free living which feeds on microorganisms. Nematodes also parasitize plants and animals. The parasitic forms have been studied in greater detail since they directly affect the human beings, their domesticated animals and crops. There is hardly any animal on earth, which is free from one or the other kind of nematode infection.

Nematodes as bioindicators

Biotic indicators of soil ecological health or condition can be used to assess the current status of vital ecological processes in soil and change in processes through time. Any indicator should reflect the structure and (or) function of ecological processes and respond to changes in soil condition that result from land-management practices.

Soil fauna have advantages over soil microbes as bioindicators. First, by being one or two steps higher in the food chain, they serve as integrators of physical, chemical, and biological properties related with their food resources. Second, their generation time (days to years) is longer than metabolically active microbes (hours to days), making them more stable temporally and not simply fluctuating with ephemeral nutrient flushes. Nematodes, Collembola, and mites are three groups of mesofauna that have been considered for use as biological indicators. Of these three groups, nematodes have been evaluated most often for their use as indicators.

Since the 1970s, nematodes have been used as environmental biomonitors for aquatic systems. For example, Panagrellus redivivus has been used as a biomonitor to detect toxin concentrations that affect molting and organism size through stimulation, inhibition, or lethality, and provides a rapid bioassay that costs less than 10% of a Salmonella bioassay. The nematode has been used to determine toxic effects of about 400 single chemicals.

Nematodes have several biological features that reinforce their use as indicators. First, nematodes have a permeable cuticle, which allows them to respond with a range of reactions to pollutants and correspond with the restorative capacity of soil ecosystems. Second, some nematodes have resistant stages such as cryptobiosis or cysts that allow them to survive inactively during environmental conditions unfavorable to growth and (or) development. However, some nematode taxa such as Dorylaimidae have no resistant stages, which may make them more sensitive to environmental change. Finally, nematodes have heat shock proteins that are highly conserved. Expression of these proteins is enhanced when exposed to stresses such as heat, metal ions, or organic toxins. Perhaps these proteins could serve as biomarkers for ecotoxicological assessment of soils.

Nematodes can be used as effective soil health bioindicators because they are commonly found, easy to sample, and well classified into functional (feeding) groups, and nematode taxa are well classified. Nematodes have diverse life strategies, ranging from colonizers (short life but high reproduction rate) to persisters (long life, but low reproduction rate). Furthermore, they have the ability to respond readily to changes in the soil‘s physical and chemical properties. Some nematodes can survive harsh, polluted, or disturbed environments better than others, and some have short life cycles and respond to environmental changes rapidly (e.g., colonizers).

Understanding nematode life strategies whether colonizers or persisters can provide information about the level of soil disturbances. Most importantly, nematodes have numerous interactions with other soil organisms and play important roles in soil nutrient cycling. Therefore, nematode faunal analysis provides an insight into soil food web conditions and associated soil health.

In terms of function, nematodes have different life strategies and feeding behaviors in the soil food webs. For example, at the bottom of the food chain are fast growing, fast-breeding, bacteria-feeding nematodes (bacterivores) and at the top are slow growing, slow reproducing, predatory nematodes. Generally after a soil disturbance, the soil community is dominated by the fast-growing, bacteria-feeding nematodes, then it slowly transforms into a more diverse community consisting of nematodes with various feeding groups (i.e., bacterivores, fungivores, omnivores, and predatory nematodes). Omnivorous nematodes feed on various soil microbes including bacteria and fungi and smaller nematodes. Omnivorous and predatory nematodes are typically the last groups of nematodes to colonize a soil ecosystem after a disturbance.

Role of nematodes in soil mineralization

In general, a healthier soil is composed of a diverse mixture of nematode feeding groups. Availability of nutrients from soil organic matter to plants relies on the mineralization (release) of nutrients from the organic matter. When organic matter is first added into the soil, it is in a form that is unavailable for plant uptake until it is decomposed by bacteria or fungi. After initial decomposition, some organic matter will be converted into an inorganic form that plants can uptake. However, these same bacteria or fungi may tie up (immobilize) nutrients in the soil until they are grazed by bacterivorous and fungivorous nematodes. However, overgrazing by these nematode groups can reduce the overall activity of bacteria and fungi. Fortunately, in the hierarchy of the soil food web, predators such as omnivorous and predatory nematodes, and mites, feed on these bacterivorous and fungivorous nematodes, thus allowing more nutrients to be released into inorganic form for plant to uptake. Thus, an increase in predatory nematodes may contribute to increased nutrient mineralization and associated plant productivity.

Under field conditions, bacterivorous and predatory nematodes are estimated to contribute (directly and indirectly) about 8% to 19% of nitrogen mineralization in conventional and integrated farming systems, respectively (Beare, 1997). Nematodes contribute to nitrogen mineralization indirectly by grazing on decomposer microbes, excreting ammonium, and immobilizing nitrogen in live biomass (Beare, 1997; Ferris et al., 1998; Ingham et al., 1985). Predatory nematodes also regulate nitrogen mineralization by feeding on microbial grazing nematodes, a conduit by which resources pass from bottom to top trophic levels (Wardle and Yeates, 1993). Although plants depend on nitrogen for their survival and growth, ecological disruptions such as cultivation or additions of mineral fertilizer increase nitrogen availability, sometimes in excess of, or asynchronous with, plant needs. Increased availability of nitrate and ammonium is associated inversely with successional maturity of nematode communities in cultivated mineral soils for agricultural purposes (Neher, 2001).

Nematode community analysis

Comprehensive studies on nematode faunal analysis have been conducted over the last few decades to validate that nematodes are good soil health bioindicators. Four nematode community indices commonly used as soil health indicators are maturity index (MI), enrichment index (EI), structural index (SI), and channel index (CI). MI weighted mean of the colonizer-persister (c-p) values of nematodes in all trophic groups, it provides the stability of the nematode community in the soil food web. EI depicts whether the soil food web is enriched with nutrients, whereas SI illustrates if the soil communities are stable and stress enriched stable enriched stress depleted stable depleted Increase organic inputs EI Reduced tillage SI. A Simplified Food Web Structure on Enrichment Index (EI) and Structure Index (SI) trajectories 4 undisturbed. CI indicates whether the soil food web is diminished by stress or limited in nutrient resources. To give a general perspective, perennial cropping, reduced-till farming systems, and undisturbed natural ecosystems such as forests usually have higher MI and SI than most conventional tillage agro-ecosystems. Conversely, soil recently amended with manure or other organic matter with high N content would have higher EI than those fertilized synthetically. Soil that is drier or being fumigated would have higher CI than soil without external stress. Without high biological diversity, a soil ecosystem would be vulnerable to environmental changes, disturbances and other stresses. Nematode community indices were correlated with concentration of many soil nutrients, microbial biomass, plant growth, and even foliar insect damage. Therefore, using nematodes as bioindicators reflects both soil biotic and a biotic factors (e.g. toxin, nutrients), and provides insight into soil health.

Conclusion

In conclusion, it makes ecological sense to use nematodes as bioindicators of soil condition. Nematodes represent a central position in the soil food web and correlate with ecological processes such as nitrogen cycling and plant growth. Although there are few persons trained and few commercial laboratories available to identify free-living nematodes in large numbers of samples, nematode taxonomy is more extensively developed than the taxonomy for other soil fauna such as mites, protozoa, and collembolans. Priority research areas for implementation of nematodes as indicators of soil condition across large geographic scales include verification of life-history characteristics, feeding preferences, identification of key taxa, correlation of key taxa to disturbance, and calibration of indices relative to ecosystem, climate, and soil type.

RECENT MICROBIOLOGICAL ADVANCES FOR COMBATING SOIL POLLUTION

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Soil, an essential part of ecosystem, serves as the source and sink of the elements of life. Any adverse change in its composition will have direct implications on the life on earth. World's Soil Resources Report (SWSR) has identified soil pollution as one of the main soil threats affecting global soils thereby posing threat to foodsecurity as well as the human health. Soil pollution has deteriorated large areas of agricultural lands and has adversely affected soil biodiversity. The diversity of soil contaminants and their spread has achieved an alarming trend finely correlating with increased anthropogenic activities.

Soil remediation is a term used for various processes used to decontaminate soil. Several soil remediation methods are in practice ranging from physical, chemical and biological methods either to remove or minimize the adverse effects of soil pollutants. Soil remediation approaches are often dependent on soil type, composition, nature of contaminant, handling intensity, feasibility and cost etc. Among the several approaches, **bioremediation** offers cost-effective and eco-friendly approaches for soil clean-up. Bioremediation is defined as "use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments of quality from soil and water". Bioremediation is a natural process which relies on microorganisms and plants to metabolize contaminants using them as energy source as they carry out their normal life functions.

Depending on the type of organisms involved in bioremediation, it is broadly classified as phyto bioremediation and microbial bioremediation. However these can be used in combination with other remedial measures. **Phytoremediation** uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil. Most scientific and commercial interest in phytoremediation relies on phytoextraction (removing metals or organics from soils by accumulating them in the biomass) and phytodegradation (using plants to uptake, store and degrade organic pollutants), using selected plant species grown on contaminated soils. Microbial **bioremediation** involves the use of mainly microorganisms i.e. yeast, fungi or bacteria to clean up contaminated soil. Techniques rely on promoting the growth of specific microflora or microbial consortia that are indigenous or introduced to the contaminated sites that are able to perform desired activities. **Microbial** enrichment is done through addition of nutrients, by adding terminal electron acceptor or by controlling moisture and temperature conditions. In bioremediation processes, microorganisms use the contaminants as nutrient or energy sources.

Why Microbes?

- Wider adaptability: Microorganisms are extremely widespread occupying every possible niche even those considered extreme for any complex life forms. Microbial life is evidenced in extreme habitats from extremely dry and cold deserts in the Antarctic and deep into permafrost soils to geothermal and humid soils in volcanic areas, from extremely acid mines with sulfuric acid to high alkaline areas. Their ability to endure selective pressures of the environment have made them adaptable to new types of habitats created by anthropogenic activities, such as those polluted with heavy metals, radionuclides, and high concentrations of toxic xenobiotic compounds such as polychlorinated biphenyls, hydrocarbons and pesticides.

- Metabolic diversity: All metabolic reactions are mediated by enzymes belonging to groups of oxidoreductases, hydrolases, lyases, transferases, isomerases and ligases. Microorganisms are endowed with metabolic properties driven by a vast array of enzymes suited for the task of attacking recalcitrant substances. Many enzymes have a remarkably wide degradation capacity due to their nonspecific and specific substrate affinity. Microbial oxygenases have a broad substrate range and are active against a wide range of compounds, including halogenated organic compounds, that comprises the largest groups of environmental pollutants. Many microorganisms produce intra and extracellular laccases capable of catalyzing the oxidation of phenolic and aromatic substrates. Microbial lipases effectively degrades hydrocarbon from contaminated soil. (Karigar and Rao, 2011). Often microbes work in communities sharing complimentary metabolic steps resulting in enhanced degradation rates

Advantages of microbial bioremediation (Abatenh et al., 2017)

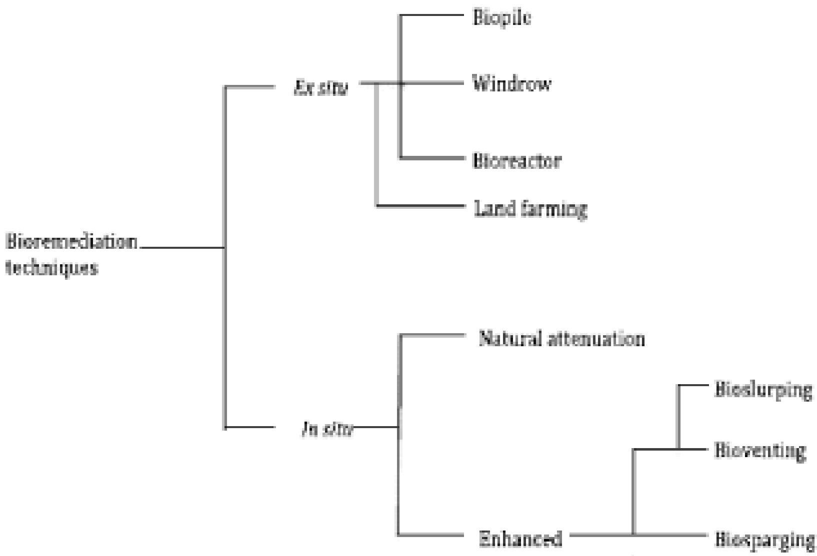
- Natural process and an acceptable waste treatment process for contaminated material such as soil.
- Requires very less effort and can often be carried out on site
- Cost effective process in comparison with conventional methods (technologies) used for clean-up of hazardous waste.
- Helps in complete destruction of the pollutants, many being transformed to harmless products
- It does not use any dangerous chemicals.
- Eco-friendly and sustainable.

Disdvantages of microbial bioremediation

- Limited to biodegradable compounds that. Not all compounds are susceptible to rapid and complete degradation. Biological processes are often highly specific.
- Regulatory uncertainty remains regarding acceptable performance criteria for bioremediation.

Bioremediation techniques: (Vidali et al., 2001; Azubuike et al., 2016)

There are two basic types of bioremediation based on treatment site.



Source: Azubuike et al., 2016

In Situ Bioremediation

1. Treating polluted substances at the site of pollution.
2. Does not require any excavation, hence little or no disturbance to soil structure.
3. Uses harmless microorganisms (with chemotactic affinity to pollutants) to eliminate the chemical contaminations.
4. status of electron acceptor, moisture content, nutrient availability, pH and temperature are among the important factors to be considered for successful treatment
5. in situ microbial bioremediation techniques might be enhanced (bioventing, biosparging), while others might proceed without any form of enhancement

(intrinsic bioremediation or natural attenuation).

- Bioventing: Involves controlled stimulation of airflow by delivering oxygen to unsaturated zone to increase indigenous microbial activity. Amendment with nutrients and moisture is done to encourage microbial activity thereby ac celerating microbial transformation of pollutants to a harmless state. Used in restoring sites polluted with light spilled petroleum products
- Biosparging: Combines vacuum-enhanced pumping, soil vapour extraction and bioventing to achieve soil bioremediation. It is used to remediate soils contaminated with volatile and semi-volatile organic com pounds
- Intrinsic bioremediation (natural attenuation): Involves passive remediation of polluted sites, without any external intervention. The process relies on both microbial aerobic and anaerobic processes to biodegrade polluting substances including those that are recalcitrant. This is successfully used to treat chlorinated solvents, dyes, heavy metals, and hydrocarbons polluted sites
- Engineered in situ bioremediation: performed through the introduction of certain microorganisms to a contamination site. Improved physico-chemical conditions are provided to support enrichment and bioactivity the exogenously amended microorganisms.

Ex situ bioremediation:

1. These techniques involve excavating pollutants from polluted sites and sub sequently transporting them to another site for treatment.

- Biopile: Involves above-ground piling of excavated polluted soil, followed by nutrient amendment, aeration and moistening to accelerate remediation by basically increasing microbial activities.
- Windrows: This method relies on periodic turning of piled polluted soil to bring uniformity in aeration, distribution of pollutants and nutrients to speed up degradation activities (assimilation, biotransformation and mineralization) of indigenous and/or transient hydrocarbonoclastic bacteria. Windrow composting is an aerobic and thermophillic process that involves combining contaminated soil with nonhazardous organic amendments such as manure or agricultural wastes.
- Bioreactor:Contaminated soil in form of dry matter or slurry is treated in vessel (bioreactors) in which raw materials are converted to specific product(s) following series of biological reactions. Excellent control of bioprocess parameters (temperature, pH, agitation and aeration rates, sub strate and inoculum concentrations) is one of the major advantages of bioreactor-based bioremediation.

- Land farming: contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded by stimulating indigenous biodegradative microorganisms thereby facilitating aerobic deg radation. In general, the practice is limited to the treatment of superficial 10–35 cm of soil

Microorganisms involved in bioremediation process:

Microorganisms prove potent candidates for bioremediation as they function as natural decomposers in varied ecosystems. Ease of proliferation, generation rate, chemotaction and enzymatic potential make them ideal for bioremedial applications. Microrganisms for bioremediation should fulfill the following requirements (Alexander,1994)

a) Should possess effective enzymes for bioremediation

b) Should thrive and demonstrate bioactivity under polluted environment

c) Should be able to get access to the fixed/insoluble contaminant

Several microorganisms such as Corynebacteria, Mycobacteria, Pseudomonads, yeast act as bioemulsifiers and use oil hydrocarbons as source of carbon and energy. Many degrade synthetic compounds (xenobiotics) such as remnants of pesticides in agroecosystems. Fungi and anaerobic bacteria are known to degrade dye compounds. Microbial bioremediation is performed through different mechanisms such as biosorption, biodegradation, bioaccumulation and biotransformation of the contaminant molecules. Following table lists a few microbes with proven bioremediation potentials.

Table 1: Microorgansims for bioremediation (Source: Abaten et al., 2017, Cycon et al., 2017)

Microorganisms	**Compound** **Hydrocarbons**
Penecillium chrysogenum	Monocyclic aromatic hydrocarbons, benzene, toluene, xylene and phenol compounds
Pseudomonas putida, P. veronii, Achromobacter sp., Flavobacterium sp. , Acinetobacter sp.	Petrol, diesel, polycyclic aromatic hydrocarbons, toluene
Cyanobacteria, Bacillus licheniformis	naphthalene
	Oil
Fusarium sp.	oil
Aspergillus niger, Candida glabrata, Saccharomyces cerevisiae	Crude oil

Pseudomonas cepacia, Bacillus cereus, Bacillus coagulans, Citrobacter koseri and Serratia ficaria	Diesel oil, crude oil
	Dyes
Bacillus subtilis	Oil-based paints
Pycnoporus sanguineous, Phanerochaete chrysosporium and Trametest rogii	industrial dyes
Bacillus spp. ETL-2012, Pseudomonas di-azo dye	Textile Dye (Remazol Black B), Sulfonated Reactive Red HE8B, RNB dye aeruginosa, Bacillus pumilusHKG212
Exiguobacterium indicum, Exiguobacterium aurantiacums, Bacillus cereus and Acinetobacter baumanii	azo dyes effluents
Bacillus firmus, Bacillus macerans, Staphylococcus aureus and Klebsiella oxytoca	vat dyes, Textile effluents
	Heavy metals
Saccharomyces cerevisiae	Heavy metals, lead, mercury and nickel
Pseudomonas fluorescens and	Fe2+, Zn2+, Pb2+, Mn2+ and Cu2+
Lysinibacillus sphaericus CBAM5	cobalt, copper, chromium and lead
Geobacter spp.	Fe (III), U (VI)
Bacillus safensis	Cadmium
Pseudomonas aeruginosa, Aeromonas sp.	U, Cu, Ni, Cr
	Pesticides
Bacillus, Staphylococcus	Endosulfan
Enterobacter	Chlorpyrifos
Pseudomonas putida, Acinetobacter sp., Arthrobacter sp.	Ridomil MZ 68 MG, Fitoraz WP 76, Decis 2.5 EC, malathion
Acinetobactor sp., Pseudomonas sp.,	chlorpyrifos and methyl parathion
Arthrobacter sp. DAT1	Atrazine
Catellibacterium caeni sp. novDCA-1T	Butachlor,Alachlor,Acetochlor,Propisochlor
Bacillus sp. DG-02	Bifenthrin,fenpropathrin, Cypermethrin,Cyfluthrin, cyhalothrin, deltamethrin

Recent advances in bioremediation

Pre-genomics scenario were greatly relying on culture dependent techniques that involved isolation, identification and screening of microbes with bioremediation potential, carried out in labs followed by field studies. Applicathat involved isolation, identification and screening of microbes with bioremediation potential, carried out in labs followed by field studies. Applications of genetically engineered microorganisms (GEM) in bioremediation received a great deal of attention. Due to regulatory risk assessment concerns, and the uncertainty of their practical impact and delivery under field conditions, the efforts remain confined to lab. Though a vast number of microorganisms were studied and explored for bioremediation, low success rate with bioaugmentation necessitates studies to understand the contribution of uncultivable counterparts to get deeper insights into their role in bioremediation.

Omics- approaches in microbial bioremediation:

With the advent of high throughput sequencing technologies and in silico analyses, advanced 'omics' tools such as genomics, transcriptomics and metabolomics are being increasingly utilized to design the strategies for bioremediation. 16S rRNA gene sequencing technologies and related molecular-based approaches like denaturing gel electrophoresis upgraded the field of microbial ecology studies by helping to profile complex microbial diversity, thus overcoming the biases inherent in culture based profiling. Metagenomics powered with next generation sequencing and computational tools have made a breakthrough in opening up the 'microbial black box' associated with the polluted environments. Sequence phylotyping proved valid information on microbial diversity. Functional metagenomics also offer a powerful tool to understand the functional aspects of gene pool operating in an environment. It also allows cloning and expression of genes from uncultivable microorganisms to screen for enzymatic activities thus aiding in discovery of novel genes and metabolism. Metagenomics based bioremediation approaches are emerging potent tools as they help in identifying key microbial processes and optimal community composition enabling mineralization of pollutants (Thomas et al., 2012). Databases also offer a rich stock of genes for construction of designer microbial strains for targeted approaches (Chandran and Das, 2011). Metatrancriptomics and proteomics approach helps to determine the expression of functional genomes henceforth useful in ascertaining the genes active in a particular environment. Proteomic approaches have revealed novel pathways operating in aerobic and anaerobic degradation of toxins, extending more possibilities in identification of novel enzymes (Dore et al., 2015). Microbial metabolomics study helps us to analyze the dynamic operation and functional aspects of microbial communities by exploring the role of low-molecular weight metabolites (Malla et al., 2018). Thus omics approaches present a remarkable tool in deciphering the mechanisms of bioremediational pathways. Integrated knowledge on 'Omics' would possibly aid successful execution of efficient bioremediational strategies by tracking responsible organisms.

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FARMER PARTICIPATORY APPROACHES FOR SOIL HEALTH MANAGEMENT- A CASE IN FARMER FIRST PROGRAMME OF ICAR CPCRI AT PATHIYOOR PANCHAYATH

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Soil health management was practiced by the farming community using soil fertility enhancement and management integrating traditional and time tested methods and strategies using locally available resources. In the case of coconut systems, integrated farming systems generally followed paved the ways for soil replenishment of nutrients through recycling and integrating appropriate crops/ farm enterprises. Recently soil test based nutrient management; supplementation is an accepted and recommended strategy for mitigating nutritional problems and improving efficiency of farming in general. The existing farmers practice was unscientific use of fertilizers and mostly, in no way connected to the crops or cropping system in their coconut gardens. The knowledge, skill and adoption of soil testing, as a compulsory practice is also not satisfactory as per the data collected from field situations.

Participatory soil health management in FFP

ICAR CPCRI is implementing the ICAR Farmer FIRST Programme (FFP) in Pathiyoor panchayath of Alappuzha district as a stakeholder participatory programme. Integrated nutrient management in coconut gardens of the FFP area, which is root (wilt) disease affected tract, is one of the major interventions as per the need analysis and prioritization of participating farmers.

The major steps of the participatory soil health management intervention were as follows:

1. Soil collection campaign initiated during May 2017

♦ Creating awareness among the coconut farmers for scientific and judicious application of nutrients in organic and inorganic form

♦ Involving coconut producers societies for facilitating and supporting soil sample collection in grid mode (5 ha grids)

♦ The soil test based use of nutrients and crop management practices require social mobilization and social engineering to enable the farmers to realize the need and taking soil samples and seeking out advice from the ICAR CPCRI scientists. The social mobilization included Participatory Rural Appraisal (PRA), neighborhood gatherings and distributing extension literatures.

♦ Farmer participants under Crop, Horticulture, natural resource management (NRM) were involved in the soil health campaign programme.

2. Participatory soil sampling

"Tell them and they will forget,

Show them and they may remember,

Involve them and they will understand"

This is the essence of experiential learning in farming among the communities.

Soil sampling techniques and awareness to management of soil, based on soil test results among coconut farming community is very crucial in achieving resource efficiency. Pathiyoor panchayath, the Farmer FIRST Programme location is situated in Alappuzha district, consists of 19 wards. At the 2001 India census, Pathiyoor (Village) had a population of 22,184 with 10,461 males and 11,723 females. The FFP is being implemented in all the 19 wards of the panchayath under six modules as different interventions. After conducting farmers' meeting in each village and depending upon soil type, crop, slope and management, about 30 per cent of farmers' fields were selected for sampling using stratified random methodology. The identified farmers were made into groups for demonstration of soil sampling procedure. Training programmes also conducted in various wards of the FFP panchayath. Collected soil samples were labeled with cluster name, village name and farmer's name. In most of the clusters, coconut producers' societies or ward members were involved in participatory soil sampling. Collected soil samples were analyzed in the soil chemistry laboratory at the ICAR CPCRI.

Map of Pathiyoor in Alappuzha district, Kerala state

Soil health cards were drawn based on the soil test results in 5 ha grid area and 61 soil health cards distributed in 2017 to the FFP farmer participants.

Soil health management among the coconut farmers consists of not only soil test based nutrition management but also following integrated balanced nutrition regime including organic and inorganic fertilizers.

The soil health management process at the panchayath level promotes scientific interventions in the following areas in FFP.

- Integrated root (wilt) disease management of coconut gardens in the 19 wards of the FFP intervention panchayath. The soil testing activities could help in the judicious application of nutrients to rejuvenate and regain the health of the palms as well as the soil for sustainable impact in income through yield improvement.
- Promoting organic recycling through composting, organic recycling, green manuring, basin management with cowpea, recycling of animal manures, mulching of coconut basins for moister conservation, cultivation in fallow land improving the texture and productivity of the soils and increasing area under intercrops for soil conservation and improving total income from unit area.
- Integration of technologies and ensuring scientists farmer cooperation, coordination and participatory interventions the soil health management in root (wilt) affected coconut areas could be achieved in sustainable manner

Outcome and impact expected

- Awareness creation and social pressure in participation and adoption of the soil testing campaigns
- Evolvement of social leadership in the basic natural resource management process
- Documentation of soil health status of panchayath
- Aid in rural Planning process for agriculture
- Tool for researchers in analysis of soil health status, problems and constraints in the process and impact of adoption in improving parametrs

Appendix I

List of Abbreviations

Sl.No.	IPCC	Intergovernmental Panel on Climate Change
1	SOC	Soil Organic carbon
2	NUE	Nutrient Use Efficiency
3	INM	Integrated Nutrient Management
4	GHG	Green House Gas
5	COGENT	The International Coconut genetic Resources Network
6	EOD	Earth Overshoot Day
7	ICAR	Indian Council of Agricultural Research
8	FAO	Food and Agricultural Organization
9	ITPS	Intergovernmental Technical Panel on Soils
10	NRM	Natural Resource Management
11	CTCRI	Central Tuber Crops Research Institute
12	CPCRI	Central Plantation Crops Research Institute

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