Tropical soils: Importance, Research And Management

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Abstract

It has been reviewed papers and personal investigations about soil tropical soils fertility. It was pointed out the importance of tropical soils for quantity and quality of yields of many crops. It was discussed soil quality, soil degradation, integrated nutrient management, maximization of the use the use of organic materials, balanced use of inorganic fertilizers, minimizing losses of plant nutrients, methods for conservation cropping management of low productive soils, polices for soil and fertility management and composting waste to improve and maintained tropical soils fertility.

Key words: tropical soils, soil degradation, nutrient management, organic materials, composting, polices of soil fertility management.

Introduction

Soil supports the growth of plants which supply the world with food, biomass and renewable energy. It provides habitats for biodiversity, species and genes, and is a major source of raw materials. It also stores, filters, and transforms nutrients, substances and water, and it acts as a carbon sink in global climate regulation.

Soil fertility

Soil as one of the tree main components of the Atmosphere, water and air, play an important role for maintaining the life in the Earth. The short determination what is soil fertility is connected with its main ability to provide crops and microbes with essential nutrients. Additionally soil fertility give an effect on nutrient cycling, climatic change, carbon sequestration, soil erosion, soil organic matter, soil degradation, bioenergy carbon neutral (reduces emissions from fossil fuels (25%), carbon release of 5% thus supply photosynthesis of plants with CO_2 for their respiration, biochar sequestration carbon negative (reduces emissions from biomass), net carbon withdrawal from atmosphere (20%) and effect on tropical agroecosystem (www.organicagriculture.co; www.organicagriculture.co/soil-fertility-management.php; soil fertility, SSS-17)). “Soil quality” word was suggested in 1993 in a International Soil Science Conference (Budapest, Hungary) to replace word “soil fertility” Soil quality includes two more words such as: soil health and assessment of the farmers of soil productivity. But in the agricultural practice scientists and farmers still prefer to use “soil fertility”.

Results and Discussion

Factors influencing soil fertility are: 1. Infiltration of water; 2. Content of organic matter; 3. Soil structure; 4. Active soil life; 5. Exploitable depth; 6. Minerals; 7. Soil acidity (pH); 8. Sufficient drainage; 9. Release of nutrients; 10.Parent soil; 11. Ground water (Picture 1 and 2).

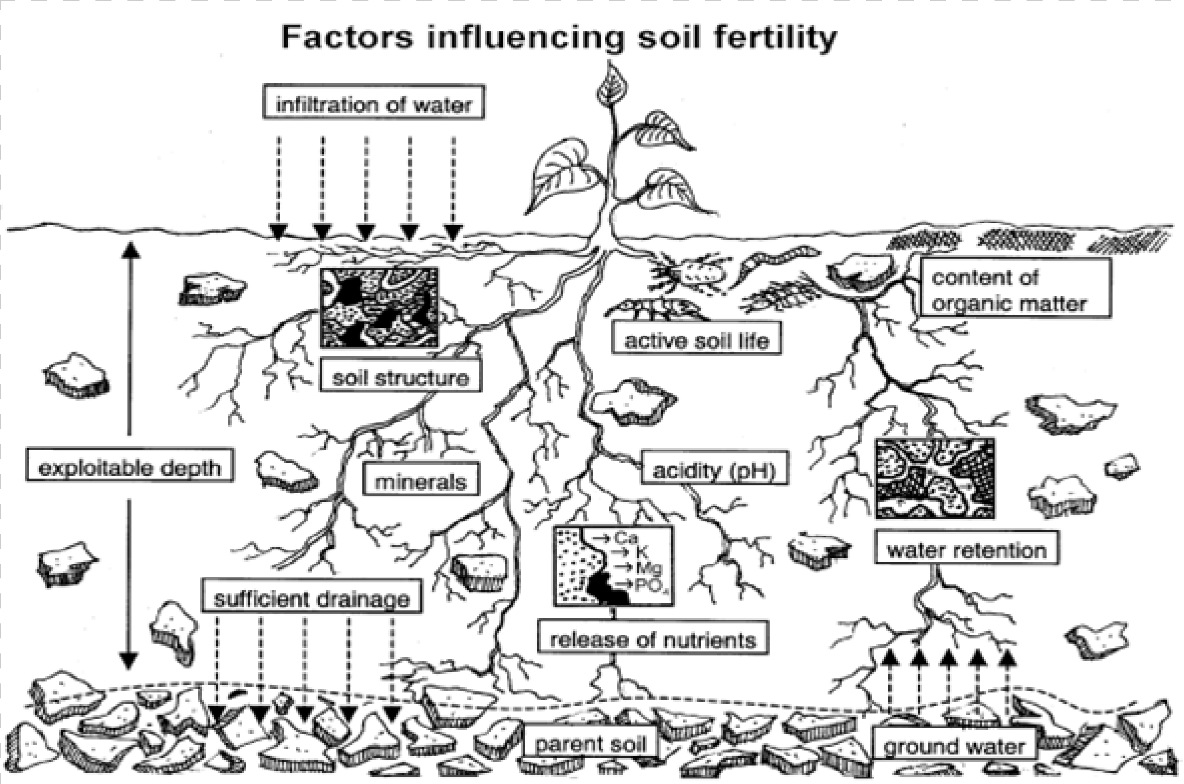

Figure 1. *Factors affecting soil fertility (http://agriinfo.in/default.aspx)*

Methods for soil fertility evaluation

Biological methods (http://agriinfo.in/default.aspx?):

1. Field trial; 2. Pot culture; 3.Seedling method; 4. *Aspergilus niger* method; 5. Toxicity test by carry out germination test; B. Use a visual symptoms of nutrient deficiency or toxicity test (growth of seeds and seedlings); C. Plant analyses methods: 1. Total elemental analyses; 2. Plant tissue tests; D. Soil analyses methods: pH, ammonium and nitrate nitrogen and their ratio, total number of microbial population of main physiological groups of microorganisms, number of sensitive microorganisms such as nitrifying bacteria, free living nitrogen fixing bacteria, symbiotic N_2-fixers, spore forming bacteria and ratios between different groups of microorganisms

Figure 2. *Soil with good fertility (http://ourworld.unu.edu/en/recommended-reading-for-the-un-international-year-of-soils-2015)*

The most reliable tests for soil fertility are field tests (Booklet No. 353, SSS-17) but they are time consuming, laborious and expensive. Depending on the purpose they can be assessed: manures, composts, different fertilizers, water consumption and way of irrigation, breeding trials etc. Important steps to carry out such experiments are: site selection, layout, cultural operation, test phases, qualitative determination, quantitative determination, complex fertilizer trials, permanent manorial trials. Expected results can be plant growth, seed production, vegetative mass, swiftness of the fruits and their yield, appearance, how early yield will be available to the market, profitability etc.

Fewer indicators may be sufficient to assess soil quality

Although soil quality is best assessed using a wide range of indicators, a smaller set may be more practical and still provide the necessary information needed to choose between land management systems (Kostov and Lynch, 2002; Lima, A.C.R., Brussaard, L., Totola, M.R., et al., 2013). A soil quality index combines indicators into one value by prioritising (or weighting) them according to their importance in the context, for example, the type of crop or environmental factors will influence the weighting. Researchers studied: 1. Conventional tillage: 2. Pre germinated; 3. No tillage, the soil preparation done around two months before sowing. They did not found statistically significant differences between studied indexes. It appeared that more important for management practice have been soil texture suggesting that clay contain of 40-60% is more susceptible for influences from the chosen management system. Finally they accepted that smaller number of indicators can provide useful information for management decisions.

A new method for evaluating threats to soil biodeversity

Researchers concluded (Gardi et all. 2013, IYS, 2015) that there are not enough baselines information to assessed effect to soil biodiversity from climatic changes, agriculture intensification or soil erosion. The authors used a mathematical model to quantify the relative severity of each treat based on experts' analysis. The top most severe treats emerged as intensive exploitation of land, decline of organic material found in soil, and habitat disruption. Further analyzing using mapping software demonstrated that soil biodiversity is under threat in 56% of EU territory. Of the area studied, 15% was classed as high, very high or extremely high threat. Authors pointed out that *research and monitoring are urgently needed to protect soil biodeversity*.

Increased concerns over fluvial carbon losses from deforested tropical peatlands. Over 20% more carbon could be being released by tropical peatlands than previously estimated, a new study suggests. The research highlights the large quantities of carbon lost to rivers from deforested and degraded peatlands in Indonesia, in addition to carbon released as CO_2 gas (Moore, S., Evans, C.D., Page, S.E. *et al*., 2013). The level of carbon in the water draining from the peat swamp forests was measured over a year at weekly intervals. The results indicated that the channels draining the degraded forest contained about 55% more organic carbon in the water than the channels draining the intact forest. The average loss from degraded peat swamp forests was calculated to be 97 grams of carbon per square metre of land per year (as opposed to 63 grams from the intact forest), and most of this was lost during the rainy season. The researchers estimated that the total amount of carbon being lost from the peatlands, including the water-borne carbon loss, is 22% higher than other estimates which only consider carbon lost as CO_2 gas. Based on these figures and data on different land uses across southeast Asia, they then calculated that there has been a 45% increase in organic carbon lost to rivers in Borneo, Sumatra and *the Malaysian peninsula (from 4.7 to 6.8 million tonnes of carbon per year) since 1990*, owing to the conversion of peat swamp forests into disturbed degraded peatland. For the whole of south-east Asia, peatland degradation was estimated to have produced a 32% increase in organic carbon lost to rivers. The study suggests that this may be an underestimate, because no data were available for the conversion of peatlands to industrial plantations, another important type of land use change.

Tropical Agriculture and the Environment

The are two theories in management of tropical agriculture and also to other world areas: 1. Relationship between population and soil productivity will go this way that soil soon will be degraded beyond recovery and population incomes will not be enough to survived. 2. Second theory is to keep soil productivity to a such level that permits you to recover soil fertility, maintained less erosion, use organic materials, apply biofertilizers, support biological nitrogen fixation and do not applied too high levels of mineral fertilizers thus big parts of them to be lost as N_2O. So systems as low impute fertilizers and partly organic are the most suitable to maintain soil fertility and can make enough incomes to survive. (http://athene.umb.no/emner/pub/eds215/lecturedevelopment.htm; Kostov and Lynch, 2002

Soil fertility management

1. Soil degradation and tropical agriculture. Soil is key factors affecting plant growth. The major functions of soils are to provide plants with nutrients, water and oxygen. Simply saying soil fertility is capacity of soil to support plants growth. Soil degradation are processes that negatively affect soil fertility. Soil properties affected by soil degradation are nutrient content, water holding capacity, topsoil depth, acidity, salinity, porosity, and soil biomass. The main processes causing soil degradation are: nutrient depletion, soil erosion, compaction, accumulation of harmful components (salinization and acidification); soil organic matter reduction. Soil degradation have serious economic consequences: lower return of investments in the agricultural sector, insufficient quantity and quality of the food, higher food prices, increased government expenditure on health, reduce government revenue due to less collected taxes on agricultural goods, flus to urban area, increased sedimentation of dams due to soil erosion. It is established that soil degradation have already significant impact on productivity of about 16% of the global agricultural land. Combining the new map of agricultural land with existing expert assessment of soil degradation suggest that 75% of crop land at Central America is seriously degraded, 20% in Africa (mostly pasture) and 11% in Asia. Soil degradation is the reason that many International Institutions emphasizing soil fertility management to enhance agricultural productivity.

2. Integrated nutrient management. Integrated nutrient management is a way to combat nutrient depletion. This is an approach to combine organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation. The main difference between natural and agricultural ecosystem is that in agricultural ecosystem the plant nutrients are constantly removed and exported. In soil fertility management the following principles are important: 1. Maximize use of organic material; 2. Balance use of inorganic fertilizers and 3. Minimize losses of plant nutrients. There is no written recommendation because of significant differences in alternative use of organic materials, access to market, price ratio of inputs and outputs, labor cost, farmers knowledge. Therefore local adaptation is always necessary. There are still discussion which approach farmers to follow: low input agriculture, high input agriculture, partly organic and full organic agriculture. Integrated nutrient management permit to take more flexible position because there are big differences in natural resources and socio-economic conditions. For example soil resources depend on the depth of soils. Deeper soil fix atmospheric C significantly in bigger amount.

3. Maximize the use of organic material. Agriculture in tropics highly depend on the release of plant nutrient from soil organic matter and from organic manure. Soil

organic matter play a critical role in maintaining soil fertility, water holding capacity, cation exchange capacity, acting as buffer against pH changes in soil, reducing surface crusting. However organic materials are not enough all over the world. Organic materials when are produced locally are more attractive because of lower price and lower transportation cost as compare to mineral fertilizers. However the following limitations to use organic fertilizers have to be mentioned: 1.Too low quantities are available to meet requirements of moderate yield; 2. Only a limited amount of phosphorous is supplied; 3. Application of manure is much more labor intensive, have low N content (1-2-3%) as compared to fertilizers which have 20-40% N; 4. Release of nutrients from organic sources is not well synchronized in time with plants demands for nutrients; 5. The quality of organic fertilizers differs greatly and their application should be different for different areas and crop systems. Generally low quality organic fertilizers/materials have to be used as surface mulch to protect soils from erosion and weed control but high quality organics fertilizers can be used as direct plant nutrient source. Combine application of advanced bio fertilizers, bio pesticide, organic farming methods will make soil fertility management sustainable in time.

There have been efforts to introduce so-called Low External Input Agriculture. It relies on cover crops, animal manure and improved fallows to maintained soil fertility (Kostov at all., 2002). There is a problem for cover crops to supply sufficiently phosphorous plants needs. Malaysian composts also do not have enough P to replace mineral fertilizer (Wan Rashida at all., 2004).

4. <u>Balanced use of inorganic fertilizers</u>. Fertilizers use varies greatly among continents. In 1994/5 fertilizers use per hectare averaged more than 216 kg in East Asia and 77 kg in South Asia. Compared to 10 kg in Sub-Africa and 65 kg in Latin America. Inorganic fertilizers have un immediate effect and very often well synchronized with plant growth. Recovery of N from leguminous plants incorporated into soil is 1-30%, while the recovery of fertilizer N is 20-50%. Fertilizers increase root and top biomass. Roots and crop residues left as mulch can contribute to improve soil organic matter balance (Kostov at all. 2002). Fertilizers use can also increase water use efficiency in crop production.

   Inorganic fertilizers should be combine with organic material. In Malaysia well matured composts using sludge and POME during their production have good level of available N and K which can substitute inorganic fertilizers. Thus acidifying effect from fertlizers will be reduced and also improve soil physical characteristics. Using only inorganic fertilizer for soil fertility maintenance is not a suitable practice.

   Nitrogen and phosphorous are elements which limits crop production in the tropics. Composts and organic fertilizers contain low level of P and for this reason application of inorganic P is very important in tropics. Rock phosphate is suitable P fertilizers but P is slow release also from this type of phosphorous. Single, double and triple superphosphate are more suitable because they release P faster and are water soluble.

So Rock Phosphate is more suitable for acids soils in Malaysia. Rock phosphate is competitive if supply at approximately 25% from the price of super phosphate. Nitrogen fixation also can be improved if P deficiency is removed. On soils without P deficiency can grow big variety of crops.

An indicator of rate of return is value cost ratio (VCR). This is the value of yield increased due to fertilizers application divided by the fertilizers cost. This value must be 2 or greater to cover yield risk. In wetland tropics application of inorganic fertilizers is very risky and one heavy raining can remove all applied fertilizers. This is the reason why in Sabah (Malaysia) during December and January farmers avoided to apply fertilizers. A combination of fertilizers use, soil conservation and water harvesting techniques can deduce the risk. Adjusting fertilizers application according to weather forecast is known as "responsive farming" and can increase profitability very high. Another technique is point application which reduce the price dramatically and increase fertilizers use efficiency.

5. Minimizing losses of plant nutrients. Losses from the agricultural system can be in the form of harvested product, soil erosion, gaseous losses and leaching. Soil erosion can be in two forms: water erosion and wind erosion. The removal of nutrients with the harvest product is not considered as lost but it is related with the desired profit. But from the point of view to maintain soil quality it have to be consider to prepare the next fertilizers application program to be balanced and especially to provide nutrients as organic materials (composts and manures). Soil erosion is very damageable factor. It removed not only nutrients but reduce topsoil depth, water holding capacity. Eroded material contain finer particles of the soil that are rich in nutrients. Soil erosion depend on such parameter as topsoil depth, rooting depth of plants, crops cultivation, distribution of soil nutrients in soil profile, water holding capacity of the different soil layers, and amount and intensity of rainfall. Bulgarian scientist Mianushev (2013) also reported strong reduction of soil erosion at application of inorganic and organic materials due to root and top mass increased. Application of manure is at about 25 t/ha every 3 years, green mass every 3 years, and usage of cover crops in rotation such as wheat, N_2 fixing grasses, barley etc. Losses from water erosion at the arable eroded land in Bulgaria are now 130,000 grain t/year. For the next 10 years it is expected losses to be 700,000 grain t/year only from water erosion. Economically effective fertilizers application of the main nutrients in tropical area are: N120,P120,K120/ha; for grasses the recommendation is: N100:P100:K100. The causes of soil degradation are both related to the natural resource base, farming practice and polices. It have to be realized that problems with soil erosion can not be solved by individual farmers. Now more attention is given not to the different structure of terraces but for crop cover or combination of both including tillage methods. For example zero tillage practice have been found the most effective.

6. What are recommendations of Natural Resources Conservation Service of USA. (www.nrcs.usda.gov). They recommend Conservation Cropping System Methodology. By introducing Conservation Cropping System management can

contribute: increase soil infiltration, to reduce the risk from droughts, floods, markets, maintain water quality, reduce NO_3-N less in tile water, health soil and healthier profits, to avoid huge losses of non-renewable resources, not to change landscape, water quantity, less runoff, less flood damages, sediments and nutrient losses, improve air quality, save energy, healthy wildlife, Public cost savings, reduce inputs, filter sediments provides habitat, reduces pesticide application by half, reduce commercial fertilizer application, increase capture of the sun's energy by using winter cover crops to add an extra 4 to 5 money from photosynthesis, only one extra inch of water in August (saved through soil health practice) can mean an extra 20-40 bushels per acre in corn yield, reduce compaction and increase weed control. To make soil health priority through conservation cropping system you have to implement: a functioning no-till system, cover crops, nutrient management, pest management, crop rotation, buffers. Indiana's soil health strategy: 1. Established a state soil health specialist position; 2. Established area soil health team to identify local training and technical needs; prioritize contribution agreements, staffing decisions, developments of the tools, alternative work situations and mobile planning concepts; make soil health a priority in the Indiana communication plan, require NRCS Indiana employees meet skill level for soil health concept; support soil health as a training priority for all employees; ensure partners and leaders are aware of positive effect of conservation cropping system on soil health

7. Management of low productive soils There are low productive soils which need application of specialized technologies. *Heavy metal contaminated soils*: There are soils which after mining activity have not been used and their fertility have not been recovered. Usually these soils are acidic and contain more then one heavy metal over the standards. To neutralize further contamination to healthy soils must be take measures for re-cultivation. There are two approaches: a) USA approach is to cover the soil surface with $CaCO_3$ up to reach values of pH 7.3. But using this method plants, especially grasses, can not grow because at pH over7 all trace elements are blocked and can not be taken by plants; b) second approach is to determine potential soil acidity (how much soil will be acidify during the coming times) and to apply CaO or $CaCO_3$ according to measured acidity. But in both case microbial diversity have to be recovered and these soil have to be treated with 20 cm compost layer (Kostov and van Cleemput, 2001). Then not sensitive grasses have to be used to cover the treated soils to avoid erosion processes. Salinized soils are managed by leaching and application of gypsum. Strongly eroded soils are planted with nitrogen fixing grasses and grass mixtures but before planting they are treated with big amount of compost or manure. Weathered soils which are typical for tropical conditions including Malaysia are treated with alkaline solution as bunch ash to neutralize exchangeable Al and then compost is applied to recover soil microbial diversity and structure of the soil. Application of humic and fulvic acids to these soils is very useful management practice. It was carried out a personal study in Belgium using: 4 Indonesian, 4 Malaysian and 4 Belgium soils with the same acidic pH of 4.5. Soils were also determine for availability of exchangeable (toxic) Al. It was found that Malaysian and

Indonesian soils showed exchangeable (toxic) Al but Belgium soils despite having the same acidity did have exchangeable Al due to its high organic matter content (2.8%). Acidified soils must not be treated with inorganic fertilizers and must be treated with CaO plus organic fertilizers such as composts to recover their structure and removed toxic (available) forms of heavy metals. Soils with low fertility will resulted in deforestation, desertification, loss of biodiversity and influenced climatic change.

8. Polices for soil fertility management. The process of creating a more sustainable and productive agriculture requires public action along many paths. Political/economic factors are of vital importance for soil fertility management such as prices of input and output, access to credit and related interest rates, infrastructure and markets. Policies which affect these factors are fiscal and monetary policies, credit policies, and investment in infrastructure. For example exchange rate will affect the price of fertilizers. Investment in soil fertility management will be warranted when there is balance between private and social cost. For example an investment may give too little return in order to be an interesting option for the farmer, may be beneficial from a public point of view. The private farmers are more focused on short term benefits than society. The benefits of the society of erosion control programs can be related to reduction of poverty, to avoid siltation of dams, and destruction of roads. Private farmers have also to be interested to substitute bigger parts from inorganic fertilizers by making their own composts/manures using plant residues and other organic materials. So farmers have to be interested more in new technologies which can strengthen the integration between crops and livestock production, enhance recycling of organic materials, developing low cost and efficient methods for fertilizers application and moisture conservation. Fertilizers used always have to be accompanied by recycling of organic materials to ensure soil microbial diversity (Gardi at all., 2013), to avoid pollutions of ground waters and rivers, waterlogging and salinization of irrigated land, human health problems related to pesticide use, to reduce CO_2 and N_2O emissions to reduce global worming effect, to uptake CO_2 from air (more fertility and deeper soils fix more atmospheric CO_2) and to keep soil quality for future generations. Soil fertility management have fundamental importance for the development and sustainability of tropical agriculture production.

9. Composting wastes to improve and mainatain soil fertility. Special attention have to be given to tropical composting of wastes. (Kostov and van Cleemput, 2001; Kostov and Ngan, 2002; Vladeva and Kostov, 2002; Kostov at all. 2004; Wan Rashida at all., 2004; Kostov at all., 2005; Kostov 2008;). Application of all kinds matured composts to tropical soils will increase soil organic matter, will protect soils from soil erosion, will improve physical properties of soils, will increase water holding capacity of soils, will supply with nutrients plants in accordance with their needs, reduce acidifying activity of mineral fertilizers (EFB compost have pH =8.5-9) , will have very strong bioremediation effect on available (toxic) heavy metals, aluminum and arsenic and increase the quantity and quality of the yield and finally will increase profitability of palm oil plantations, palm oil mills and all types of agricultural practices occupied

with tropical plants. Using zero waste discharged composting technology we can contribute to increase humus content of tropical soils by 1.4 kg humic acid, 7.2 kg organic C , 1 kg K_2O, 0.4 kg P_2O_5, 0.2 kg MgO, 0.1 kg CaO, 0.4 g B at application rate 20 kg compost/palm oil tree/year. Also compost contain trace elements. It was established by huge area experiment (in ha Palm Oil Plantation in Sabah, Lahad Datu) that additional to mineral fertilization, the application of humic acid (imported from USA) to palm oil plantations at rate of 300 g/tree/year can increase the yield at Sabah area (Malaysia) up to 37t FFB (Fresh Fruit Bunches)/ha/1-3 years. Also it have to be taken into account that optical properties of compost humic acids which are not the same as compare to very old soil humic acids. Amount of fulvic acid in composts is also very important to soil fertility because they balanced photosynthesis processes in plants and regulate release of carbon by root system to soils and soil microorganisms. Compost have also strong bioremediation effect on heavy metals and As because it pH is near to 9 and it can increase soil pH in active zone of young roots.

Picture 3. *Turning windrows to optimize microstructure, O_2 and moisture content*

Picture 4. *Biocontrol properies of compost on banana dseases*

Picture 5. *Biocontrol properties of zero waste discharged compost*

Conclussion

The 68th UN General Assembly declared 2015 the International Year of Soils (IYS) (A/RES/68/232).(http://www.fao.org/soils-2015/about/en/)

The Food and Agriculture Organization of the United Nations has been nominated to implement the IYS 2015, within the framework of the Global Soil Partnership and in collaboration with Governments and the secretariat of the United Nations Convention to Combat Desertification.

The IYS 2015 aims to increase awareness and understanding of the importance of soil for food security and essential ecosystem functions.

The specific objectives of the International Year of Soils 2015 (IYS) 2015 were to:

•Raise full awareness among civil society and decision makers about the profound importance of soil for human life;

•Educate the public about the crucial role soil plays in food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development;

•Support effective policies and actions for the sustainable management and protection of soil resources;

•Promote investment in sustainable soil management activities to develop and maintain healthy soils for different land users and population groups;

•Strengthen initiatives in connection with the SDG process (Sustainable Development Goals) and Post-2015 agenda;

•Advocate for rapid capacity enhancement for soil information collection and monitoring at all levels (global, regional and national).

Soils are a finite natural resource and are nonrenewable on a human time scale. Soils are the foundation for food, animal feed, fuel and natural fiber production, the supply of clean water, nutrient cycling, buffers for floodings and droughts and range of ecosystem functions. About 80% of soils are not irrigated but they produce 60% from the global agriture production. The area of fertile soils covering the world's surface is limited and increasingly subject to degradation, poor management and loss to urbanization. Increased awareness of the life-supporting functions of soil is called for if this trend is to be reversed and so enable the levels of food production (world food production have to be increased by 60% but for developing countries by 100%) necessary to meet the demands of population levels predicted for 2050. Soils play key role for carbon cycle and can fix CO2 thus reducing negative effect of climate changes. Soils maintain also biodeversity, support growth of the plants and produce foods, fuels, medicine products and drinking water. Also 33% from soils are moderate to strongly degraded due to consumption of nutrients, acidification, salinization etc. New agricultural practices have to be applied such as agroecology methods, biological agriculture, zero tillage suitable crop rotation, low impute agriculture, and forest agriculture. (http://www.fao.org/soils-2015/about/en/ ; http://ourworld.unu.edu/en/recommended-reading-for-the-un-international-year-of-soils-2015; www.bsss.bg)

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