Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course Code : **MTIGT0707** *Optional Elective :* **14** *Credits :* **3**

GEOINFORMATICS IN SOIL SCIENCE

Unit–3 Soil Nutrients and Crop Production

Prepared by

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Course Objectives:

- To learn the importance, characters and types of soil and its relation with biotic systems
- To study the significance of soil nutrients and micronutrients
- To understand relevant aspects like soil organic matter, water holding property and landscape
- To learn the application of Geological Technology and Geoinformatics in soil resources mapping and management
- To learn the application of Geoinformatics in mitigating soil erosion and reservoir siltation.

SEMESTER – VII ELECTIVE PAPER-14 MTIGT0707 GEOINFORMATICS IN SOIL SCIENCE

3 Credits

1. **Introduction to Soil Science :** Nature and Importance of Soil, Soil formation, Soil survey, Physical, chemical and biological characters of soil, Relationship between Soil, plants and animal. **9 Hrs**

2. **Soil Types :** Soil types and classification, Soil genesis, Soil mineralogy and geochemistry of soil types: Laterites, Bauxites, Aridisols, Vertisols, Camborthids. Application of soil micromorphology and landscape evolution. Radiometric age determination of soils. **12 Hrs**

3. **Soil Nutrients and Crop Production :** Elements essential for plants and animals, Soil nutrients - Nitrogen, Phosphorous, Potassium, Calcium, Magnesium and Sulphur in soil and its significance in plant growth, Micronutrients. **9 Hrs**

4. **Soil Quality and Landscape :** Soil and water relations, organic matter in soil, functions of organic matter, organic matter and soil structure, organic matter and essential elements, tillage, cropping systems and fertility and case studies. **12 Hrs**

5. **Soil Management and Conservation :** Introduction, irrigation, drainage and soil management for field crops, gardens, lawns, pastures, rangelands and forests. Problem Soils - Soil surface crusting - Salinity - Erosion - Contamination. Soil conservation factors and implementation methods. **6 Hrs**

6. **Current Contours: (Not for Final Exam; only for Discussion):** Environmentally safe and sustainable methods of mitigating soil erosion and reservoir siltation using Geological Technology and Geoinformatics; Development of suitable and pragmatic methods to protect soil from fertility loss, soil pollution and degradation.

References:

1. Nyle, C. Brady, Ray R. Weil, The Nature and Properties of Soils (13th Edition) Prentice Hall, 2002.
2. Donald, L. Sparks, Environmental Soil Chemistry, 2002.
3. Raymond B. Daniels, Richard D. Hammer., Soil Geomorphology, John Wiley & Sons, 2000.
4. M.E. Sumner, Hand book of soil Science, 1992.
5. Donald Sparks, Donald L. Sparks D, Environmental Geochemistry, Academic Press, 2002.

Course Outcomes:

After the successful completion of this course, the students are able to:

- *Understand the importance and the physical, chemical and biological properties of soils*
- *Know the different types of soils and classification*
- *Differentiate the reflectance properties of soils and mapping them using satellite data*
- *Understand the problems to soils using Remote Sensing, field surveys in GIS platform through modeling.*
- *Suggest pragmatic soil management and conservation practices using Remote Sensing, field surveys in GIS platform through modeling and*
- *Understand the importance of soil nutrients, quality and relation with landscape.*

Unit - 3 Soil Nutrients and Crop Production

Elements essential for plants and animals, Soil nutrients - Nitrogen, Phosphorous, Potassium, Calcium, Magnesium and Sulphur in soil and its significance in plant growth, Micronutrients. **9 Hrs**

Plant nutrition

- **Plant nutrition** is the study of the chemical elements that are necessary for growth. In 1972, E. Epstein defined a criteria for an element to be essential for plant growth.

- In its absence the plant is unable to complete a normal life cycle

- (-seed germination-seedling-growth-pollination-fruit/seed development-).

- **Sixteen chemical elements** are known to be important to a plant's growth and survival. The sixteen chemical elements are divided into two main groups:

  Non-mineral and

  Mineral

Elements essential for plants and animals

Elements essential for **plants**

16 out of the 90 elements of soil, are:

1. Carbon
2. Hydrogen
3. Oxygen
4. Phosphorous
5. Potassium
6. Nitrogen
7. Sulphur
8. Calcium
9. Iron
10. Magnesium
11. Boron
12. Manganese
13. Copper
14. Zinc
15. Molybdenum and
16. Chlorine

Elements essential for **animals**

Animals are also in need of the same nutrients
With the exception of Boron
And the addition of

1. Sodium
2. Cobalt
3. Selenium and
4. Iodine

Non-mineral and **Mineral nutrients** **are highly essential for plants**

TABLE 4.1 Elements Essential for Nutrition of Plants

Element	Adequate Concentration (% dry wt. of Tissue)	
Carbon	45	
Oxygen	45	
Hydrogen	6	
Nitrogen	1.5	macro-nutrients
Potassium	1.0	
Calcium	0.5	
Phosphorus	0.2	
Magnesium	0.2	
Sulfur	0.1	
Chlorine	0.01	micro-nutrients
Iron	0.01	
Manganese	0.005	
Zinc	0.002	
Boron	0.002	
Copper	0.0006	
Molybdenum	0.00001	

Source: Zinke, P.J. 1977. "Man's activities and their effect upon the limiting nutrients for primary productivity in marine and terrestrial ecosystems," In *Global Chemical Cycles and Their Alterations by Man*, ed. W. Stumm, p. 92. Berlin: Dahlem Konferenzen.

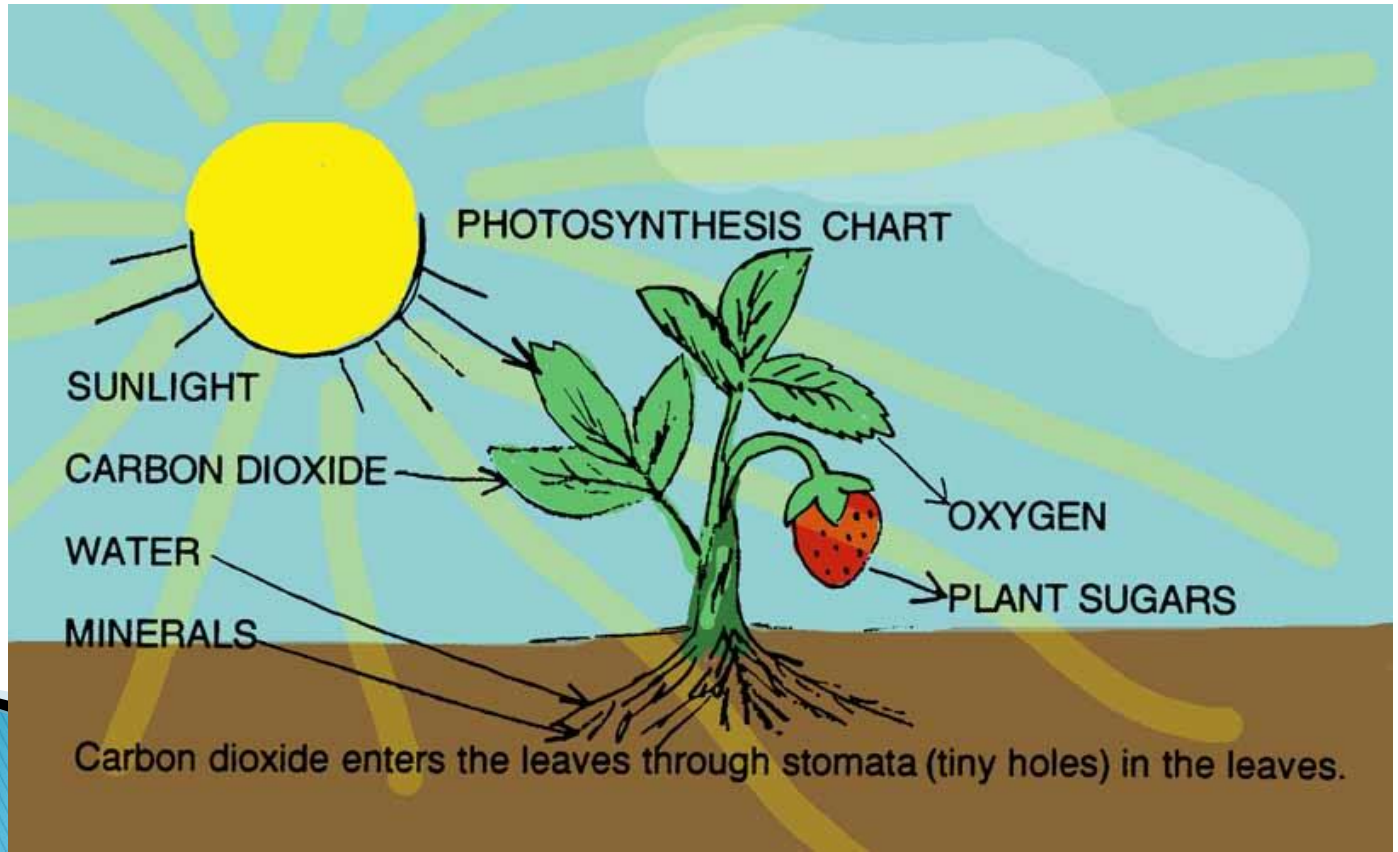
Non-Mineral Nutrients

- The **Non-Mineral Nutrients** are **carbon (C), hydrogen (H), & oxygen (O).**

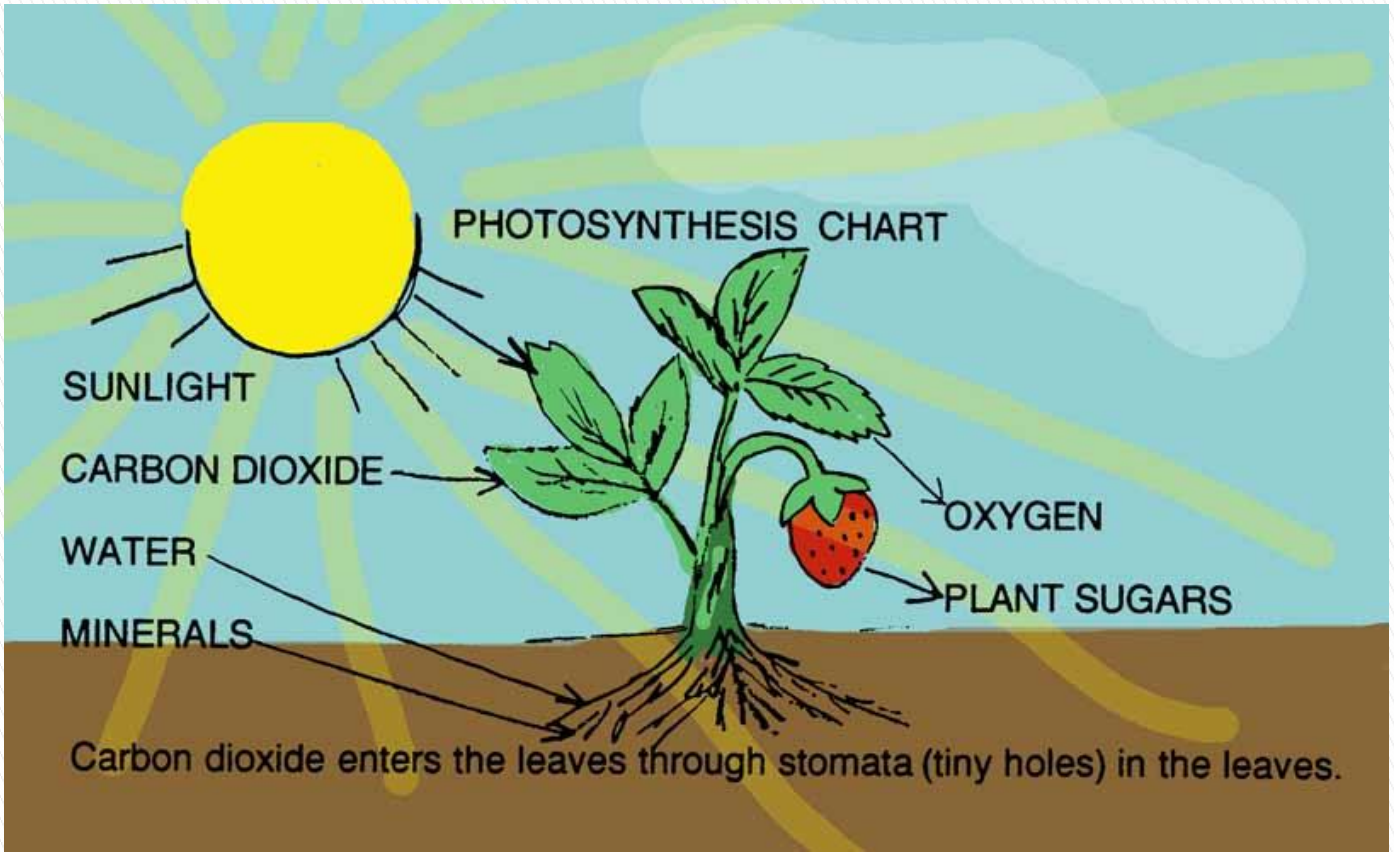
CarHydrOxy

- These nutrients are found in the air and water.
- Since plants get carbon, hydrogen, and oxygen from the air and water, there is little farmers and gardeners can do to control how much of these nutrients a plant can use.

- In a process called **photosynthesis**, plants use **energy from the sun** to change **carbon dioxide** (CO_2 – carbon and oxygen) and **water** (H_2O– hydrogen and oxygen) into starches and sugars.
- These starches and sugars are the plant's food.
- **Photosynthesis** means "making things with light"



- Nearly all nutrients are used in ionic forms
- Plant roots release hydrogen ions as they absorb other nutrient cations and exchange bicarbonate ions for nutrient anions from soil solution
- Nitrogen is most often the limiting element in plant growth



Mineral Nutrients

- The **13 mineral nutrients**, which come from the soil, are dissolved in water and absorbed through a plant's roots.
- There are not always enough of these nutrients in the soil for a plant to grow healthy. This is why many farmers and gardeners use fertilizers to add the nutrients to the soil.
- The mineral nutrients are divided into two groups: macronutrients and micronutrients.

MACRONUTRIENTS

The primary nutrients are:

- **Nitrogen (N),**
- **Phosphorus (P)**
- **Potassium (k)**

NPK

These major nutrients usually are lacking from the soil first because plants use large amounts for their growth and survival. These elements are generally required in quantities ranging from 10 to 400 pounds per acre.

Nitrogen Function

- Nitrogen in the soil is the most important element for plant development.
- Nitrogen is a major part of chlorophyll and the green color of plants.
- It is responsible for lush, vigorous growth and the development of a dense, attractive lawn.
- Although nitrogen is the most abundant element in our atmosphere, plants can't use it until it is naturally processed in the soil, or added as fertilizer.

Phosporous

- Phosphorus is limited in most soils because it is released very slowly from insoluble phosphates.
- phosphorus is important for plant growth and flower/seed formation. Phosphate esters make up DNA, RNA, and phospholipids. Most common in the form of polyprotic phosphoric acid (H_3PO_4) in soil, but it is taken up most readily in the form of H_2PO_4.

Potassium

- Potassium is an essential nutrient for plant growth.
- Potassium is involved in many plant metabolism reactions, ranging from lighting and cellulose used for formation of cellular structural components, for the regulation of photosynthesis .
- It controls water loss from plants and is involved in overall plant health. Soils that have adequate potassium which allow plants to develop rapidly and outgrow . It protects plant disease, insect damage and protect against winter freeze damage.

K ....

- Soil minerals are rich in potassium naturally. However, the plant available forms are classed as **available**, **slowly available** and the **unavailable**.
- Clay soils contain more minerals and tend to have higher levels of potassium and sandy textured soils tend to contain lower amounts of potassium.

The secondary nutrients are:

- **Calcium (Ca)**,
- **Magnesium (Mg)**, and
- **Sulfur (S)**.
- There are usually enough of these nutrients in the soil so fertilization is not always needed. Also, large amounts of Calcium and Magnesium are added when lime is applied to acidic soils.

CaMagS

- **CALCIUM** – regulates transport of other nutrients into the plant and is also involved in the activation of certain plant enzymes. Calcium deficiency results in stunting.
- **MAGNESIUM** is part of the chlorophyll in all green plants and essential for photosynthesis. It also helps activate many plant enzymes needed for growth. Soil minerals, organic material, fertilizers, and dolomitic limestone are sources of magnesium for plants.
- **SULFUR** is usually found in sufficient amounts from the slow decomposition of soil organic matter.

Soil Nutrient Deficiencies

- Easily identified by the plants that grow in that soil
- The plants grow with the deficiency of certain important nutrients with some defects in their growth
- Affected growth is represented in plants through – it's stems, leave, flowers, fruits, and roots.
- In the form of colour change, stunted growth, curled leave, rotten roots and stems, etc.

Symptoms of Nutrient Deficiencies:

- **Nitrogen** – growth of plant is stunned; plants become pale yellow in color; leaf edges become reddish brown.
- **Phosphorus** – root growth is stunted; thin stalk; maturity of plant is delayed; plant becomes purplish in color.
- **Potassium** –plant stems are weakened; leaf edges appear brown and dry. Necrotic and chloritic leaves.

Chlorosis is the yellowing of leaf tissue due to a lack of chlorophyll, while **necrosis** is the death of plant cells or tissues.

Necrotic (A), chlorotic (B) leaves and normal leaves (C)

Macronutrient Deficiencies & Soils

Element	***Soil Factor Causing Deficiency***
N & K	Excessive leaching on coarse-textured low organic matter soils
P	Acid low organic matter soils
	Cold wet soils occurs during early spring
	Newly cleared soils
S	Excessive leaching on coarse-textured low organic matter soils in areas where air pollution is low (minimal levels of SO_2 in the air)
Ca & Mg	Excessive leaching on coarse-textured low organic matter soils
	Soils where large amounts of K have been applied

Pale yellow

Nitrogen deficiency

Stunned growth-phosporous deficiency

Deficiency Symptoms – Nitrogen

- General chlorosis.
- Chlorosis progresses from light green to yellow.
- Entire plant becomes yellow under prolonged stress.
- Growth is immediately restricted and plants soon become spindly and drop older leaves.

http://plantsci.sdstate.edu/woodardh/soilfert/Nutrient_Deficiency_Pages/soy_def/SOY-N1.JPG

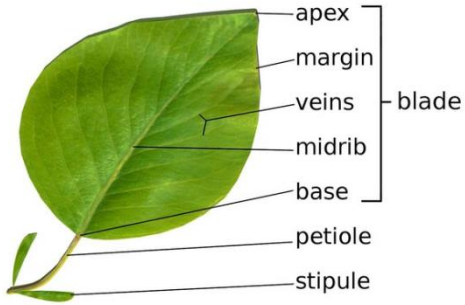
Deficiency Symptoms – Phosphorous

- Leaves appear dull, dark green, blue green, or red-purple, especially on the underside, and especially at the midrib and vein.
- Petioles may also exhibit purpling. Re-striction in growth may be noticed.

http://www-unix.oit.umass.edu/~psoil120/images/tomatox2.jpg

Merlot with advanced P deficiency symptoms.

http://www.ext.vt.edu/news/periodicals/viticulture/04octobernovember/photo3.jpg



Potassium deficient banana; older leaves become chlorotic, then necrotic, and the tip of the midrib bends downward.
Potassium deficient corn; margins of older leaves become chlorotic and necrotic.

Deficiency Symptoms – Potassium

- Leaf margins tanned, scorched, or have necrotic spots (may be small black spots *which* later coalesce).
- Margins become brown and cup downward.
- Growth is restricted and die back may occur.
- Mild symptoms appear first on recently matured leaves.

http://www.ipm.iastate.edu/ipm/icm/files/images/antonio004f.jpg

Calcium deficiency

leaf edges become curly;

terminal buds may die

Deficiency Symptoms – Calcium

- Growing points usually damaged or dead (die back).
- Margins of leaves developing from the growing point are first to turn brown.

http://hubcap.clemson.edu/~blpprt/acid_photos/BlossomEndRot.JPG

Cont…

- **Calcium** – leaf edges become curly; terminal buds may die; blossoms lose their petals prematurely.
- **Magnesium** – leaves become thin and brittle; leaves lose their color at the tips and the areas between the veins.
- **Sulfur** – lower leaves of the plant becomes yellowish in color, roots and stems are small.

Cont…

- **Boron** – terminal buds are light green; dark spots appear on the roots; stems crack.
- **Copper** – plants develop bleached appearance.
- **Iron** – leaves become yellow but veins remain green; leaves curl upward.
- **Manganese** – spots of dead tissue on the leaves may drop out, giving the leaves a ragged appearance.
- **Molybdenum** – symptoms are similar to those of nitrogen deficiency.
- **Zinc** – terminal leaves are dwarfed; bud formation is reduced.

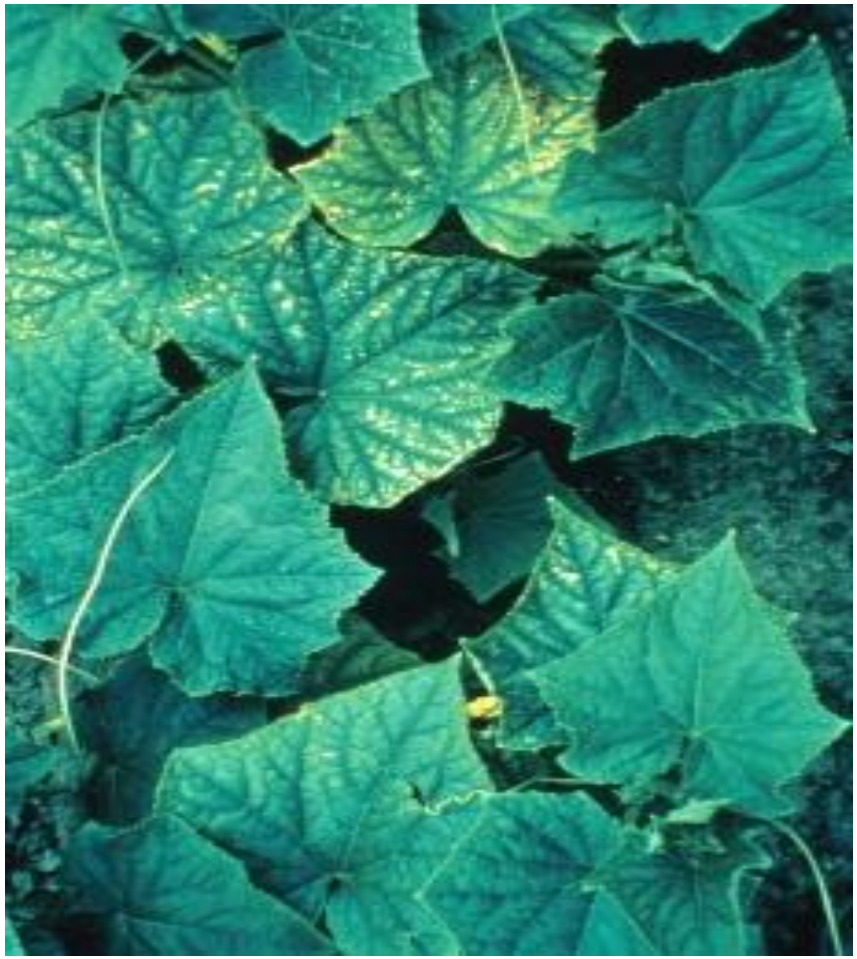
Magnesium deficiency

Sulfur deficient sorghum; young leaves are uniformly chlorotic.

Deficiency Symptoms – Magnesium

- Marginal chlorosis or chlorotic blotches which later merge.
- Leaves show yellow chlorotic interveinal tissue on some species, reddish purple progressing to necrosis on others.
- Younger leaves affected with continued stress.
- Chlorotic areas may become necrotic, brittle, and curl upward.
- Symptoms usually occur late in the growing season.

LEAF BLOTCH is **a plant disease especially of fungal origin producing irregular dead or discolored areas in the** leaves



http://quorumsensing.ifas.ufl.edu/HCS200/images/deficiencies/-Mgcq.jpg

Deficiency Symptoms – Sulphur

- Leaves uniformly light green, followed by yellowing and poor spindly growth.
- Uniform chlorosis does not occur

http://www.ces.ncsu.edu/plymouth/cropsci/graphics/sulfur2.jpg

http://www.ag.ndsu.nodak.edu/aginfo/entomology/ndsucpr/Years/2007/june/7/soils.jpg

Sulphur deficiency

Young leaves become chlorotic

ESSENTIAL NUTRIENT FOR ANIMAL GROWTH

- The macronutrients such as Carbon, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and
- the micronutrients are boron, chlorine, cobalt, copper, iron, manganese, molybdenum, nickel and zinc are the mineral needed for animal growth.
- In addition to these, some elements such as **selenium** and **iodine**, though not required by plants, are essential nutrients for animals.

- Over the millions of years animals have been on the planet, there has been ongoing adjustment in a particular period to changing soil and climatic conditions.
- In each climatic period there has been generally been a balance created between the nutrient needs of the animals and the ability of the soil to supply it.
- Nutrient cycling is essential for ultimate sustenance of plants and animals.

Selenium

- Selenium is among the rarer elements on the surface. Selenium occurs naturally in the environment
- Well fertilized agricultural soil generally has about 400 mg/ton since the element is naturally present in phosphate fertilizers and is often added as a trace nutrient.

- selenium is more readily absorbed by animals through the digestive tract. It has been estimated that lactating dairy goats absorb about 65% of ingested selenomethionine
- Selenium substances in soil are usually broken down to selenium and water fairly quickly, so that they are not dangerous to the health of organisms.

http://www.lenntech.com/periodic/elements/se.htm#ixzz1YYU1twR6

Iodine

- **Iodine compounds are found in** seawater, soil, and rocks.
- Once in the air, iodine can combine with water or with particles in the air and can enter the soil and surface water, or land on vegetation when these particles fall to the ground or when it rains.
- Iodine can remain in soil for a long time because it combines with organic material in the soil. It can also be taken up by plants that grow in the soil.
- Cows or other animals that eat these plants will take up the iodine in the plants.

Cont…

- The reason that iodine ultimately concentrates in the soil is the result of its chemistry. Iodine is one of the halogens. The halogens are prominent anions in the environment.
- The horse has a high sensitivity for iodine.
- Even just an extra of 35 mg iodine per day (adult horses, dry matter intake: 10 kg) can cause severe health risks.

- Plant nutrition is a difficult subject to understand completely, partially because of the variation between different plants and even between different species or individuals of a given clone.
- The macronutrients are consumed in larger quantities and are present in plant tissue in quantities from 0.2% to 4.0% .
- Each of these nutrients available in soil in different places are useful for a variety of essential functions of plants and animals.

SOIL MICRONUTRIENTS & PLANTS

Soil Micronutrients

- Micronutrients are elements which are essential for plant growth, but are required in much smaller amounts than those of the primary nutrients; nitrogen, phosphorus and potassium.
- The micronutrients are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and chloride (Cl).
- While chloride is a micronutrient, deficiencies rarely occur in nature, so discussions on supplying micronutrient fertilizers are confined to the other six micronutrients.

Cont…

- Micronutrients are present in plant tissue in quantities measured in parts per million, ranging from 5 to 200 ppm, or less than 0.02% dry weight.
- Deficiencies of micronutrients have been increasing in some crops.
- Some reasons are higher crop yields which increase plant nutrient demands, use of high analyses NPK fertilizers containing lower quantities of micronutrient contaminants, and decreased use of farmyard manure on many agricultural soils.
- Micronutrient deficiencies have been verified in many soils through increased use of soil testing and plant analyses.

TABLE 4.1 Elements Essential for Nutrition of Plants

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Carbon	45	
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Hydrogen	6	
Nitrogen	1.5	macro-nutrients
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Source: Zinke, P.J. 1977. "Man's activities and their effect upon the limiting nutrients for primary productivity in marine and terrestrial ecosystems," In *Global Chemical Cycles and Their Alterations by Man*, ed. W. Stumm, p. 92. Berlin: Dahlem Konferenzen.

How Plants Absorb Nutrients?

- Through leaves (foliar) or through soil
- High micronutrient demand is supplied through soil
  - active uptake of specific nutrients
- Micronutrients can be foliarly applied (spray)
  - mechanism is primarily diffusion
  - good quick fix methods in greenhouses, etc.
- Most soil nutrients enter through roots.

Micronutrients

- The term micronutrient is encouraged by the American Society of Agronomy and the Soil Science. They are needed in trace amount. They generally required in quantities of about 6 grams per hectare of molybdenum to 280 kg per hectare of iron and manganese.
- The micronutrients are **boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo)** and **zinc (Zn)**.

Boron

- Helps in the use of nutrients and regulates other nutrients.
- Aids production of sugar and carbohydrates.
- Essential for seed and fruit development.
- Sources of boron are organic matter and borax.
- Secondary roles may be in sugar transport, cell division, and synthesizing certain enzymes.
- Boron deficiency causes necrosis in young leaves and stunting.

Copper

- Important for reproductive growth.
- It competes with zinc and copper in the soil for position (availability) to plants. Without zinc and copper plants wont grow either.
- Available copper in soil is held as a cation(cu++) on surface of clay mineral.
- Aids in root metabolism and helps in the utilization of proteins.

Iron

- Essential for formation of chlorophyll.
- Iron is also used by enzymes to regulate transpiration in plants.
- It competes with zinc and copper in the soil for position (availability) to plants.
- Without zinc and copper plants wont grow either.

zinc

- Essential for the transformation of carbohydrates.
- Regulates consumption of sugars.
- Part of the enzyme systems which regulate plant growth.
- Sources of zinc are , zinc oxide, zinc sulfate, zinc chelate.

Manganese

- Functions with enzyme systems involved in breakdown of carbohydrates, and nitrogen metabolism.
- It aids in the synthesis of chlorophyll and in nitrate assimilation.

Molybdenum

- Helps in the use of nitrogen
- Soil is a source of molybdenum.

Legumes need more molybdenum than other crops, such as grass or corn, because the symbiotic bacteria living in the root nodules of legumes require molybdenum for the fixation of atmospheric nitrogen

Deficiencies

- The deficiencies of micronutrients have become major constraints to productivity, stability and sustainability of soils
- A brief discussion of micronutrient functions and nutrient deficiency symptoms in plants and soil conditions affecting micronutrient availability serves to help understand their importance in crop production and to recognize symptoms of possible deficiencies.
- Deficiencies of these elements in crops are widespread in the region due to one or more of the following main reasons

Deficiencies …contd…

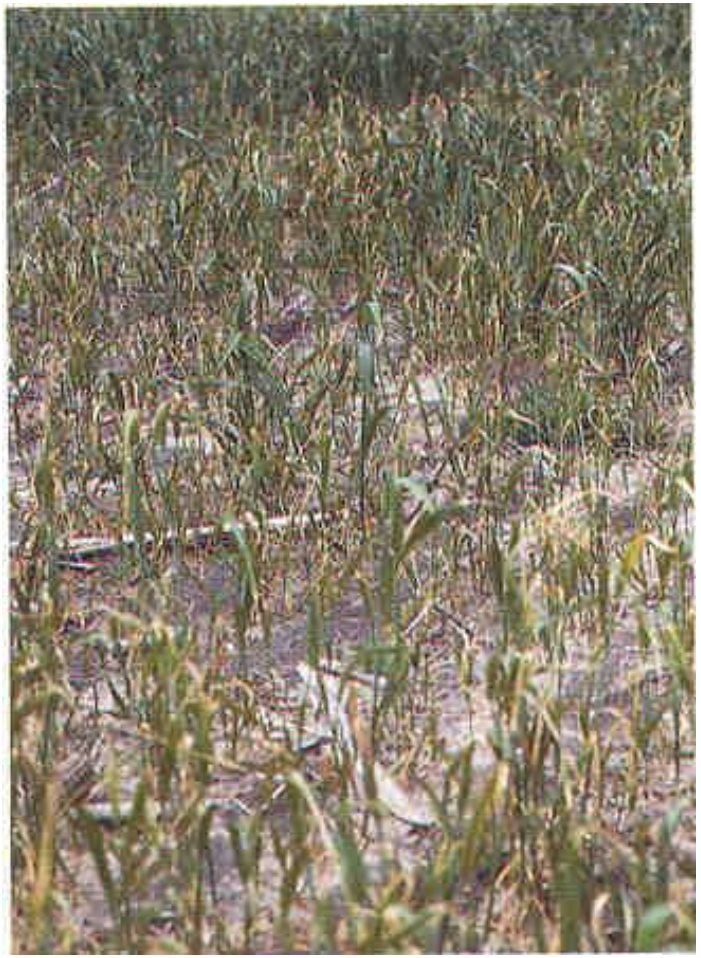
- Cultivating poor sandy soils with low contents of micronutrients
- High pH values of the soil negatively influencing the availability of these nutrients.
- Occurrence of high salt contents affecting adversely the uptake of nutrients
- High content of $CaCO_3$ in the soil
- Prevailing agronomic practices hindering continuous supply of nutrients (e.g. periods of wet/dry soils)
- Continuous intensive cropping without adding micronutrients to the soil (nutrient depletion)

Micronutrient Deficiencies & Soils

Element	***Soil Factor Causing Deficiency***
Fe	Poorly drained soils, Low organic matter in soils, >7.0 pH, Soils high in P
Zn	Cold wet soils low in organic matter and highly leached, High pH soils (pH>7.0), Soils high in P, Exposed subsoils
Cu	Peat and muck soils, High pH, sandy soils, Soils heavily fertilized with N
B	Excessive leaching on coarse-textured low organic matter soils, Soils with pH>7.0
Mn	Excessive leaching on coarse-textured low organic matter soils, Soil with pH>6.5
Mo	Soils high in Fe oxides, high adsorption of molybdenum, Soil cropped for a long time

Deficiency Symptoms – Copper

- Leaves wilt, become chlorotic, then necrotic.
- Wilting and necrosis are not dominant symptoms.



http://images.google.com/url?q=http://ipm.ncsu.edu/Scouting_Small_Grains/Grain_images/fig4.jpg&usg=AFQjCNE2vzRwrqp65VR_xKRlo2LQOgWI3g

Deficiency Symptoms – iron

- Distinct yellow or white areas appear between veins, and veins eventually become chlorotic.
- Symptoms are rare on mature leaves.

http://bexar-tx.tamu.edu/HomeHort/F1Column/2003Articles/Graphics/iron%20chlorosis.jpg

Deficiency Symptoms – Manganese

- Chlorosis is less marked near veins.
- Some mottling occurs in interveinal areas.
- Chlorotic areas eventually become brown, transparent, or necrotic.
- Symptoms may appear later on older leaves.

http://www.ca.uky.edu/HLA/Dunwell/KHC/110-122.JPG

Deficiency Symptoms – Zinc

- Leaves may be abnormally small and necrotic.
- Internodes are shortened.

http://agri.atu.edu/people/Hodgson/FieldCrops/Mirror/Nutrient%20Def_files/slide24.jpg

http://plantsci.sdstate.edu/woodardh/soilfert/Nutrient_Deficiency_Pages/corn_def/CORN-ZN1.JPG

Deficiency Symptoms – Boron

- Young, expanding leaves may be necrotic or distorted followed by death of growing points.
- Internodes may be short, especially at shoot terminals.
- Stems may be rough, cracked, or split along the vascular bundles.

http://www.canr.msu.edu/vanburen/ffc12.jpg

Remedies for micronutrient deficiency :

- **1. Soil treatment**
  - Adding fertilizers containing micronutrients
- **2. Crop treatment**
  - Adding fertilizers containing micronutrients to the soil
  - Breeding cultivars for high micronutrient efficiency
  - Spraying crops/fodder with micronutrients

Cont…

3. Animal treatment :

- • Addition to water
- • Feeding blocks
- • Supplementation
- • Injection
- • Producing fodder with high micronutrient content

4. Human treatment :

- • Food fortification
- • Supplementation (capsules … etc.)
- • Increasing natural contents in food produced
- . There is no only one way to overcome micronutrient deficiencies.
- . Treatments differ from preventive and curative measures.