UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE

# Tropical Fruit Production LPLK10367U

## Notes taken during the course, including lectures, exercises, curriculum, and practicals

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Link to GitHub reporsitory

# Course Description

## Education

MSc Programme in Agriculture
MSc Programme in Environment and Development
MSc Programme on Global Environment and Development

## Content

The course focuses on developing capacities for sustainable production of tropical crops. The students will be exposed to major crop science elements that are instrumental for a sustainable crop production. Focus is on optimizing the use of agrobiodiversity and management practices considering the socio-economic characteristics and climate change challenges.

Main disciplines are:

i. Agronomy with reference to tropical conditions.
Tropical crop physiology; crop genetic resources, agrobiodiversity and breeding; crop management; crop protection; soil fertility. Cultivation of crops under challenging conditions of climate change (e.g drought, salinity).

ii. Tropical Crops
An overview of major tropical crops groups in relation to their uses (roots and tubers; legumes; minor cereals; spices; stimulants; underutilized species), their intrinsic properties and their cultivation with special emphasis on small-holder conditions and resilience for climate change.

iii. Cropping systems
Crop production optimization strategies for sustainable production (intercropping, use of legumes for mitigation/adaptation). Innovations to optimize sustainable production systems (crop: phenotyping, breeding, protection). The use of agrobiodiversity for diversification, sustainable intensification and value chain enhancement.

## Learning Outcome

Provide students, having a BSc-level background in agricultural, social sciences or sciences involved with development of the tropical region, with a comprehensive understanding of the properties of selected tropical environments, crop species and their management facing climate change. Focus is on climate related production constraints; that is abiotic and biotic stresses, and human endeavor to optimize crop production in small-scale farming, within the context of poverty alleviation and sustainable crop production.

When students have completed the course, they should have attained:

### Knowledge

- Manage key elements to characterize production systems in the tropics
- Demonstrate knowledge of the principles of tropical crop production
- Understand the characteristics of major tropical crops
- Demonstrate overview of tropical cropping systems in relation to agro-ecological and socio-economic conditions
- Demonstrate knowledge on different strategies to optimize production systems in the tropics
- Manage basic tools for participatory work and research

### Skills

- Characterize production systems of tropical areas of the globe
- Design cropping calendars for selected major crops species
- Analyze and synthesize diverse types of information and data on tropical crop production
- Apply a relevant analytical software for statistics
- Apply relevant participatory rural appraisal methods
- Develop tropical crop production plans in relation to given agro-ecological and socioeconomic conditions
- Design and analyze the implementation of projects in a tropical crop production environment

### Competences

- Data management, analysis, and critical approach
- Assess and formulate agronomic components of development support programmes
- Advice extension and research institutions in tropical countries
- Perform and interpret quantitative and qualitative statistical information to analyze scenarios of crop production and innovation
- Propose innovative optimization strategies for sustainable crop production in the tropics

# Litterature

Papers and videos uploaded on Absalon
Tropical Crop Production I - Selected papers
Tropical Crop Production II – Manual for practical and theoretical exercises

# Recommended Academic Qualifications

Basic courses in biology, statistics, social sciences and sciences related to sustainable development
Academic qualifications equivalent to a BSc degree is recommended.
Academic qualifications equivalent to a BSc degree is recommended .

# Teaching and Learning Methods

The course applies blended learning with lectures supported by videos, digital tools, theoretical and practical exercises.

# Workload

**Table 1:** *A table with an overview over the workload for the course.*

| **Category** | **Hours** |
|---|---|
| Lectures | 30 |
| Preparation | 68 |
| Theory exercises | 55 |
| Practical exercises | 24 |
| Excursions | 7 |
| Project work | 8 |
| Guidance | 10 |
| Exam | 4 |
| Total | 206 |

# Exam

**Table 2:** *A table with an overview over the elaborated description of the course*

| | |
|---|---|
| Credit | 7.5 ECTS |
| Type of assessment | Oral examination, 30 min |
| Type of assessment details | During the course the student participate in group work in which they write a group report (approximate 10 pages). The students are individually examined in the content of the group report and are further examined in the rest of course curriculum. Examination in the report weight 35 % and examination in curriculum weight 65 %. No preparation time before the oral examination. |
| Examination prerequisites | Submitted and approval of the reports for theoretical and practical exercises |
| Aid | All aids allowed |
| Marking scale | 7-point grading scale |
| Censorship form | • No external censorship<br>• Several internal examiners |
| Re-exam | • As the ordinary exam.<br>• If the student did not participate in a approved group report, an assignment is given three weeks before the exam. The student has to hand in an individual report based on the assignment (approximate 5 pages). At the oral examination the students will then be examined in the report and in the rest of the curriculum. Examination in the rapport weight 35 % and examination in curriculum weight 65 %. |

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# Chapter 1
# Lecture Notes

## 1 Lecture 01 - 02/09-2025

### 1.1 The Tropical Environment

#### 1.1.1 Aim

- Overview the most important aspects of tropical climates.
- Ability to figure out how the climate is likely to be in certain places in the tropics.
- Idea of which crop you can grow.

### 1.2 What Determines the Climate?

The climate is determined by several factors, including temperature and precipitation. Key aspects are the yearly average temperature and the yearly range in temperature, as some areas experience a larger difference between the highest and lowest temperatures than others. Similarly, average precipitation is important, but the yearly variation in rainfall also plays a significant role.

#### Core takeaway:

Climate is primarily defined by temperature and precipitation, considering both yearly averages and seasonal variations. Likely exam-relevant.

### 1.3 Classification: Latitudes

- Tropical zone from 0°–23.5°(between the tropics) latitude: Here, solar radiation reaches the ground nearly vertically, more water evaporates, and the air is often moist. A dense cloud cover reduces the effect of solar radiation on ground temperature.
- Subtropics from 23.5°–40°latitude: These regions receive the highest radiation in summer, have relatively thin cloud cover, and receive less moisture.
- Temperate zone from 40°–60°latitude: This zone is characterized by significantly differing seasons and day lengths, less frequent climate extremes, a more regular distribution of precipitation, and a longer vegetation period.

- Cold zone from 60°–90°latitude: The poles in this zone receive less heat through solar radiation, and day length varies the most. Vegetation is only possible during a few months and is often sparse.

### Core takeaway:

Earth's climate zones are classified by latitude, each with distinct characteristics regarding solar radiation, temperature, precipitation, and vegetation periods. Likely exam-relevant.

## 1.4 Circles of Latitude and Longitude

### 1.4.1 Earth's Movement and Tropical Rain Belt

The Earth spins around its axis, akin to a top, a process known as Earth's rotation. Simultaneously, it orbits or revolves around the Sun. The tropical rain belt runs along the equator and extends to about the Tropic of Cancer (23.5°north latitude) and Tropic of Capricorn (23.5°south latitude). By approximately 30°north and south latitude, the air cools enough to sink back to the surface, creating high pressure (H) and drier conditions.

### 1.4.2 Earth's Orbit and Solar Energy

The Earth's revolution around the sun takes 365.24 days. At the equator, the Earth rotates at roughly 1,700 km per hour. The Earth is closest to the sun (perihelion) on January 3rd at 147 million km, moving faster at 27 km/s. It is furthest from the sun (aphelion) on July 4th at 152 million km, moving slower. Solar energy is relatively constant, approximately 400 $W/m^2$/year. About 300 $W/m^2$/year is lost as terrestrial re-radiation, leaving a surplus of 100 $W/m^2$ at the surface. Most of the radiation is absorbed by the Earth and warms it. Some of the outgoing infrared radiation is trapped by the Earth's atmosphere, which also contributes to warming.

### Core takeaway:

Earth's rotation and revolution influence climate patterns, including the tropical rain belt, and its interaction with solar energy dictates global temperatures. Likely exam-relevant.

## 1.5 The Tropics

The tropics are characterized by a high input of solar radiation and high maximum temperatures, with little variation in temperature. Water supply is the most significant variable, marked by high rainfall variability and high rainfall intensity. The tropics cover 42% of the Earth's surface.

### 1.5.1 Characterize the tropics !

### 1.5.2 Precipitation

Precipitation patterns in the tropics include:

- Wet climate (between 5°and 10°of the equator).
- Wet dry climate (between 10°and 20°).
- Two wet seasons: typically 1000-2000 mm (e.g., Salvador, Abidjan).
- Two shorter rainy seasons (e.g., Nairobi).
- One long rainy season: monsoonal, 750-1500 mm (e.g., Manila).

- One short rain season: 250-750 mm (e.g., Darwin, Hyderabad).
- Dry climate (e.g., Alice Springs, Lima, Khartoum)

### Core takeaway:

The tropics receive high solar radiation and experience consistent high temperatures, with water supply and significant rainfall variability being defining features across different precipitation zones. Likely exam-relevant.

## 1.6 Three Major Biomes

A biome is defined as a community of similar plants and animals occupying a large area. The three major biomes are Forest, Savanna, and Desert.

### 1.6.1 Tropical biomes and annual precipitation (mm)

Tropical biomes exhibit extremely high biodiversity, encompassing 50% of the world's terrestrial plant and animal species, despite covering only about 6% of the world's land area.

### Core takeaway:

The tropics host three major biomes—Forest, Savanna, and Desert—which are critical for global biodiversity, harboring half of the world's terrestrial species in a small land area. Likely exam-relevant.

## 1.7 Deforestation

Before human intervention, rainforests covered 15% of the Earth's land area, but today they cover only 6%. In the last 200 years, the total area of rainforest has decreased from 1,500 million hectares to less than 800 million hectares. A third of tropical rainforests have been destroyed in just the last 50 years. Approximately 119,000 - 150,219 $km^2$ are lost each year, affecting the world's most spectacular ecosystems.

### Core takeaway:

Deforestation has drastically reduced tropical rainforest coverage, leading to a significant loss of these vital ecosystems globally. Likely exam-relevant.

## 1.8 Daily Weather Cycle in the Tropical Rainforest

In the morning, the sun shines and heats up the ground, causing hot and wet air to rise. In the afternoon, dark clouds form, bringing rain and thunderstorms to the rainforest.

## 1.9 Prevailing Winds

### 1.9.1 Latitudinal Variation in Evapotranspiration and Precipitation

(figure, see slide 9)

## 1.10 Remember!

- Hot air weighs less than cold air.
- Hot air can contain more water than cold air.
- Air will flow from areas of high pressure towards areas with low pressure.
- Condensation of water releases energy.
- The temperature of the air drops approximately 1 degree for every 100 m, or 0.5 degrees if the air contains water.
- Objects moving in the northerly or southerly direction will be deflected clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere (Coriolis force) (see also Slide 10).

### Core takeaway:

Atmospheric dynamics, driven by temperature, pressure, and the Coriolis force, dictate air movement, moisture content, and temperature changes critical for understanding weather patterns. Likely exam-relevant.

## 1.11 Coriolis Force

When the Earth rotates, a point close to the equator moves much faster than a point at one of the poles. This movement creates specific patterns on Earth and affects winds and ocean currents.

### Core takeaway:

The Coriolis force, a result of Earth's rotation, deflects moving objects and significantly influences global wind and ocean current patterns. Likely exam-relevant.

## 1.12 Tropical Storms

Tropical storms include Hurricanes (in the Caribbean and United States) and Typhoons (in the Pacific Ocean). These storms are characterized by wind speeds exceeding 115 km/hour, low pressure, and a circular pattern of isobars with a diameter of 150-650 km. They bring extreme rainfall (up to 200 mm/day) and steep gradients that produce high wind speeds.

### 1.12.1 Cyclones Around Australia

## 1.13 Monsoons

Monsoons are large-scale sea breezes that occur when the temperature on land is significantly warmer or cooler than the temperature of the ocean. These temperature imbalances happen because oceans and land absorb heat in different ways.

### Core takeaway:

Tropical storms like hurricanes and typhoons are intense low-pressure systems with high winds and extreme rainfall, while monsoons are seasonal wind shifts caused by differential heating of land and sea. Likely exam-relevant.

## 1.14 Southeast Asian Rainforests

Southeast Asian rainforests experience four different seasons: the winter northeast monsoon, the summer southwest monsoon, and two inter-monsoon seasons.

- The northeast monsoon season (November to March) has steady winds from the north or northeast, originating from Siberia, which bring typhoons and other severe weather. The east coasts of the Southeast Asian islands receive heavy rains during this time.
- The southwest monsoon season (May to September) has less wind and is slightly drier, though it still rains every day.
- During the inter-monsoon seasons, the winds are light. All seasons are hot and humid, with very little seasonal variation in temperature.

### Core takeaway:

Southeast Asian rainforests experience distinct monsoon seasons driven by regional wind patterns, resulting in varied rainfall but consistently hot and humid conditions year-round. Likely exam-relevant.

## 1.15 Tropical Rainforests

Tropical rainforests are characterized by a type of tropical climate with no dry season, meaning all months have an average precipitation value of at least 60 mm (2.4 in). There are no distinct summer or winter seasons; it is typically hot and wet throughout the year, with both heavy and frequent rainfall. Around the equator, there are two seasons with heavy rainfall, receiving up to 10 meters a year. As one moves away from the equator, it becomes a bit drier in some months, but there is still more than 2 meters of rain annually. Most of the rainfall does not reach the ground directly, as the trees act as a canopy and catch the rain.

### 1.15.1 Rainforest Burned Down in South America

(image, see slide 14)

### Core takeaway:

Tropical rainforests are defined by continuous high rainfall, consistent high temperatures year-round, and the significant role of their dense canopy in intercepting precipitation. Likely exam-relevant.

## 1.16 Tropical Desert

Major tropical desert areas include the Sahara and Kalahari deserts in Africa, Arabian, Iranian and Thar Deserts in Asia, Arizona and Mexican deserts in North America, and the Great Australian Desert.

### 1.16.1 Oasis with Date Palm

(image, see slide 15)

### 1.16.2 External Resources / Ecosystem Map

*[Requires further research: This section primarily provides links to external resources (YouTube and a NOAA ecosystem map) and does not contain descriptive content within the slides themselves.]*

## 1.17 A Simple Illustration of the Major Crop Types in Relation to Climate

*[Requires further research: This slide title suggests an illustration but the content is not provided.]*

### Core takeaway:

Tropical deserts are extensive arid regions found across multiple continents, characterized by very low precipitation and extreme temperatures. Likely exam-relevant.

# 2 Lecture 02 - 04/09-2025

## 2.1 Fertility of Tropical Soils

The plan for the day includes discussing factors of soil formation, aspects of soil fertility, an introduction to tropical soil types, and the role of soil organic matter and soil fertility. A group exercise on how to improve the fertility of degraded soils is also part of the plan.

### 2.1.1 What is soil?

Soil is defined as the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants (see also Slide 2).

**Core takeaway:** This section introduces the course, the instructor, the agenda, and a fundamental definition of soil. Exam relevance marker: Likely exam-relevant (definition of soil).

## 2.2 Soil Profile and Formation

### 2.2.1 Soil Profile

Figure: An illustration of a soil profile, depicting layers down to bedrock (see slide 2).

### 2.2.2 What is soil?

This slide reiterates the definition of soil (see also Slide 1).

### 2.2.3 Soil formation

#### 2.2.3.1 Weathering

Weathering is the disintegration and decomposition of solid rock material, encompassing both chemical and physical processes. The most important form of chemical weathering involves H+ ions from water penetrating rock mineral structures and displacing ions like K+, Ca2+, Mg2+, and Al3+. This process causes minerals to break down into clay and leads to the leaching of ions.

### 2.2.4 Primary particles

#### 2.2.4.1 Mineral fraction

The mineral fraction of soil is categorized by particle size:

- Sand size fraction: 50 $\mu m$ - 2 $mm$
- Silt size fraction: 2 $\mu m$ - 50 $\mu m$
- Clay size fraction: < 2 $\mu m$

**Core takeaway:** Soil formation involves weathering of bedrock into primary particles, which are classified by size.
Exam relevance marker: Likely exam-relevant (weathering definition, particle sizes).

## 2.3 Soil Components and Factors of Soil Formation

### 2.3.1 Clay size fraction

- Clay size fraction: < 2 $\mu$m

### 2.3.2 Soil organic matter

The pool of soil organic matter is defined as biologically derived soil material (see also Slides 14, 15, 16). It consists of:

- A large fraction of humic substances
- Fresh and partly decomposed plant residues
- A small fraction of living soil microbial biomass

### 2.3.3 Soil texture

This slide poses a question: "A soil with 35 % sand, 35 % clay and 30 % silt called?"
*[Requires further research: The answer to the soil texture question is not provided directly on the slide.]*

### 2.3.4 Soil Structure

*[Requires further research: This headline is present, but no content is provided for 'Soil Structure' on this slide.]*

### 2.3.5 Factors of soil formation

The factors influencing soil formation include (see also Slides 4, 5):

- Parent material
- Climate
- Topographical position
- Biological factors
- Time

### 2.3.6 Parent Material

Parent material refers to in situ rocks (bedrock) (see also Slide 4).

**Core takeaway:** This section details soil particle sizes, defines soil organic matter, lists the five key factors of soil formation, and introduces parent material. Exam relevance marker: Likely exam-relevant (soil organic matter components, factors of soil formation).

## 2.4 Parent Material and Climate in Soil Formation

### 2.4.1 Parent Material

Bedrock consists of sedimentary or metamorphic rock brought to the surface by geological processes. Parent materials are derived from the weathering of bedrocks and interact with other soil formation factors to determine the secondary minerals formed (see also Slide 3).

### 2.4.2 Climate

A hot and humid climate leads to intensive weathering and leaching (see also Slide 3). This removes Aluminum ($Al$) and Silicon ($Si$), resulting in the formation of the clay mineral kaolinite, which has a low Cation Exchange Capacity (CEC) and is less fertile (see also Slides 7, 8, 10, 12, 15). Kaolinite's chemical formula is Al2Si2O5(OH)4. The topographical position of a soil on a landscape will affect the impact of climatic processes (see also Slide 5).

**Core takeaway:** Parent material originates from bedrock, and climate, especially hot and humid conditions, drives intensive weathering, leaching, and the formation of low-fertility clay minerals like kaolinite. Exam relevance marker: Likely exam-relevant (impact of climate on weathering and clay formation).

## 2.5 Other Factors of Soil Formation and Soil Fertility Introduction

### 2.5.1 Topography

Erosion and leaching cause minerals to accumulate at the bottom of a slope (see also Slide 3).

### 2.5.2 Biological factors

Biological factors contribute to soil formation through (see also Slide 3):

- Faunal activity (mixing of soil)
- Plant activity (rooting, formation of acids, prevents leaching of nutrients)

### 2.5.3 Time

The age of soils varies significantly; for example, most Danish soils are approximately 12,000 years old, while some African soils are 500 million years old (see also Slide 3).

### 2.5.4 Soil fertility

Soil fertility is defined as the ability of soil to sustain and provide essential nutrients and create favorable conditions for plant growth and development (see also Slides 11, 13, 15, 16, 17). Key aspects of soil fertility include:

- Nitrogen
- Processes affecting inputs and losses of N
- Phosphorus

- Phosphorus Fixation
- Base cations
- Cation Exchange Capacity (CEC)
- Base Saturation

**Core takeaway:** Topography, biological activity, and time are crucial soil-forming factors. Soil fertility, defined by its capacity to support plant growth, hinges on nitrogen, phosphorus, base cations, CEC, and base saturation. Exam relevance marker: Likely exam-relevant (definition of soil fertility, factors of soil formation).

## 2.6 Nitrogen and Phosphorus in Agroecosystems

### 2.6.1 Nitrogen in Agroecosystems

Figure: A diagram illustrates the nitrogen cycle within agroecosystems (see slide 6). Inputs to the system include N fixation, deposition, organic fertilizer, and inorganic fertilizer. Outputs consist of leaching, denitrification, and NH3 volatilization. Internal processes within the soil involve mineralization, ammonification, nitrification, immobilization, and plant uptake. The forms of nitrogen include organic N, plant N, $NH_4^+$, and $NO_3^-$.

### 2.6.2 P availability in soil

Figure: A diagram shows phosphorus availability in soil (see slide 6). Phosphorus exists in stable, labile, and organic forms, as well as in the soil solution P. Inputs of phosphorus come from manure, waste, and mineral fertilizer. Outputs include plant uptake and loss of P, as well as leaching. A significant process affecting phosphorus is Phosphorus Fixation (see also Slides 5, 11, 12, 13, 17).

**Core takeaway:** Nitrogen and phosphorus cycles in agroecosystems involve complex inputs, outputs, and internal processes that determine nutrient availability. Exam relevance marker: Likely exam-relevant (understanding N and P cycles, P fixation).

## 2.7 Cations and Cation Exchange Capacity (CEC)

### 2.7.1 Base and acid cations in soil

#### 2.7.1.1 Base cations

These positively charged ions include Calcium ($Ca_2^+$), Magnesium ($Mg_2^+$), Potassium ($K^+$), Sodium ($Na^+$), and Ammonium ($NH_4^+$) (see also Slides 5, 9, 11, 12, 13).

#### 2.7.1.2 Acid Cations

These include Aluminium ($Al_3^+$), Iron ($Fe_3^+$), and Hydrogen ($H^+$).

### 2.7.2 Clay Minerals

Common clay minerals are classified as 1:1 type (e.g., Kaolinite) and 2:1 type (e.g., Smectite) (see also Slides 4, 8, 10, 15).

#### 2.7.2.1 Isomorphous substitution

Isomorphous substitution is a process where a higher charged ion is replaced with a lower charged ion within the mineral structure, resulting in a net negative charge. Examples include $Si_4^+$ being replaced with $Al_3^+$ in the tetrahedral sheet, and $Al_3^+$ being replaced with $Mg_2^+$ in the octahedral sheet.

### 2.7.3 Cation Exchange Capacity (CEC)

CEC is defined as the amount of exchangeable cations that a soil can adsorb (see also Slides 4, 5, 8, 10, 12, 15, 17). It is expressed in terms of centimoles of positive charge adsorbed per unit of mass, specifically in centimol positive charge per kg of soil (cmol(+)/kg).

**Core takeaway:** Soil cations are categorized as base or acid, and clay minerals exhibit a net negative charge due to isomorphous substitution, which contributes to the soil's Cation Exchange Capacity (CEC). Exam relevance marker: Likely exam-relevant (definitions of base/acid cations, isomorphous substitution, CEC).

## 2.8 Cation Exchange and Clay Mineral CEC Values

Figure: This figure illustrates cation exchange on a plant root, where $H^+$ ions are exchanged for other cations from the soil solution (see slide 8). It also shows cation exchange occurring on the surfaces of organic material and clay particles.
Different clay minerals possess varying CEC values and properties:

**Table 1.1:** *An overview of clay minerals and their properties*

| Type of clay mineral | Type | CEC /cmol (+)/kg | Expansible | pH dependent charge |
|---|---|---|---|---|
| Kaolinite | 1:1 | 1–10 | No | Most |
| Smectite | 1:2 | 80–120 | Yes | Little |
| Vermiculite | 1:2 | 120–150 | Partly | Little |
| Illite | 1:2 | 20–50 | No | Medium |
| Allophane | Amorphous | 50–150 | No | Most |

**Core takeaway:** Cations are exchanged between plant roots, soil solution, and charged surfaces of clay and organic matter, with different clay minerals having distinct CEC values and characteristics influencing their behaviour. Exam relevance marker: Likely exam-relevant (mechanism of cation exchange, comparative CEC values of different clay minerals).

## 2.9 pH Dependent Charge and Base Saturation

### 2.9.1 pH Dependent Charge

Figure: A graph visually represents the relationship between pH and charge, indicating how soil charge can be pH-dependent across a range (e.g., pH 4.0, 5.0, 6.0, 7.0) (see slide 9).

### 2.9.2 % Base Saturation

Base Saturation is defined as the percentage of the exchange complex that is saturated with base cations (see also Slides 5, 12). It is measured in centimoles of positive charge. Adsorbed cations are in equilibrium with solution cations. The formula for Base Saturation is:

$$\text{Base Saturation} = 100\% \times \frac{\text{Base Cations}}{\text{CEC}}$$

An example calculation is provided: Given CEC = 40 cmol(+)/kg, $K^{+}$ = 16 cmol/kg (= 16 cmol(+)/kg), $Ca^{++}$ = 4 cmol/kg (= 8 cmol(+)/kg), $Mg^{++}$ = 2 cmol/kg (= 4 cmol(+)/kg). Base saturation = 100 x (16+8+4) / 40 = 70%.

**Core takeaway:** Soil charge can be pH-dependent, and Base Saturation quantifies the proportion of exchange sites occupied by base cations, indicating soil fertility. Exam relevance marker: Likely exam-relevant (definition and calculation of base saturation).

## 2.10 Estimating CEC and Base Saturation for Tropical Soils

### 2.10.1 Estimate the Cation Exchange Capacity (CEC) of the two soils

### 2.10.2 Exercise 1

This exercise provides characteristics for two soil types for estimation:

- Ultisol: Kaolinite, pH 4.6, 60% clay, 4% organic matter (see also Slides 11, 12)
- Vertisol: Smectite, pH 7.2, 20% clay, 2% organic matter (see also Slides 11, 12, 13)

The calculation of CEC would involve considering CEC contributions from both clay and organic matter. A table providing average CEC values for different clay minerals is given (Avg. 4 cmol(+)/kg for Kaolinite, Avg. 95 cmol(+)/kg for Smectite, etc.) (see also Slide 8).

### 2.10.3 Exercise 2

This exercise requires calculating the base saturation of the two soils (Ultisol and Vertisol) based on the CEC values calculated in Exercise 1, using given base cation contents.

**Core takeaway:** Exercises are presented to estimate CEC based on clay mineral type and organic matter content, and subsequently calculate base saturation, for different tropical soil types. Exam relevance marker: Likely exam-relevant (practical application of CEC and base saturation calculations).

## 2.11 Fertility Comparison and Tropical Soil Types

### 2.11.1 Discuss which soil is more fertile and how?

This question prompts a comparison of the fertility of Ultisol and Vertisol, using the following base cation content data:

**Table 1.2:** *Cation content in different soil types*

| **Soil type** | $K^{+}$ (cmol) | $Mg^{2+}$ (cmol) | $Ca^{2+}$ (cmol) | $Na^{+}$ (cmol) |
|---|---|---|---|---|
| Ultisol | 0.08 | 0.1 | 0.3 | 0 |
| Vertisol | 2.1 | 2.4 | 3.2 | 0.2 |

(Table, see slide 11)

### 2.11.2 Tropical soil types

Soils are classified according to the United States Department of Agriculture (USDA) Soil Taxonomy. The tropical soil types listed are:

- Oxisol (see also Slide 12)
- Ultisol (see also Slide 12)
- Alfisol (see also Slide 12)
- Vertisol (see also Slides 12, 13)
- Andisol (see also Slide 13)
- Aridisol (see also Slide 13)

### 2.11.3 Oxisols

Oxisols are soils with an oxic horizon, meaning they are highly weathered and dominated by Iron- and Aluminum oxides, with some kaolinite present. They typically have less than 10% weatherable minerals. Oxisols are formed under conditions of intensive weathering and leaching in hot and humid climates.

**Core takeaway:** This section provides data for comparing soil fertility between Ultisols and Vertisols and introduces the major classifications of tropical soil types, with a detailed description of Oxisols. Exam relevance marker: Likely exam-relevant (characteristics of tropical soil types, comparison of fertility).

## 2.12 Characteristics of Tropical Soil Orders

### 2.12.1 Oxisols

Continuing from the previous slide, Oxisols are characterized by:

- Low CEC (see also Slides 4, 5, 7, 8, 10, 15, 17)
- High P fixation (see also Slides 5, 6, 11, 13, 17)
- Low pH

### 2.12.2 Ultisol

Ultisols possess an argillic horizon (clay accumulation) and are subject to intensive weathering and leaching in hot and humid climates (see also Slides 10, 11). Their characteristics include:

- More weatherable minerals than Oxisols
- Well drained
- Low CEC
- Low level of bases
- High P fixation
- Low pH

### 2.12.3 Alfisol

Alfisols also feature an argillic horizon (clay accumulation) (see also Slide 5). Key attributes are:

- Higher base saturation than Ultisol (see also Slides 5, 9)
- Seasonal moisture deficit
- Transition zone to semi-arid climates

- Medium CEC
- > 35% base saturation
- Medium fertility

### 2.12.4 Vertisol

Vertisols are distinguished by a high content of expanding clay minerals (see also Slides 10, 11, 13).

**Core takeaway:** This section details the distinct characteristics, particularly in terms of CEC, P fixation, pH, and base saturation, for Oxisols, Ultisols, and Alfisols, and introduces Vertisols. Exam relevance marker: Likely exam-relevant (comparative characteristics of different tropical soil orders).

## 2.13 Further Characteristics of Tropical Soil Orders

### 2.13.1 Vertisols

Continuing the description, Vertisols are typically:

- Formed from highly basic rocks and in climates that are seasonally humid
- Sticky when wet
- Hard when dry
- Neutral – alkaline pH
- Medium – high content of basic cations (see also Slides 5, 7, 9, 11)
- High fertility (see also Slides 5, 11, 12, 15, 16, 17)

### 2.13.2 Andisol

Andisols are:

- Young soils developed from volcanic material
- High contents of organic matter (see also Slides 3, 14, 15, 16, 17)
- High content of basic cations
- High fertility
- High P fixation

### 2.13.3 Aridisols

Aridisols are:

- Found under arid soil moisture regimes (i.e., in dry areas)
- Typically sandy
- Too dry for crop production unless irrigated
- Often used for grazing
- Low content of organic matter

**Core takeaway:** This section completes the overview of tropical soil orders, highlighting the high fertility of Vertisols and Andisols due to their unique properties, and the challenges associated with Aridisols in dry regions. Exam relevance marker: Likely exam-relevant (characteristics of Vertisols, Andisols, and Aridisols).

## 2.14 Soil Organic Matter and Carbon Cycling

### 2.14.1 Soil organic matter and fertility

Soil organic matter largely comprises fresh and partly decomposed plant residues, with a smaller fraction consisting of living soil microbial biomass (see also Slides 3, 15, 16). Figure: A diagram illustrates the flow of carbon in the soil-atmosphere system (see slide 14). Atmospheric carbon is fixed through photosynthesis. Carbon is lost to the atmosphere through respiration. Organic carbon enters the soil via above- and below-ground litter. Some carbon transforms into soil organic carbon, while some is lost to the atmosphere through soil respiration.

**Core takeaway:** Soil organic matter is critical for fertility, composed mainly of plant residues and microbial biomass, and plays a central role in the global carbon cycle. Exam relevance marker: Likely exam-relevant (composition of SOM, basic carbon cycle).

## 2.15 Factors Affecting Soil Organic Matter and Importance in Tropics

### 2.15.1 Soil organic matter and fertility

#### 2.15.1.1 Inputs:

Factors contributing to soil organic matter include:

- Crop/vegetation
- Farming practice/residue use
- Manure applications

#### 2.15.1.2 Outputs:

Factors influencing the loss or transformation of soil organic matter include:

- Climate (temperature, precipitation)
- Soil properties (texture, mineralogy, stabilization, pH, etc.)
- Biological factors (decomposer organisms, etc.)
- Chemical factors (quality of residue, etc.)
- Soil management (tillage, drainage, etc.)

### 2.15.2 Soil organic matter in tropical soils – why bother?

Soil organic matter is particularly important in tropical soils because:

- These soils are often weathered and low in nutrients
- They frequently contain clay types with low CEC
- They are erodible
- They experience high intensity rainfall events
- There is serious water deficiency in semi-arid and arid tropics

**Core takeaway:** Soil organic matter levels are a balance of inputs and outputs influenced by climate, soil properties, biological and chemical factors, and management. Its importance is amplified in tropical soils due to inherent challenges like low nutrient content and erodibility. Exam relevance marker: Likely exam-relevant (factors influencing SOM, reasons for SOM importance in tropics).

## 2.16 Soil Organic Carbon (SOC) and Soil Health

### 2.16.1 Soil organic matter in tropical soils – why bother?

Tropical soils have been most depleted, yet their productivity must be increased to meet the demands of a growing population (see also Slide 15).

### 2.16.2 SOC is an important indicator of soil health

#### 2.16.2.1 Soil Organic Carbon

Management options to increase soil organic matter (SOM) / soil organic carbon (SOC) include:

- Tillage
- Crop rotations
- Perennials
- Root system
- Cover crops
- Crop residues
- Animal manure
- Biochar

SOC influences soil health through its Physical, Chemical, and Biological impacts:

- Physical: Aggregate stability, improved soil structure, improved soil porosity, bulk density, water holding capacity
- Chemical: Cation Exchange Capacity (CEC), soil pH, binds heavy metal (see also Slides 4, 5, 7, 8, 9, 10, 12, 15, 17)
- Biological: Earthworms, soil microorganisms, soil ecosystem

**Core takeaway:** SOC is a crucial indicator of soil health, with various management practices available to increase it, leading to significant physical, chemical, and biological benefits in the soil. Exam relevance marker: Likely exam-relevant (importance of SOC, management options, benefits of SOC).

## 2.17 Strategies for Enhancing Soil Fertility and Carbon Pool

### 2.17.1 Reduction of P fixation

Figure: Chemical structure showing $CO$ - $O^-$ and $Al_3^+$ (see slide 17). This illustrates how organic matter can chelate aluminum, thereby reducing $P$ fixation (see also Slides 5, 6, 11, 12, 13).

### 2.17.2 Reduction of $Al$ toxicity

Figure: Chemical structure showing $CO$ - $O^-$ and $Al_3^+$ (see slide 17). Organic matter also helps in the reduction of $Al$ toxicity.

### 2.17.3 Improve soil structure

Figure: Diagram showing how organic material and clay contribute to soil structure (see slide 17).

### 2.17.4 Strategies for Enhancing the Soil Carbon Pool

The management options to increase Soil Organic Matter (SOM) listed are:

- Tillage
- Crop rotations
- Perennials
- Root system
- Cover crops
- Crop residues
- Animal manure
- Biochar

### 2.17.5 Theoretical exercise: How to increase soil fertility of degraded soils?

This exercise involves discussing possible ways to improve the fertility of degraded soils in groups (see also Slide 18). Group inputs count as the deliverable.

**Core takeaway:** Enhancing the soil carbon pool through various management strategies directly improves soil fertility by reducing P fixation and Al toxicity, and improving soil structure. Exam relevance marker: Likely exam-relevant (benefits of SOM, management strategies).

## 2.18 Group Exercise: Management Options for Degraded Soils

### 2.18.1 Potential Management Options to increase SOM:

The potential management options to increase soil organic matter (SOM) in degraded soils include:

1. Integration of legumes as intercrops or in rotation
2. Inorganic fertilizer
3. Manure (livestock)
4. Green manure, mulching, residue retention
5. Agroforestry techniques (including fallowing)
6. No tillage

### 2.18.2 Questions:

For each management option, the following questions are to be discussed:

1. What are the benefits of the option?
2. Which problems could (potentially) limit the adoption?
3. What are possible solutions to the problems/limitations?

**Core takeaway:** This section outlines a practical exercise for identifying and evaluating various management options, from legumes to no-tillage, aimed at increasing soil organic matter and improving degraded soil fertility, considering both benefits and potential limitations. Exam relevance marker: Likely exam-relevant (management practices for soil fertility, critical thinking about their adoption).

# Chapter 2
# Abbreviations and Explanations

| Topic | Abb. | Description |
|---|---|---|
| **Leaching** | **n.a.** | *leaching refers to the process by which substances, such as ions, minerals, or nutrients, are removed or lost from the soil. This often occurs due to water penetrating the soil and displacing these substances* |

# Appendices

## 1 Appendix 1 - Practical Exercise 01

| PE1: Tropical Crop products |
| --- |
| Group n. 01<br><br>Group members:<br>- Lucas Daniel Paz Zuleta, TZS159 |
| Photo of your culinary preparation<br> |
| List the tropical products used:<br>White rice, Pequi, Okra, Black beans, lentils, Cassava, salad (mix; rocula, spinach), Assorted Cherry tomatoes, Pineapple, Lentils, Olive oil, Palm hearts, and Jílo. |

Discuss the potential macro nutrients composition of your dish (Use chatgpt):
**Potential Macronutrient Composition of the Dish**

- **Carbohydrates:**
  White rice, cassava, lentils, and black beans are major carbohydrate sources, providing both starch and dietary fibre. Pequi and pineapple add natural sugars. Okra, cherry tomatoes, salad greens, palm hearts, and jiló contribute smaller amounts of carbohydrates, mainly fibre.
- **Proteins:**
  Black beans and lentils are the primary plant-based protein sources. Spinach, arugula, and other salad vegetables contribute minor amounts of protein.
- **Fats:**
  Olive oil and pequi are the main fat sources. Pequi contains monounsaturated fats, while olive oil contributes healthy unsaturated fats. Small contributions may also come from palm hearts.
- **Fibre:**
  High levels of dietary fibre come from legumes (black beans, lentils), okra, cassava, salad greens, cherry tomatoes, jiló, and pineapple. Okra in particular also adds soluble fibre (mucilage).

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This dish is **balanced**:

- **Carbohydrates** from rice, cassava, and legumes.
- **Proteins** mainly from legumes.
- **Fats** from olive oil and pequi.
- **Fibre and micronutrients** from vegetables, fruits, and jiló

[H]