Sonja Kuster 20/06/2023
Unit Code: T/602/3921
UNIT GUIDE 2023-24

The Interaction of Soil Environments and Woody Plants

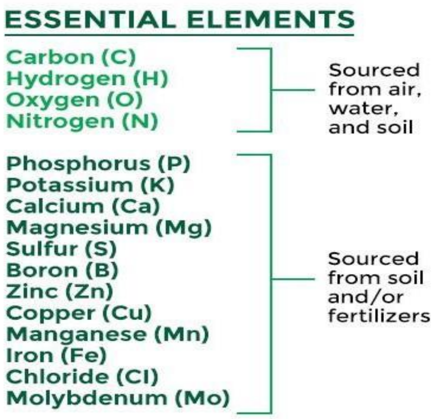
LO 3. Understand the role played in woody plants by the principal macro and micronutrient

3.1. Describe two ways in which soil type affects nutrient availability

Soil is a major source of nutrients for plant growth.
Several factors improve a plant's ability to use nutrients:
Type of soil: The more clay and organic matter a soil has, the higher its CEC will be, and the more cationic (positively charged) nutrients it will retain.
Soil pH: The pH affects how tightly nutrients are bound to soil particles. If the soil pH is extremely high (basic) or very low (acidic), many nutrients become inaccessible to the plant because they are no longer dissolved in the soil water.
Types of nutrients in the soil: Some nutrients affect the availability of other nutrients. In fact, an apparent deficiency of one nutrient may be caused by a large amount of another.
Amount of soil water: Too much rain leaches nutrients from the soil. If there is too little water, the nutrients cannot dissolve and move into the plant.
Anything that affects the plant's growth: If growing conditions are good, a plant will absorb nutrients from the soil. If the plant experiences extremes in temperature, incorrect light levels, or waterlogged or compacted soil, it will have a limited ability to absorb nutrients. Also, plants in dormant stages absorb few nutrients.
Other factors that affect the availability of soil nutrients include leaching, soil erosion, denitrification, volatilization, nitrogen immobilization and crop nutrient uptake.
Leaching
This is the washing downward of nutrients in the soil below the root zone. Some of the factors influencing leaching include:
Mobility of nutrients: When there is sufficient water in the soil, nutrients in soil solution can be easily washed down beyond the root zone. An example is nitrogen present in the form of nitrate; a highly mobile negatively charged ion.
Soil texture: Leaching occurs in soils which have high water infiltration rates and low ability to hold nutrients. Examples of such are the sandy soil and clay soil.

A nutrient can be classified as ‘essential’ when it has the following criteria:
Plant cannot complete basic functions or complete its life cycle without that nutrient.
A deficiency can be corrected only by the application of that specific nutrient and not substituted by another.
The nutrient plays a direct role in the plant’s metabolism.

There are 17 essential nutrients:
hydrogen, oxygen, carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, chloride, iron, boron, manganese, zinc, copper, molybdenum, and nickel.



https://omexcanada.com/blog/16-essential-elements

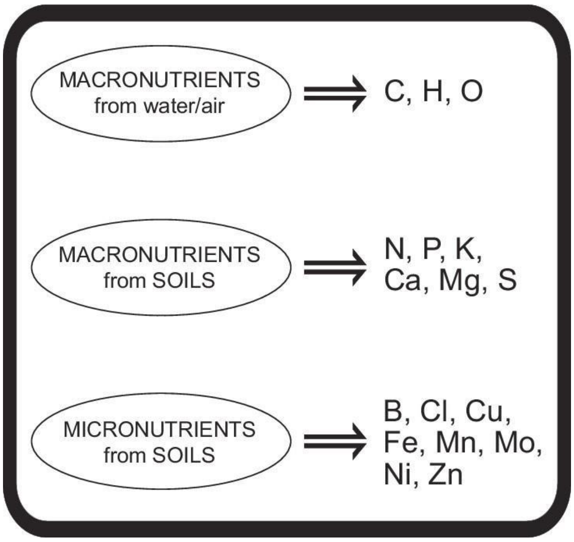
Relative amounts (out of 100) of the essential nutrients required by most plants.

Primary Nutrients	Amount
Carbon (C)	45
Oxygen (O)	45
Hydrogen (H)	6
Nitrogen (N)	1.5
Potassium (K)	1
Phosphorus (P)	0.2
Secondary Nutrients	**Amount**
Calcium (Ca)	0.5
Magnesium (Mg)	0.2
Sulfur (S)	0.1

Micronutrients	Amount
Iron (Fe)	0.01
Chlorine (Cl)	0.01
Manganese (Mn)	0.005
Boron (B)	0.002
Zinc (Zn)	0.002
Copper (Cu)	0.0006
Molybdenum (Mo)	0.00001

Trees need a substantial amount of these nutrients. For this reason, these are the main nutrients contained in fertilizers. Trees do not need as much of the secondary nutrients, such as calcium, magnesium, and sulphur.

Beneficial elements: Silicon (Si), Nickel (Ni), Sodium (Na), Cobalt (Co), Selenium (Se), Aluminium (Al) are 'friends' to the other elements.
Some of these nutrients are supplied by soil, water, and air – while others need to be supplemented with the use of fertilizer. There are other nutrients that can be beneficial in specific crops, but they are currently not listed as 'essential.'



carbon (C) hydrogen (H) oxygen (O)

nitrogen (N) phosphorus (P) potassium (K) calcium (Ca) magnesium (Mg) sulphur (S)

boron (B) chlorine (Cl) copper (Cu) iron (Fe) manganese (Mn) molybdenum (Mo) nickel (Ni) zinc (Zn)

Deficiency in any one of these mineral elements reduces plant growth and crop yields. Plants generally acquire their mineral elements from the soil solution.

Plants need six mineral elements in large amount:
nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S),
whilst chlorine (Cl), boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni) and molybdenum (Mo) are required in smaller amounts.

Nitrogen (N), Phosphorus (P), and Potassium (K) are the most frequently required in a crop fertilization program.
Nitrogen is necessary for the formation of amino acids, proteins, DNA and RNA. It is essential for plant cell division and vital for plant growth.
Phosphorus promotes early root formation and growth, and is involved in photosynthesis, respiration, energy storage and transfer, cell division and enlargement.
Potassium is involved in carbohydrate metabolism and the break down and translocation of starch. Potassium also enhances disease resistance and improves winter hardiness.

Calcium (Ca), Magnesium (Mg), and Sulfur (S) are required in lesser amounts than macronutrients, but each is equally important to the crop.
Calcium increases fruit set and quality and is important for continuous cell division and formation (regulates hormonal activity).
Magnesium, the centre molecule of chlorophyll, improves utilization and mobility of phosphorus.
Sulfur is an integral part of amino acids. It helps develop enzymes, vitamins and oil contents, and aids in seed formation.

Boron (B), Zinc (Zn), Copper (Cu), Manganese (Mn), Iron (Fe), Chloride (Cl) and Molybdenum (Mo) are used in minute amounts but are just as important to plant growth and development as the major nutrients. Some micronutrients control the uptake of major nutrients and key processes.

- **Boron** is an essential component of cell wall formation and is key for the germination of pollen grains and growth of pollen tubes.
- **Zinc** aids plant growth hormones and enzyme system and is necessary for chlorophyll production and carbohydrate formation.
- **Copper** plays a major role in photosynthesis. This element improves the flavour of fruits and vegetables and can help prevent ergot in cereals.
- **Manganese** aids in chlorophyll synthesis and increases the availability of phosphorus and calcium.
- **Iron** promotes the formation of chlorophyll and acts as an oxygen carrier.
- **Chloride** promotes crop health and enhances the maturity of small grains on some soils.
- **Molybdenum** is needed to convert inorganic phosphates to organic forms in the plant and aids in the nodulation of legumes, especially in acidic soils.

Cations (+)		Anions (-)		
Nitrogen	NH_4^+	Nitrogen	NO_3^-	
Potassium	K^+	Phosphorus	$H_2PO_4^-$	HPO_4^{2-}
Calcium	Ca^{2+}	Sulfur	$SO4^{2-}$	
Magnesium	Mg^{2+}	Boron	H_2BO_3	H_2BO^{3-}
Manganese	Mn^{2+}	Molybdenum	$HMoO_4^-$	MoO_4^{2-}
Copper	Cu^{2+}	Chloride	Cl^-	
Zinc	Zn^{2+}			

https://www.haifa-group.com/articles/calcium-essential-plant-nutrient

Roots absorb plant-available nutrients from the soil as positively or negatively charged ions

Cations	
Copper Iron Manganese Zinc	Positively charged - bind to soil particles Solubility is greatest under acid conditions Most likely deficient on calcareous soils or soils extremely high in organic matter where strong chelation decreases availability
Anions	
Boron Chlorine Molybdenum	Negatively charged – subject to leaching In short supply in areas where they are readily leached and not being replenished by organic matter decomposition

https://gardenculturemagazine.com/cation-and-anion-exchange-capacity-and-why-it-matters-to-your-grow/

The ability of roots to penetrate the soil, as well as the availability of water, nutrients, and oxygen, is significantly impacted by the composition and texture of the soil, which are influenced by pH, clay content, and other factors.

Composition	Water availability	Nutrient availability	Oxygen availability	Root penetration ability
Sand	Low: water drains out	Low: poor capacity for cation exchange; anions leach out	High: many air-containing spaces	High: large particles do not pack tightly
Clay	High: water clings to charged surface of clay particles	High: large capacity for cation exchange; anions remain in solution	Low: few air-containing spaces	Low: small particles pack tightly
Organic matter	High: water clings to charged surface of clay particles	High: ready source of nutrients, large capacity for cation exchange; anions remain in solution	High: many air-containing spaces	High: large particles do not pack tightly

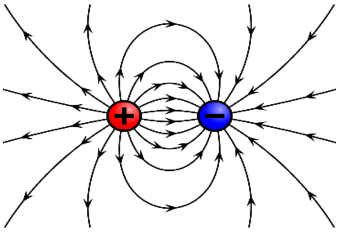
https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients#table%201-4 How do plants take up soil micronutrients?

Root hairs play a crucial role in the process of mineral and water absorption in plants. These specialised extensions of root tissue increase the surface area of the root, allowing for enhanced absorption. The uptake of ions from the soil's water is facilitated by root hairs. However, the accessibility of ions in soil water varies depending on the soil's characteristics. In clay-rich soils, positively charged ions (cations) are strongly bound to clay particles, making them less available for absorption by root hairs. This binding also prevents cations from being washed away by heavy rain. On the other hand, anions are easily washed away by rainfall as they readily dissolve in soil water, making them readily accessible to plant root hairs.

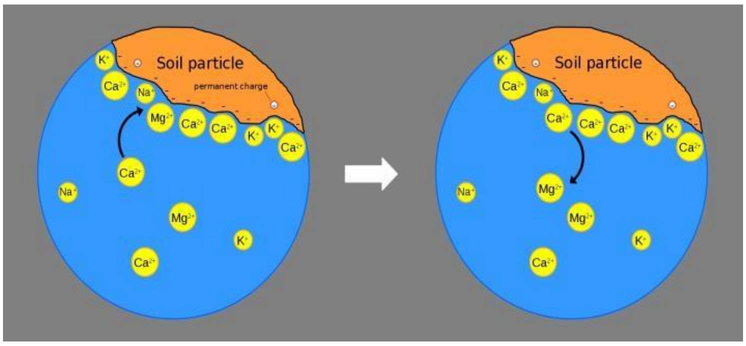
Clay soils are incredibly valuable to farmers, as they retain good levels of both nutrients and water.

Mineral nutrients are transported into root cells by osmosis. Soil minerals need to be soluble – dissolvable in water – so they can be absorbed by roots and transported around a plant to the cells that need them. If the soil is too dry, mineral nutrients may be present, but cannot be taken up by the plant as there is not enough water to transport them.

Negative charges on the surfaces of soil particles bind positively-charged atoms or molecules (cations), but allow these to exchange with other positively charged particles in the surrounding soil water. This is one of the ways that solid materials in soil alter the chemistry of the soil.

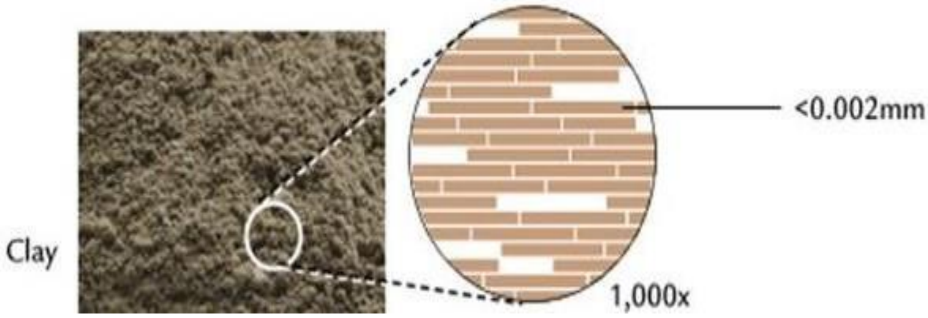


Electric charge can be positive or negative



Cation exchange at the surface of a soil particle

Soil particles with a negative charge can efficiently attract positively charged nutrient ions. Clay particles, being negatively charged, have a strong affinity for essential nutrients such as potassium, calcium, and magnesium. Consequently, clay soils are rich in nutrients and are ideal for growing various crops.



Due to their small size, clay particles offer a larger surface area for nutrient ions to bind to. This reduces the risk of leaching and allows for a higher concentration of nutrients to remain within the soil profile. The ability of clay particles to hold onto these nutrient ions is advantageous in maintaining their availability for plant uptake.

During heavy rains, clay soils are susceptible to waterlogging. This causes the clay particles to bond tightly together, limiting air infiltration and preventing water from percolating through the soil profile. Consequently, essential micronutrients like copper and zinc may become insoluble in excess water, reducing their accessibility to plants. Since nutrients can only be absorbed by roots when dissolved in water, plants growing in waterlogged clay soils may struggle to obtain the necessary nutrients.

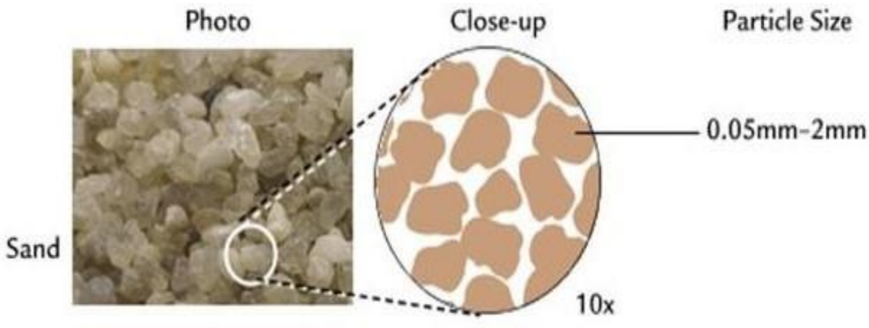
Clay soils retain a significant amount of water, resulting in slower warming during the spring compared to mineral and organic materials. As temperatures rise, microbial activity increases, leading to greater nutrient production. However, the slower warming of clay soils can affect the availability of phosphorus, as its availability decreases when the soil temperature drops below 20°C. This can pose challenges for crops in obtaining sufficient phosphorus from the soil during the spring.

Although clay soils have a high nutrient density and are less prone to leaching, there is still a possibility of nutritional deficiencies in plants grown on these soils. Antagonism can occur in the soil, where certain nutrients outcompete others, leading to reduced uptake of the less dominant components. This can result in imbalances and deficiencies in plant nutrition.

High levels of potassium in clay soils can compete with magnesium. This is because both nutrients carry a positive charge and are vying for attachment to the negatively charged clay particles. Consequently, the presence of one nutrient in high concentration can reduce the availability of the other in the soil profile.

Instead of solely depending on the soil, where essential nutrients might be lost at times, foliar treatments offer a way for plants to directly absorb the necessary nutrients through their leaves.

One of the most common UK soil types is **sandy soils**.



Characteristics of Sand

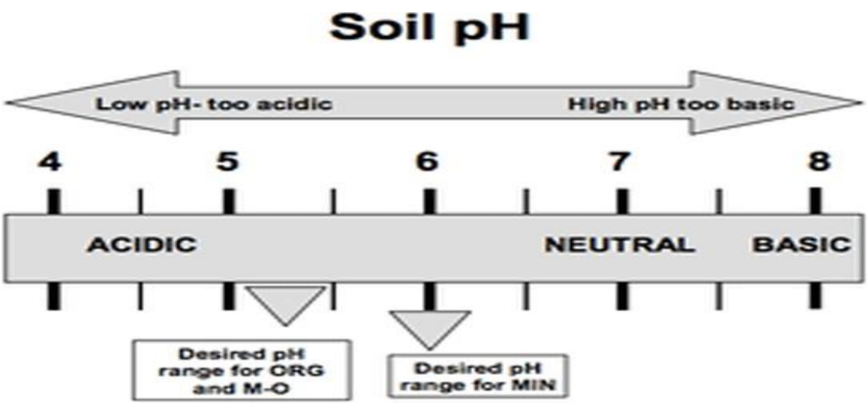
Character	Sand
Size	(2.0 – 0.02) mm
Visibility	Visible by the naked eye
Shape	Round
Water holding capacity	Low
Infiltration	Very rapid
Aeration	Very rapid
Macro pores	Large
Micro pores	Small
Surface area	Low
Adhesion, Cohesion, Plasticity, Swelling, Stickiness	Very low
Total porosity	Low
Tillage	Easy
Fertility	Very low

Chemical activity	Inactive
Mineral	Quartz and mica dominate
Feel on rubbing between thumb and finger	Gritty

Coarse sands and sandy loams tend to be warmer compared to soils with finer textures, and they also have better aeration. This leads to increased microbial activity. However, these types of soils often support less plant growth due to their poor fertility and limited water-holding capacity.
The larger size of sand particles poses a challenge when it comes to retaining nutrients. Unlike clay particles, sand particles range from 0.2 to 2.0 mm in size, making the soil profile more permeable. Consequently, nutrients in the soil are more likely to escape through the profile and be lost. Moreover, water can quickly pass through the soil profile after heavy rainfall, carrying away nutrients in the process.
Another reason why sandy soils struggle to retain nutrients is the lack of charge in sand particles. This means that nutrient ions with negative or positive charges find it difficult to bind to the sand particles in the soil profile, increasing the likelihood of their loss through erosion or leaching.
In arid environments, sandy soils face difficulties in retaining moisture. This poses a challenge for crops to access nutrients in the soil, especially for nutrients like boron that rely on mass flow for uptake into plants.
Nitrogen and sulphur are two nutrients that require special attention in sandy soils. They are essential for plant growth but are easily leached from the soil during heavy rainfall. Therefore, in sandy locations, carefully planned foliar fertiliser applications are crucial to prevent crops from experiencing severe deficiencies that could hinder their development and, more importantly, reduce their yield potential.

Soils can be classified according to their pH value:

- 6.5 to 7.5—neutral
- over 7.5—alkaline
- less than 6.5—acidic, and soils with pH less than 5.5 are considered strongly acidic.



The availability of nutrients and other substances in soil water, which are essential for plant growth, is influenced by the pH of the soil. Different nutrients are more easily accessible in either acidic or alkaline environments.
When the pH decreases, the acidity of the soil increases. Most plants thrive in a pH range of 5.5 to 8. If the pH goes beyond this range, there can be unfavourable changes in soil chemistry and microbiology, leading to reduced growth and yield.
If the soil becomes strongly acidic (pH less than 5.5), it can negatively impact plant growth due to factors such as aluminium toxicity, manganese toxicity, calcium deficiency, magnesium deficiency, and low levels of essential nutrients like phosphorus and molybdenum.
In alkaline soils, there may be shortages of zinc, copper, boron, and manganese. Soils with very alkaline pH values (higher than 9) are likely to have high sodium concentrations.

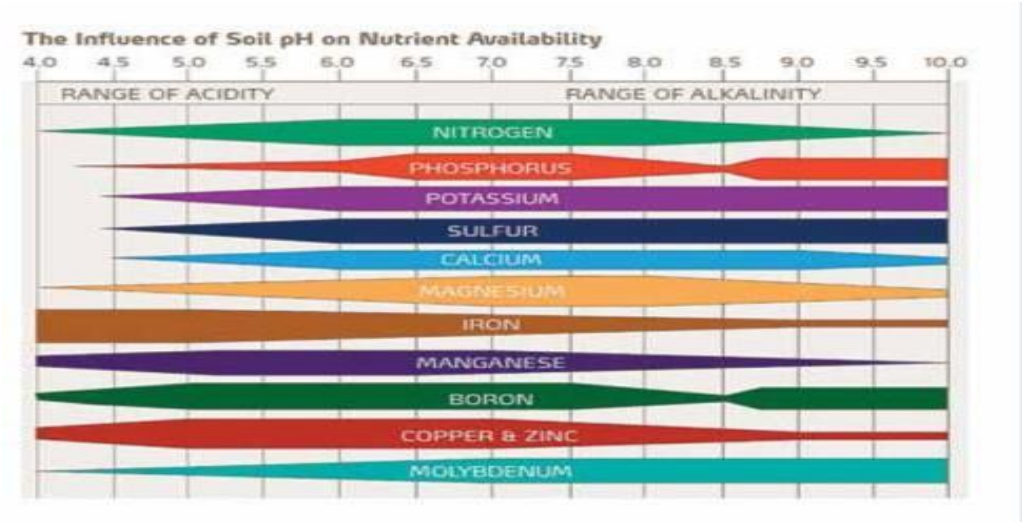
Sandy soils, due to their low buffering capacity and rapid water percolation, are more prone to having acidic pH levels (below 7) compared to other soil types. Soils with a higher clay or organic matter content have more surface sites that can hold hydrogen ions, making them better equipped to withstand pH drops. Clays generally have better buffering capacity than loams, and loams are better buffered than sands.

Source
https://fmc-agro.co.uk/blog/sandy-soils-and-crop-nutrition https://fmc-agro.co.uk/blog/clay-soils-and-crop-nutrition https://theconstructor.org/building/soil-types-sand-silt-clay-loam/25208/ https://en.wikipedia.org/wiki/Cation-exchange_capacity
https://www.agric.wa.gov.au/soil-acidity/soil-ph?page=0%2C2
https://scienceofagriculture.org/
https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients

<u>3.2. Distinguish between two symptoms of nutrient deficiency found in named woody vegetation</u>

Pinus, Larix, and Cedrous are part of the family of Coniferales.
Trees and other plants obtain their vital ingredients from air, water, and soil. The most fundamental building ingredients are carbon (C), oxygen (O), and hydrogen (H). Their sources are air and water. They unite to build more complicated structures, such as the sugars that make up plant tissues. Besides, there are at least 14 other mineral elements, which are supplied by the soil, that are essential for growth. Minerals play a significant part in plant metabolism. They are pieces of organic structures that are vital for the existence of living beings, such as proteins and nucleic acids. They play a role in the facilitation of a range of enzymatic reactions and act as charge carriers and osmotic regulators. Their contribution to cell division and differentiation, as well as photosynthesis, is also crucial. In short, mineral intake and dispersion are critical to tree growth in numerous ways.

Macronutrients are needed in the largest amounts and micronutrients are needed in small amounts. The ratio of soil supply to plant absorption determines the likelihood that a nutrient may become scarce.
Individual macro- and micro-element deficiencies cause specific growth difficulties as well as decline in overall plant health because they interfere with vital biochemical and physiological processes. To ensure that the plant absorbs all the necessary minerals, proportions between the various components must be regulated.
Different micronutrients serve various purposes. Numerous factors frequently influence biological processes like respiration, nitrogen fixation, and chlorophyll synthesis.
Insufficient amounts of micronutrients in urban trees are frequently caused by high soil pH (7.8–8.2 on soils with significant lime concentration), which renders the nutrients inaccessible to the plant.



https://conifersociety.org/conifers/articles/fertilizing-conifers/

Chlorosis of Pine trees
Pines frequently struggle on high-pH soils. Many pine species require a pH of 5.2 to 6.0; however, many soils have a pH of 7.0 or higher due to the limestone bedrock beneath. When the pH is this high, iron (Fe) and manganese (Mn) may be in a form that is inaccessible to the tree, even if they are present in the soil, preventing the nutrients essential for healthy green growth in pines from being taken up. The outcome is stunting and, more notably, needle

yellowing.
Late winter and early spring are frequently the seasons when pine chlorosis is more common or more obvious. There could be two causes for this. First, during this period, the soil is frequently moist from rain or snowmelt. Because of a lack of oxygen and an inability to absorb nutrients, plants cannot grow normally in waterlogged soils. Second, the plant is getting ready to expand, and while it is still hidden from view, new growth may be absorbing nutrients from the older needles.

https://www.forestpests.org/nursery/yellowschlorosis.html

Larix: Larch
Phosphorus (P) is important for root development in trees. It is the main fertilizer required at establishment stage. Deficiency will seriously limit growth.
Phosphorus deficiency symptoms in conifers include:

- Poor height growth
- Dull green color on needles
- Reduced needle length
- Foliage appears sparse
- Death of older needles in severe cases Phosphorus (P) deficiency can also cause low nitrogen (N) availability in soils, resulting in combined P and N deficiency symptoms.

In young trees, phosphorus deficiency is characterized by short, yellow-tipped needles on branch ends (left), while in mature trees it is characterized by narrow, thin crowns (right), Riverhead Forest.

https://www.researchgate.net/figure/In-young-trees-phosphorus-deficiency-is-characterised-by-short-yellow-tipped- needles_fig14_286931750

Conifers with a potassium (K) shortage exhibit needles that are completely discolored at the ends of shoots or that are partially yellowed. Only spruces, Douglas fir, and larches exhibit the latter, not pines. The needle's top turns yellow while the base of the needle is still green. From the yellow to the green zone, there is a 72-hour Irish Forestry slow change. The two symptoms often coexist in spruces. In pine trees, potassium shortage symptoms peak in the late winter. The needles on the short branches of the larch are primarily affected by the discoloration. The needles of the short shoots are primarily affected by the discoloration in larch.
When the K content at the conclusion of the growing season falls below the following dry matter content, deficiency symptoms appear: pines 0.45%, Douglas fir 0.45%, spruces 0.40%, and larches 0.50%.

Conifers with a potassium (K) deficiency

https://conifersociety.org/conifers/articles/fertilizing-conifers/

Cedrus
The pH level of the soil beneath cedar trees plays a crucial role in determining the amount of hydrogen present. An increase in hydrogen content leads to soil alkalinity, while a decrease results in soil acidity. Different types of cedar trees have varying preferences when it comes to soil pH. Ideally, cedar trees thrive in slightly acidic to neutral soil conditions, with a pH ranging from 6 to 6.5, or even as high as 7.5. Soil that is too acidic can lead to nutrient deficiencies, visible through symptoms like browning or yellowing of foliage, ultimately causing the decline of trees. Additionally, cedar trees struggle in waterlogged soils.

Symptomatology of deficiency of macronutrients on cedar seedlings (A. fraxinifolius) grown in nutritive solution.
The left side of each picture shows plants grown in complete nutrient solution,
and the right side shows solution
formulated with deficiency of N (A), P (B), K (C) Ca (D), Mg (E) and S (F).

Essential mineral elements needed by conifers

Macronutrients		Micronutrients	
Element	Sufficiency range % needle dry weight	Element	Sufficiency range ppm needle dry weight
(N) Nitrogen	1.2-2.0	(Fe) Iron	50-200
(P) Phosphorus	0.1-0.2	(B) Boron	10-100
(K) Potassium	0.4-0.8	(Mn) Manganese	100-250
(Ca) Calcium	0.2-0.5	(Cu) Copper	4-20
(S) Sulfur	0.1-0.2	(Zn) Zinc	10-150
(Mg) Magnesium	0.1-0.15	(Mo) Molybdenum	0.1-5.0
		(Cl) Chlorine	10-3,000

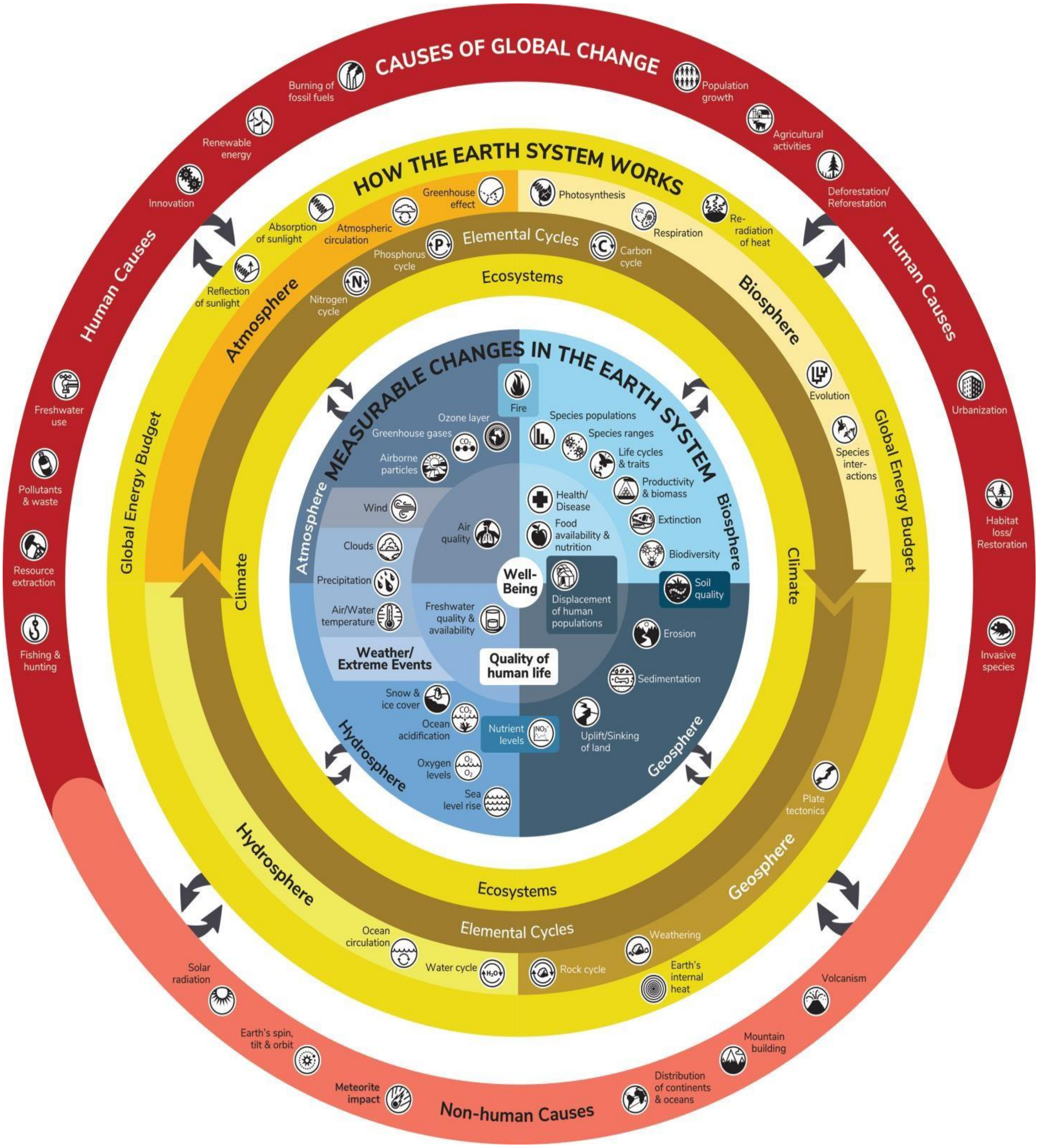
NOTE: Sufficiency ranges based on field-grown conifers. Values may range higher in container-grown nursery plants under intensive fertilization. Adapted from USDA Forest Service Forest Nursery Notes. RNGR.net

https://conifersociety.org/conifers/articles/fertilizing-conifers/

Source
https://www.healthbenefitstimes.com/larch/
https://ipm.ucanr.edu/PMG/GARDEN/ENVIRON/fertilwood.html#:~:text=Nitrogen%20and%20iron%20are%20the,especially%20with%20high%20nitrogen%20fertilizers.
https://www.treesandshrubsonline.org/articles/cedrus/ https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4621400/
https://www.bspp.org.uk/an-investigation-into-blight-of-cedar-cedrus-deodara-in-tollymore-forest-park/
https://blog.irontreeservice.com/nutrient-deficiencies-in-trees-observing-visual-symptoms-part-one/
https://byjus.com/biology/deficiency-symptoms/
https://horticulture.co.uk/coniferous-tree-types/
https://www.researchgate.net/publication/277429507_Distribution_of_Mineral_Substances_in_Different_Wood_Tissues_of_European_Larch_Larix_decidua_Mill/link/57a9af8908ae659d18249460/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

3.3. Outline the nitrogen cycle

The nitrogen cycle refers to the movement of nitrogen within and between the atmosphere, biosphere, hydrosphere, and geosphere. The nitrogen cycle matters because nitrogen is an essential nutrient for sustaining life on Earth.



https://ugc.berkeley.edu/what-is-global-change/infographic/

Nitrogen is the most abundant element in the Earth's atmosphere, comprising 78% of the total atmospheric gas. It plays a crucial role as a macronutrient for plant growth, as it is present in significant quantities within plants and is necessary for their proper development. Nitrogen levels in healthy plants can vary, ranging from an average of 3-4% to as high as 5-6% for legumes. After carbon, hydrogen, and oxygen, nitrogen has the highest concentration in plant tissues. The availability of nitrogen in soils worldwide often limits plant growth, making it a primary constraint on crop production in the UK and globally, surpassing the limitations of any other nutrient.

The nitrogen cycle is a biogeochemical process that converts nitrogen into various forms before it returns to the atmosphere. Initially, nitrogen enters the soil, followed by organisms. Nitrogen gas can exist in both organic and inorganic forms. Organic nitrogen is found in living organisms and is transferred through the food chain when organisms consume other living organisms. In the atmosphere, inorganic forms of nitrogen are more common. Symbiotic bacteria play a crucial role in converting inert nitrogen into useful forms like nitrites and nitrates, making it available to plants. Plants utilise nitrogen to produce protoplasm and amino acids, which are essential for building plant tissue and proteins. Moreover, various biochemical activities during an organism's lifecycle require the production of enzymes, which also rely on nitrogen. The growth of new leaves, the development of stems and shoots, the generation of proteins and enzymes in the roots, and the storage of protein in grains, fruits, and seeds all necessitate the production of these proteins and enzymes. Nitrogen is also vital for photosynthesis, a process where plants convert light, energy, water, and carbon dioxide into sugars and biochemical energy to support their growth. Chlorophyll molecules, which are crucial for photosynthesis in plants, contain nitrogen as an essential component. Additionally, nitrogen is necessary for the metabolic reactions involved in photosynthesis itself.

Process of the Nitrogen Cycle consists of the following steps – **Nitrogen fixation, Nitrification, Assimilation, Ammonification and Denitrification.**

These processes occur in multiple stages and are explained as follows:
The nitrogen cycle commences with the process of nitrogen fixation. During this process, atmospheric nitrogen (N2), which is primarily found in an inactive state, is converted into the useful form of ammonia (NH3). The inactive form of nitrogen gas is released into the soil through precipitation during the nitrogen fixation process, originating from the atmosphere and surface waters. Diazotrophs, which are symbiotic bacteria, complete the entire nitrogen fixation process. Azotobacter and Rhizobium also play a significant role in this process. The nitrogenase enzyme present in these bacteria can combine gaseous nitrogen and hydrogen to produce ammonia. Nitrogen fixation can occur through atmospheric fixation, which involves lightning, or industrial fixation, which involves the production of ammonia under high heat and pressure. Additionally, artificial processes, particularly industrial ones that produce ammonia and nitrogen-rich fertilisers, can address this as well.

Different Forms of Nitrogen Fixation
Atmospheric fixation: lightning energy converts nitrogen into nitrogen oxides, which plants utilise.
Industrial nitrogen fixation: ammonia is used to combine nitrogen and hydrogen, forming ammonia for fertiliser production.
Biological nitrogen fixation: Bacteria like Rhizobium and blue-green algae convert unused nitrogen into compounds for plants and animals.

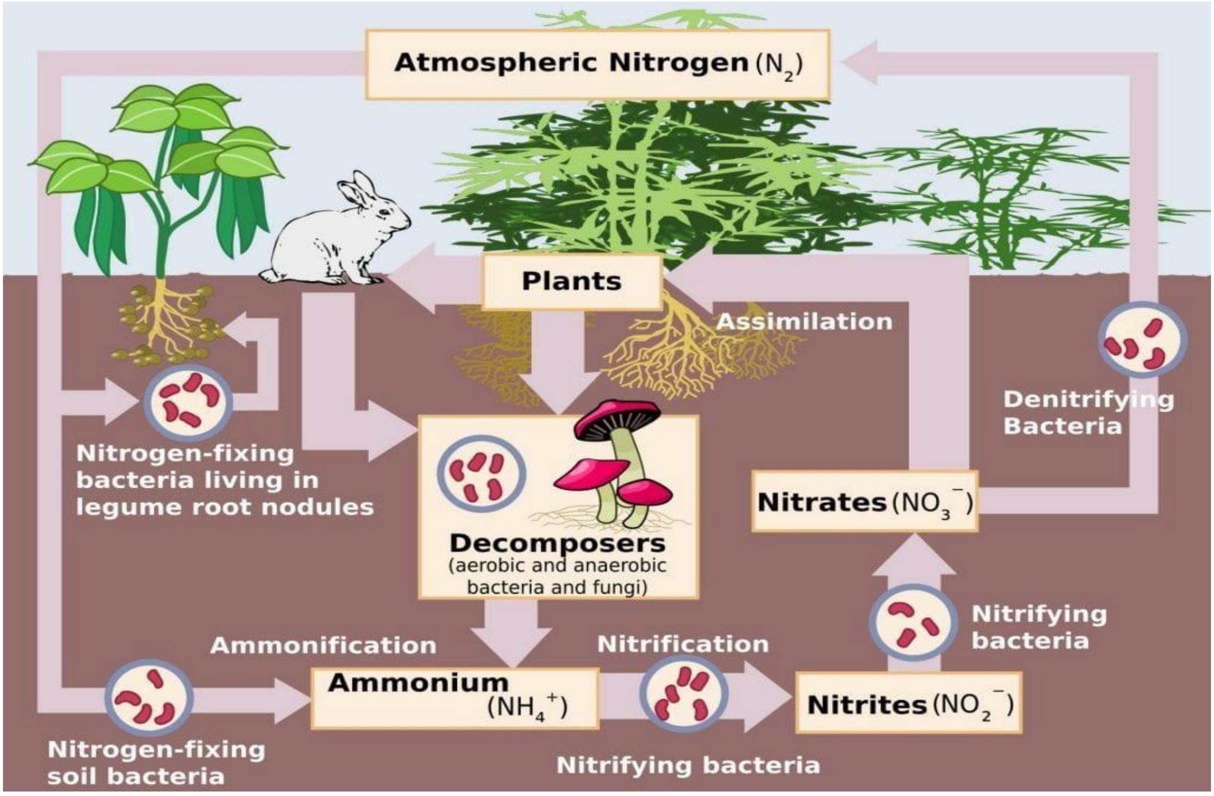
Through a process known as nitrification, soil microbes convert ammonia into nitrate. Ammonia is transformed into nitrates with the help of the Nitrosomonas bacteria. Subsequently, Nitrobacter converts the nitrites produced into nitrates. This conversion is crucial, as ammonia gas can be harmful to plants.
Assimilation
Plants absorb nitrogen molecules from the soil through their roots, which exist in various forms such as ammonia, nitrite ions, nitrate ions, or ammonium ions. These nitrogen molecules are essential for the synthesis of proteins in both plants and animals. When primary consumers consume these plants, they become part of the food chain.
Ammonification
When plants or animals die, the nitrogen present in organic matter is released back into the soil. Decomposers like bacteria or fungi in the soil convert the organic waste back into ammonium. Ammonia is produced during this decomposition process and is utilised in various biological activities.
Denitrification
Denitrification is the process where nitrate (NO3-) is converted into gaseous nitrogen (N), allowing nitrogen compounds to return to the atmosphere. This final stage of the nitrogen cycle occurs in the absence of oxygen. Denitrifying bacteria such as Clostridium and Pseudomonas convert nitrate into nitrogen gas and release it as a byproduct during denitrification.

The nitrogen cycle functions similarly in marine ecosystems as it does in terrestrial ecosystems, with the only difference being that marine bacteria are responsible for its operation. Over time, as sediments are compressed to form sedimentary rock, nitrogen-containing chemicals are released into the ocean. Through geological uplift, these sedimentary rocks are transported onto land. Research has shown that the weathering of these rocks leads to the

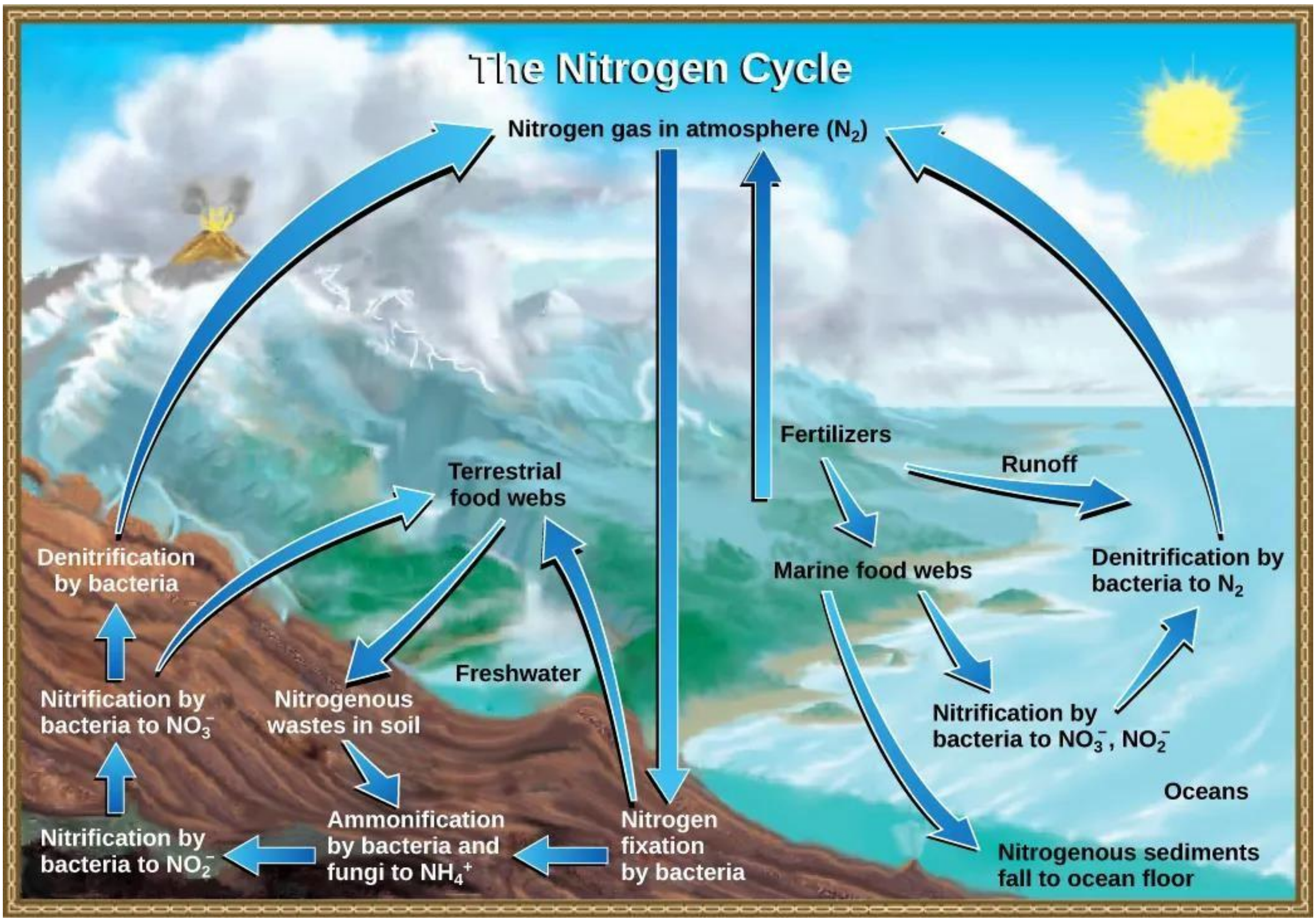
release of nitrogen, which is then utilised by plants.
The nitrogen cycle holds significant importance in several ways. Firstly, it aids in the production of chlorophyll by plants, utilising nitrogen molecules. Additionally, it facilitates the metabolic process that converts inert nitrogen gas into a form that plants can utilize. Bacteria play a crucial role in the ammonification process, decomposing animal and plant debris and indirectly contributing to environmental cleanup.
The release of nitrates and nitrites into the soil helps replenish it with essential nutrients required for cultivation. Nitrogen's involvement in the formation of various vital chemicals and significant biomolecules makes it an essential component of cells. Human activities, such as the burning of fuels and the use of nitrogen fertilisers, also contribute to the nitrogen cycle. These processes lead to an increase in the amount of nitrogen-containing chemicals in the atmosphere. Eutrophication, a consequence of nitrogen-containing fertilisers being washed away into lakes and rivers, can occur as a result.

In conclusion, the nitrogen present in the atmosphere cannot be utilised by plants or animals until it is converted into nitrogen compounds. This conversion process is facilitated by nitrogen-fixing bacteria. Plants absorb nitrogen molecules from the soil through their roots, which are then utilised by plant cells to produce proteins and other essential chemicals. Animals, in turn, assimilate nitrogen by consuming these plants or other nitrogen-containing animals, providing humans with the necessary proteins. The nitrogen cycle is completed with the help of bacteria and fungus, which break down organic matter and release nitrogenous molecules back into the soil for plant use. Some bacteria further transform these nitrogenous molecules into nitrogen gas, which eventually returns to the atmosphere. These continuous processes help maintain the nitrogen balance in the atmosphere.

The nitrogen cycle within the ecosystem involves the movement of nitrogen, with bacteria playing a crucial role by producing various nitrogen compounds that can be used by higher organisms.



https://en.wikipedia.org/wiki/Nitrogen_cycle



Nitrogen is introduced into the biosphere by nitrogen-fixing bacteria as it enters the living world from the atmosphere. Subsequently, soil bacteria convert this nitrogen and nitrogenous waste from animals back into gaseous nitrogen while simultaneously providing terrestrial food webs with the essential organic nitrogen they require. (Credit: adaptation of content by John M. Evans and Howard Perlman, USGS).

Source
Soil Ecology, Ken Killham, page 108 – 141
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