

Quadrant II – Transcript and Related Materials

Programme: Bachelor of Science (Third Year)

Subject: Botany

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Paper Title: Plant Ecology and Phytogeography

Unit: 08

Module Name: Biogeochemical cycle: Nitrogen

Module No: 45

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Notes:

Introduction to Biogeochemical cycles:

The cycling of the nutrients in the biosphere is called biogeochemical or nutrient cycle (“Bio” - living, “Geo” – earth - rock, “Chemical” - element). It involves movement of nutrient elements through the various components of an ecosystem. There are more than 40 elements required for the various life processes by plants and animals; that it’s proper growth and development. Most important elements are C, H, O, P, K, N, S, Ca, Fe, Mg, B, Zn, Cl, Mo, Co, I & Fe. These elements are continuously cycling in the ecosystem through the biogeochemical cycles and the planet earth has no input of these nutrients. The nutrients (matter) from the dead remains of organisms are recovered and

made available to the producers by decomposers. Thus the nutrients are never lost from the ecosystems. Exchange of nutrients between organisms and their environment is one of the essential aspects of an ecosystem. All organisms require nutrients for their growth, development, maintenance and reproduction. **Circulation of nutrients within the ecosystem or biosphere is known as biogeochemical cycles and also called as 'cycling of materials'.**

There are 2 basic types,

1. **Gaseous cycle** - The term gaseous cycle refers to the transformation of gases between various biogeochemical reservoirs; Hydrosphere, Atmosphere & Biosphere. Eg: Oxygen, Carbon and **Nitrogen cycles**
2. **Sedimentary cycle**: Sedimentary cycles include the leaching of minerals & salt's from the earth's crust, which then settle as sediment or rock before the cycle repeats. Eg: Phosphorus, Sulphur and Calcium - Which are present as sediments of earth)

Nitrogen cycle:

Nitrogen is an essential constituent of different biologically significant organic molecules such as amino acids and proteins, pigments, nucleic acids and vitamins. It is also the major constituent of the atmosphere, comprising about 79 per cent of it. The paradox is that in its gaseous state, N_2 is abundant but is unavailable to most life. Before it can be utilized it must be converted to some chemically usable form.

However, atmospheric nitrogen has limited availability for biological use, leading to a scarcity of usable nitrogen in many types of ecosystems. The nitrogen cycle is of particular interest to ecologists because nitrogen availability can affect the rate of key ecosystem processes, including primary production and decomposition. Human activities such as fossil fuel burning, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle. Human modification of global nitrogen cycle can negatively affect the natural environment system and also

human health. Nitrogen is present in the environment in a wide variety of chemical forms including organic nitrogen, ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2). Organic nitrogen may be in the form of a living organism, humus or in the intermediate products of organic matter decomposition. The process in the nitrogen cycle is to transform nitrogen from one form to another. Many of those processes are carried out by microbes, either in their effort to harvest energy or to accumulate nitrogen in a form needed for their growth. For example, the nitrogenous wastes in animal urine are broken down by nitrifying bacteria in the soil to be used by plants. Nitrogen cycle consists of the following steps: **fixation, ammonification, nitrification, denitrification and sedimentation.**

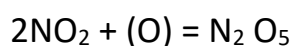
1. Nitrogen fixation: Conversion of free nitrogen of atmosphere into the biologically acceptable form or nitrogenous compounds is referred to as nitrogen fixation.

This process is of two types:

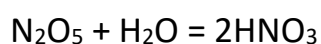
(a) Physicochemical or non-biological nitrogen fixation

(b) Biological nitrogen fixation.

In physicochemical process of nitrogen fixation, atmospheric nitrogen combines with oxygen (as ozone) during lightning or electrical discharges in the clouds and produces different nitrogen oxides:



The nitrogen oxides get dissolved in rain water and on reaching earth surface they react with mineral compounds to form nitrates and other nitrogenous compounds:



During combustion of various types, some nitrogenous compounds are formed which are washed down along with rain water. At high pressure and

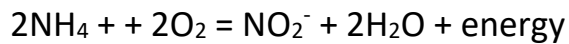
temperature, nitrogen and hydrogen react to form ammonia (industrial nitrogen fixation).

In Biological nitrogen fixation: is carried out by certain Prokaryotes. Some blue-green algae fix significant amounts of nitrogen in the oceans, lakes and soils. Symbiotic bacteria (*Rhizobium*) inhabiting the root nodules of legumes and also the species of alder, buckbrush and a number of other non-leguminous genera and symbiotic blue-green algae (species of *Nostoc*, *Anabaena*, etc.) found in free state or in the thalli of *Anthoceros*, *Salvenia*, *Azolla*, coralloid roots of *Cycas* fix atmospheric nitrogen. The relation is mutualistic because the microbes use energy from the plants to fix nitrogen that is made available to the host plants and other plants of the community. Certain free living nitrogen fixing bacteria, such as *Azotobacter*, *Clostridium*, *Beijerinckia*, *Derxia*, *Rhodospirillum* also fix free nitrogen of atmosphere in the soil. Frankia, an actinomycetous fungus found in the roots of *Alnus*, *Percia*, *Casuarina*, etc. also fixes nitrogen. Nitrogen fixing organisms combine the gaseous nitrogen of atmosphere with hydrogen obtained from respiratory pathway to form ammonia which then reacts with organic acids to form aminoacids. Biological nitrogen fixation is the major source of fixed nitrogen upto 140-700 mg/m²/year as against 35mg/m²/year by electrical discharge and photochemical fixation.

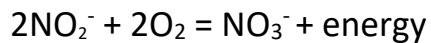
2. Nitrogen assimilation: Inorganic nitrogen in the form of nitrates, nitrites and ammonia is absorbed by the green plants and converted into nitrogenous organic compounds. , largely in the form of ammonia and nitrates is taken up by plants, which convert it into amino acids and proteins. Animals derive their nitrogen requirement from the plant proteins. Plant proteins are not directly utilized by the animals. They are first broken down into amino acids during digestion and then the amino acids are absorbed and manipulated into animal proteins, nucleic acids, etc.

3. Ammonification: The dead organic remains of plants and animals and excreta of animals are acted upon by a number of microorganisms especially actinomycetes and bacilli. These organisms utilize organic compounds in their metabolism and release ammonia.

4. Nitrification: Certain bacteria, such as *Nitrosomonas* and *Nitrococcus*, in oceans and soils convert ammonia into nitrites and then **nitrites into nitrates**. These bacteria primarily use the energy of dead organic matter in their metabolism.

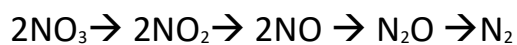


Conversion of nitrites to nitrates is brought about by several microbes like *Penicillium* species, *Nitrobacter*, *Nitrocystis* etc. *Nitrocystis oceanus* is the common marine autotroph which performs nitrification for obtaining energy.



Some nitrates are also made available through weathering of nitrate containing rocks. Both of these reactions which are performed by two nitrifying bacteria — *Nitrosomonas* and *Nitrobacter* are the parts of a single biological process called nitrification. In nitrification process, thus, ammonia is oxidized to nitrate and nitrite yielding energy. This energy is used by the bacteria to make their organic materials directly from carbon dioxide and water. Nitrate can be taken up by autotrophs at the beginning of food chain.

5. Denitrification: Ammonia and nitrates are converted into free nitrogen by certain microbes. This process is referred to as denitrification. *Thiobacillus denitrificans*, *Micrococcus denitrificans*, *Pseudomonas aeruginosa* are the common examples of denitrifying bacteria.



Nitrates of the soil are washed down to the sea or leached deep into the earth along with percolating water. Nitrates thus lost from the soil surface are locked up in the rocks, this is sedimentation of nitrogen. Nitrogen of rock is released only when the rocks are exposed and weathered. Thus a large part of nitrogen is fixed up and stored in plants, animals, and microbes.

Under natural conditions nitrogen lost from ecosystems by denitrification, volatilization, leaching, erosion, wind blown aerosols, and transportation out of the system is balanced by biological fixation and other sources. Both chemically and biologically, terrestrial and aquatic ecosystems constitute a dynamic equilibrium system in which a change in one phase affects the other.

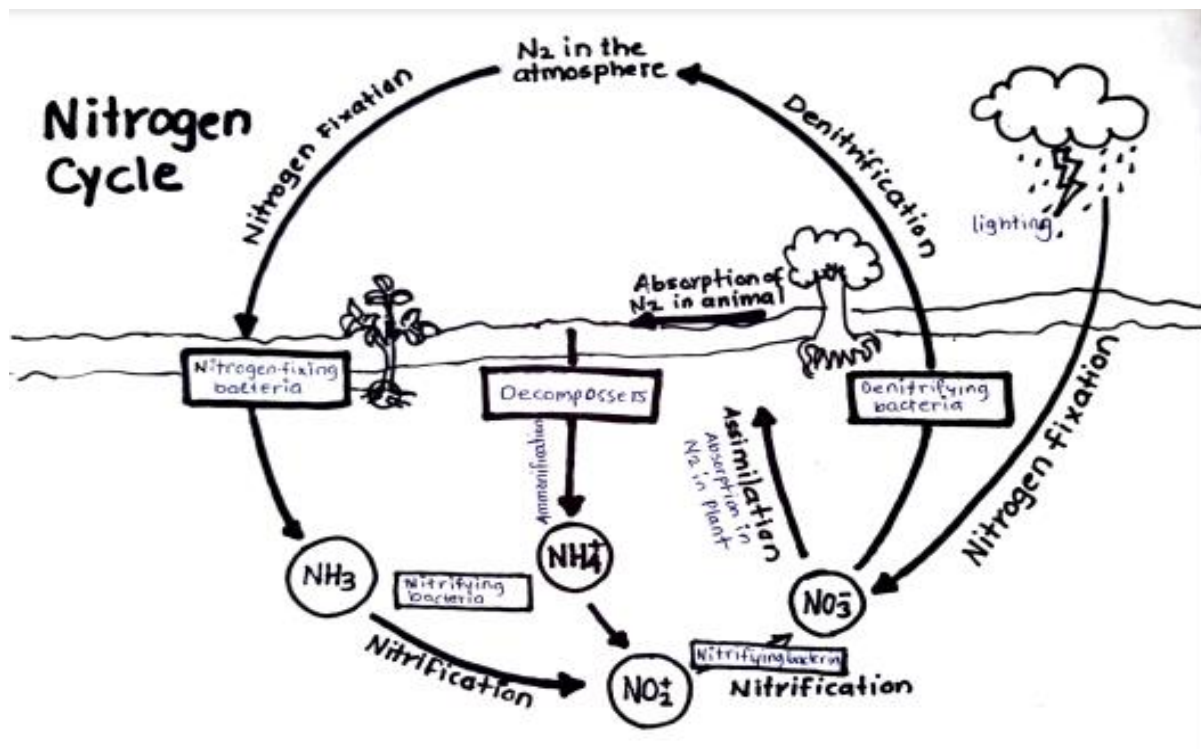


Figure: nitrogen cycle in nature

Importance of Nitrogen Cycle

Nitrogen is necessary for all known forms of life on earth. It is a component in all amino acids as it is incorporated into proteins and is present in the bases that make up nucleic acids such as RNA & DNA. Chemical processing or natural fixation are necessary to convert gaseous nitrogen into compounds, such as nitrate or ammonia which can be used by plants.

Nitrogen is important to the chemical industry, It is used to make Fertilizers, Nitric acid, Nylon, Dyes & Explosives. Nitrogen is present in virtually all pharmacological drugs & In the form of nitrous oxide it is used as anesthetic. The CPUs in computers use the N_2 -gas to keep them from heating up. X-ray detectors also rely on this element. Cryopreservation also uses N_2 -gas to conserve blood & other biological specimen. The element is used in controlling pollution, many industries use it to destroy toxic liquids and vapors in industrial tools.