IMPACT OF VARIOUS LAND USE SYSTEMS ON NITROGEN DYNAMICS – A review

Abstract: Rapid and unregulated conversion of agricultural fields into non-agricultural lands is becoming a major concern in many countries. The shortage of cultivable lands will make it harder to achieve ever-increasing food demands in upcoming years.Assessing land use-induced changes in soil nitrogen is essential for addressing agroecosystem transformation and sustainable land productivity issues.Numerous studies have shown that land use pattern has a significant effect on nitrogen storage and turnover along with varied degrees of mineralization rate and nitrogen forms present. The content of nitrogen fraction can be used as an indicator of the rate of mineralization and eventually microbial richness of soils. As per the study, it is observed that inorganic nitrogen fractions constitute hardly 1-2% of total nitrogen, whereas organic nitrogen takes up almost 98-99% of total nitrogen that is majorly sourced from organic residues in soils. The exchangeable NO_3-N and exchangeable NH_3-N are majorly plant-utilizable, easily mineralized forms whereas only amino acid-N has been proved to be directly utilizable organic nitrogen form. Even today large number of producers are dependent on synthetic nitrogen sources for crop production. Improving nitrogen use efficiency by reducing the natural losses and improving the inherent mineralization rate of organic nitrogen might help lower fertilizer dependency and so the cost of production. In this paper, soil inorganic and organic nitrogen contents, types, and its contribution to plant production are reviewed to explore the exact role of nitrogen forms as influenced under different land use systems.

Keywords: Inorganic nitrogen, organic nitrogen fractions, land use systems, total nitrogen.

Introduction:

A trade-off is necessary between meeting immediate human needs and safeguarding ecosystems from unjustified land use for goods and services in light of the increasingly serious challenges humanity is currently facing, such as climate change, nitrogen deposition, rising carbon dioxide concentrations, and associated impacts on land use changes (Sanderman *et al.*, 2017; Smith *et al.*, 2016). The development of soil fertility, food production, and soil health are all dependent on SOC and N (Schlesinger, 1990). The storage, losses, sequestration rate, and sequestration potential of SOC and N, however, are significantly impacted by changes in land use (Huang *et al.*, 2018). As a result, research into SOC and N storages, losses, and their affecting factors is essential for the restoration of vegetation.

Nitrogen is a major nutrient element for living organisms on earth and plays a central role in regulating the composition, structure, and functions of ecosystems (Fang *et al.*, 2009). Nitrogen in soil is present in different forms as protein in solid organic form to gaseous form as ammonia in lithosphere, atmosphere, hydrosphere, and biosphere. These forms are mainly divided as organic and inorganic nitrogen fractions. The balance between above two dominant forms is governed by microbial activity involved in the mineralization-immobilization turnover (MIT), the factors affecting MIT, and soil redox potential.Inorganic nitrogen in basically available form of nitrogen which contains ammonium (NH_4), ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2). Organic forms present are mainly proteins, amino acids, humus etc. Organic nitrogen comprises over 90 per cent of the total nitrogen found in soil (Pulford, 1991). Not only can the ON be mineralized into available N, but it can provide some organic components that can be directly taken up by plants. Plants colonized by mycorrhizal fungi are predicted to have greater access to ON than non-colonized plants (Schimel and Bennett 2004). Inorganic nitrogen is the main type of soil nitrogen that can be directly absorbed and utilized by plants, but only accounting to 1 per cent in the soil nitrogen (Das *et al.*, 1997). Mineralization of soil organic nitrogen is a key process for the supply of nitrogen to tropical crops.The surplus of the labile macronutrients transfers from the soil to freshwater systems after being sufficiently absorbed by plants through either subsurface crack structures or surface water flow. Eutrophication, a reduction in the amount of oxygen in the water, and the extinction of wetlands have a significant impact on the global climate. This is reinforced by the negative feedback cycle that goes as follows: loss of wetland water, rising temperature, temperature-induced evaporation, and extinction of wetlands.

Comment [P1]: Referenc

Hot, arid regions of India spanning 31.7 million hectares are characterized by a variety of landforms, soils, fauna, flora, and water resources as well as human activities. The major research priorities of present-day research are to conserve the environment, reduction of global warming and grow more food to meet the global food demands. The pattern of use of a specific land unit under varied climatic and geographical conditions that people undertake in a certain land. Land use is influenced by the land's actual utilization status (such as whether it is utilized for agriculture, forestry, or grazing), location, microclimate it creates, exposed climatic effects, change in function, and other management techniques.Altered climate and land use patternshave proved to make changes in nitrogen availability and abundance of different nitrogen forms in soil.

Comment [P2]: Referenc

Land use changes may have an impact on soil N through their effects on the stability of the soil aggregate, which has significant consequences on soil nitrogen dynamics and the terrestrial carbon cycle. Nitrogen turnover is an important indicator of the availability and presence of microbial activity in soils. Numerous studies have found that the storage of soil C and N is strongly controlled by land use. Under varied land use, there is variation in the abundance of microbial biota that participates in nutrient transformational activities. Research on the effect of land use change on soil nitrogen hold, restore, stabilize and sequestering capacity is necessary to reduce the chemical dependency for the nitrogen source. The reduction of the useof synthetic nitrogen inputs that generally end up resulting in pollution and contamination hazardsby leaching and the reduction of the major global warming effect of dinitrogen oxide (N_2O) can be achieved by improving soils' inherent capacity to turn nitrogen with the active ecosystem. This article aims to study variability in nitrogen forms and behavior as influenced due to various land use systems.

Comment [P3]: Referenc

Total nitrogen content:

The total nitrogen content represents the measurement of the amount of nitrogen present in the soil in both organic and inorganic forms in soils that are recovered by digesting the soil sample in the presence of sulphuric acid and salicylic acid. Total nitrogen content in all kinds of land use decreases with depth as it is also a function of organic matter present in soil which decreases with increasing depth. (Andrade *et al.,* 2020). The low accumulation of organic matter in semi-arid soils is due to the limited production of plant biomass and rapid mineralization during the rainy season, which results in low levels of nitrogen. Several studies have shown that grassland management systems can contribute to significant increases in TOC and TN stocks (Chen *et al.* 2009; Conant *et al.* 2001). Matos *et al.,* (2011) observed that after 50 years of continuous arable land, soil TN stocks were 10% lower than under silvopastoral system in the 0–20 cm depth interval. This indicates that in the long-term conventional tillage can significantly contribute to reducing TN stocks when compared with silvopastoral systems. The highest TN concentration in 0–5 cm depth was measured in open pasture (2.24 g kg^{-1}) followed by that in silvopastoral (1.62 g kg^{-1}) and agroforestry (0.68 g kg^{-1}) land uses by Gelaw*et al.,* (2014).The concentration of TN did not differ among land uses in 10–20 and 20–30 cm depths.

Inorganic nitrogen fractions:

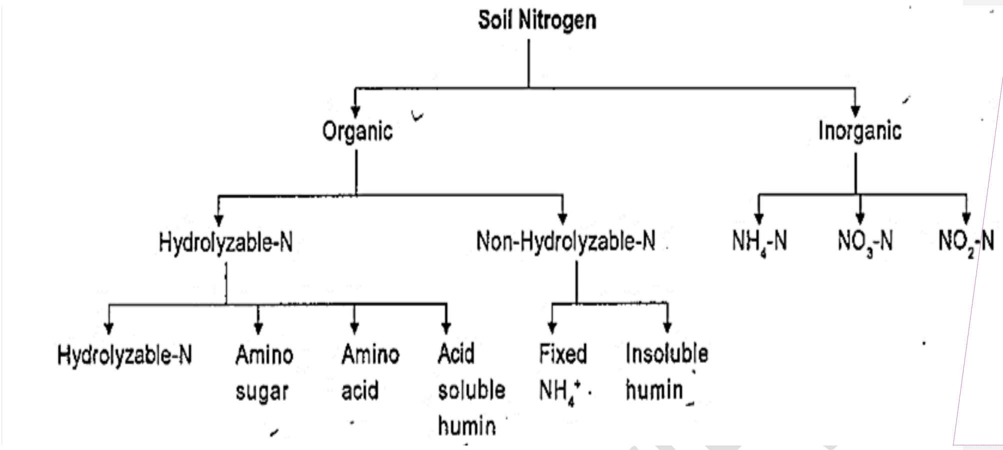


Fig 1. Flow diagram of different forms of soil N

(Source: Tusneem and Patrick, 1971)

Comment [P4]: Need a more precise picture

Deficiency of N in soil is one of the major limitations all over the world including India which has N as a major deficient nutrient even after maximum use of inorganic fertilizers which might be attributed to its losses by volatilization, denitrification or leaching. Ammonium N (NH_4-N) and nitrate N (NO_3-N) are the major forms of inorganic or mineral N available for direct uptake by plants and it support the active growing biomass of plants and animals. these are extracted from soils using 2 M KCl, distilled with MgO powder and Devarda's alloy respectively. It usually represents the transitory pool of N in terms of the total N stock in any ecosystem and generally accounts for less than 2% of the total N content of soil or less than 1% of the terrestrial N (Melillo 1981; Woodmansee *et al.* 1981). It majorly involves exchangeable NO_3-N, exchangeable NH_4-N, and fixed NH_4-N. The first two forms aremajorly utilized forms while later representing the nitrogenfixed by secondary clay minerals such as vermiculites and illites by lattice hole theory that makes it unavailable for plant use. These can be used only after being released from clay surfaces. It helps reduce the leaching losses and can be beneficial for long-term utilization by slow release.

Yao *et al.*, (2010) reported consistently high mineralizable N in natural forest and mixed tree plantation plots among different land use systems selected for study. The decreasing trend in exchangeable NO_3-N and exchangeable NH_4-N was noted in various land use systems (uncultivated, agroforestry, rice-wheat, citrus orchard, and forage crops) by Mohrana*et al*., (2022). The highest mineralizable nitrogen content was reported in field crops cultivated soils which might be due to immediate availability through synthetic nitrogen fertilizers. The lowest inorganic nitrogen contents were present in uncultivated soils. The application of synthetic inputs helps supply nitrogen in inorganic directly utilizable forms for the immediate need of crops at germination and root growth stages. The land use systems such as agroforestry, forest, and permanent horticulture having high crop residue accumulation generally lack these forms of nitrogen due to higher organic matter accumulation resulting in high organic nitrogen forms present.

Organic nitrogen fractions

The organic N, particularly the hydrolyzable form, is slowly mineralized and is transformed to mineral N through aminization, ammonification, and nitrification processes and becomes available to crops. In contrast, non-hydrolyzable N is resistant to mineralization. The stability of some fractions of the organic N is due to the formation of complex organic molecules, which resist mineralization.

Nitrogen present in the organic manures, biofertilizers, green manures, crop residues and several organic wastes, besides the N fixed with the intervention of biofertilizers, is mostly in the form of organic N. Proteins, polypeptides and amino acids (R-NH_2) are the most common organic constituents of plant and animal materials. Unless these organic forms of N are mineralized to inorganic forms, plants cannot utilize them.

Hydrolysable ammonia nitrogen

The ammonia N in acid hydrolysates accounts for 10- 20% of the total N (Stevenson 1982). Part of it comes from inorganic nitrogen including exchangeable and fixed NH_4-N while part comes from organic nitrogen compounds of amino acids such as asparagine and glutamine and amino sugars due to deamination during acid hydrolysis, and part from amides. Although difficult to differentiate how much ammonia N originates from amino acids and how much from amides (Wen 1984), it is estimated that at least half of ammonia N origin in acid hydrolysates remained unknown. In mineral surface soils, about 70% to more than 95% of the organic nitrogen is associated with minerals.all the organic fractions of nitrogen are majorly analyzed using extracted hydrolysate after 12hrs of reflux conducted using 6N HCl and n-octyl alcohol.

Amino acid nitrogen

Amino acid N is a mainly identical component in the hydrolysates, generally appearing in a proportion of 30- 45% (Stevenson 1982) but can be as much as to 56% of the total N in some surface soils (Griffith *et al*. 1976). It is the only directly utilizable organic form of nitrogen. These forms originate from the breakdown of peptide bonds of proteins, hence various ligno-protein complexes of humus become the major source of these forms. In addition to the combined amino acids in hydrolysates, soil also contains some free amino acids that do not exist in peptide linkage but occur in soil solution (Anderson and Vaughan 1985) and soil micropores, or may be absorbed on clay minerals or on the surface of humus colloids in such a manner in which they are not easily extracted by the solvents commonly used for extraction. Free amino acids may come from plant root and microorganism secretion or from the degradation of organic nitrogen (Li *et al.* 2002.)

Amino acids account for the major constituents of the low molecular weight extractable organic nitrogen in soil solution (Jones *et al.,* 2005a). Although they occur at low concentrations in soil solutions (Raab *et al.,* 1999; Öhlund and Näsholm, 2001; Jones *et al.,* 2005b), given their fast turnover rate (1–12 h) and large net fluxes, many researchers have suggested that water-extractable amino acid pools in soil solution exceed those of mineral N, particularly in cold-temperate forests (Rothstein, 2009), alpine tundra (Chapin *et al.,* 1993; Raab *et al.,* 1996), boreal forests (Kielland *et al.,* 2007), and agricultural fields (Ge *et al.,* 2009)

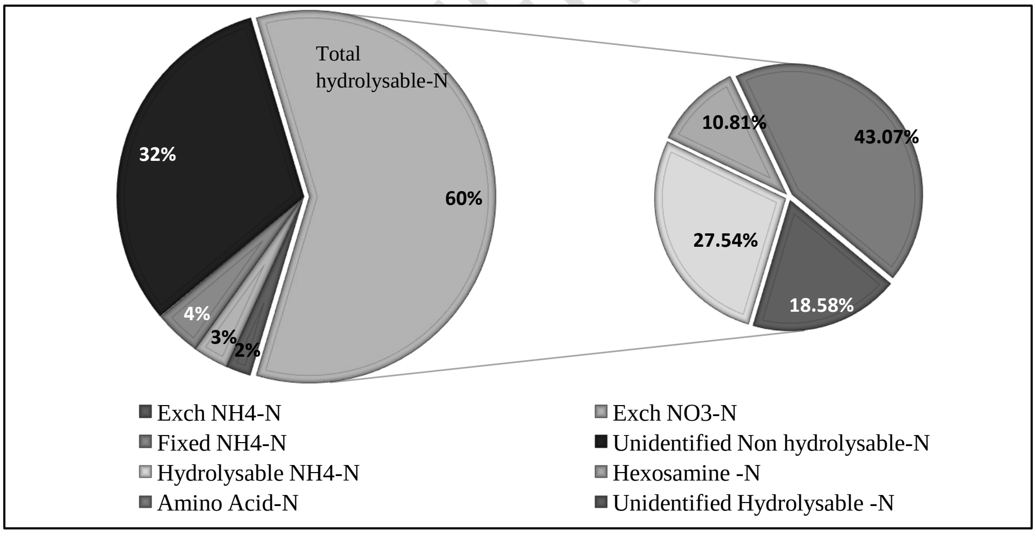
Hexosamine or amino sugar nitrogen

This represents the form of nitrogen present in sugar amine molecules of organic substances. The amino sugar N accounts for about 5-10% of total N in the majority of surface soils. The amino sugar N accounts for about 5-10% of total N in the majority of surface soils (Keeney 1982; Stevenson 1982). It mostly presentsas weakly adsorbed to the soil solid phase and it removal is majorly a biotic process which means mediated with the help of microbes. The free hexosamine indicates dissolved organic nitrogen fraction. The amino sugar N may increase with soil depth deepening (Stevenson 1957) or may not depend on soil properties (Zhuo and Wen 1992).

The above-mentioned fractions represent labile, dissolved, microbial biomass, and light fraction of organic nitrogen which can be efficiently used by crops upon mineralization.

Non-hydrolysable nitrogen

This is also known as acid-insoluble nitrogen form which usually does not get separated by acid hydrolysis. A large portion of organic nitrogen compounds is bound to pedogenic oxides and pedogenic Fe-oxides can explain 25-52% of non-hydrolysable organic nitrogen. Generally, they are considered either in heterocyclic compounds or those combined with heterocyclic or aromatic rings. Part of these N compounds might be produced by the adsorption of acid-hydrolyzed products of the insoluble soil residue, part probably by condensation of amino acids and amino sugars during acid hydrolysis; and part by the N compounds that combined with soil minerals or



entered into the mineral lattice (Anderson 1961).

Fig 2. General contribution of nitrogen forms in arable land use system

(Source: Biradar, 2021)

Unidentified hydrolysable nitrogen

The acid hydrolyzable unknown N occupies about 10- 20% of the total N in soil (Stevenson 1982). The clear information regarding the nature and characteristics of this form is still unavailable. Although difficult to determine, some unknown N has been identified, including phospholipids, chlorophyll, amines, vitamins, and nucleic acids, which may play specific functions to the growth of plants and microorganisms, but the amounts are too low to be important in soil N composition (Stevenson 1982; Anderson and Vaughan 1985; Zhuo and Wen 1992).

Nitrogen is considered as a derivative of organic matter accumulation. Any land use pattern that improves soil organic matter accumulation, restoration, stabilization, and turnover eventually contributes to the improvement of nitrogen storage in soils, particularly in organic forms. The management practices that help reduce disturbances of soil are recommended to reduce rapid losses of such as in forests, and grasslands. The $KMnO_4$-N has a lower sensitivity than Org-N and TN, implying that it is ineffective as a sensitive indicator of land use changes.The local climatic conditions such as temperature, precipitation and humidity that influence land use patterns should also be correlated with nitrogen dynamics.Mohrana*et al.,* (2018) showed a significant change in nitrogen mineralization index with changes in land use.Forage crop and rice–wheat soils had greater TN than uncultivated soils, showing a large potential for adopting these methods to adsorb TN in arid regions of India.

The three land uses grassland, forestland and arable land demonstrated distinct effects on microbial biomass N, dissolved organic nitrogen and TN. Mean TN concentrations were generally more under grassland (2.76 g N kg^{-1}) and forest (1.94 g N kg^{-1}) than arable land (1.11 g N kg^{-1}), those of under plow tillage were the least. Overall N fractions decreased markedly with increase in soil depth under grassland, forestland and no-tillage, while those of under plow tillage almost exhibited the same in 0–25 cm depth. Chen *et al.,* (2013) conducted an experiment to observe the nitrogen fraction dynamics under paddy and vegetable soil after nitrogen application. The study confirmed that extractable organic nitrogen is major contributor in total nitrogen under both LUS and amino acids nitrogen are important source of nutrient for plant growth. Total N amino sugar N were highest in vegetable soils while ammonium N, and amino acid N were highest in paddy soil.

He *et al.,* (2023) studied the effect of land use systems (natural grassland, farmland converted from natural grassland and artificial forestland) in black soil region of Northeast China on soil organic nitrogen fractions and reported that amino acid nitrogen decreased the most in farmlands by 52.2%-76.7% as compared to natural grasslands and ammonia nitrogen decreased by

46.9%-70.7%. other than amino acid N, the contents of soil organic nitrogen fractions in the artificial forestland soils was greater than in farmland. They concluded that, changes in land use types leads to changes in soil structure and vegetation cover, which in turn alter soil nitrogen cycling.

Conclusion

Nitrogen being the most important plant nutrient its natural management is quite understudied. To prevent remnants of the natural forest areas to be converted to agricultural land, management practices that optimize the use of crop residues and rotation techniques to increase SOM must not be overlooked. It has been well studied that amino acid N is the major direct contributor to the mineralized N and thus to plant production, followed by ammonia N while amino sugar N has shown no direct contribution to plants. Improvement of maximum land cover through grassland and reforestation, reduced tillage activities and maintenance of soil biota can be used as efficient and sustainable way to improve nitrogen reserves of Indian soils.

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