N-CYCLING IN A SALT AFFECTED TERRESTRIAL ECOSYSTEM IN THE MIDDLE GANGA VALLEY

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The salt-affected ecosystem in the middle Ganga valley represents an extension of the granary of the Indian sub-continent. Nitrogen recharging of the ecosystem is brought about every year by rain, blue-green algal activity and some free living microbes during the warm and wet monsoon period which is confined to four months only. Autolysis and extracellular release of the nutrient by the blue-green algal flora, microbial decomposition along with the mineralization process and the activity of a few burrowing animals aid in system feedback for a sustained biological activity. Runoff, grazing and volatilization are responsible for loss of nitrogen from the system. Some conservation and feed back by the aerobiological algal flora, which maintain a dynamic flux with moisture as the key factor, cannot be ruled out.

Key words: N-cycling, Salt-affected ecosystem, Middle-Ganga-Valley.

Eversince agriculture was introduced to the Indus valley irrigation systems have been expanded resulting a network of canal systems. With rapid extension of irrigation water-logging assumed a formidable magnitude (Whyte 1961) and a concomitant rise in salinity occurred. The rate of the spread of salinity is being estimated to be about 50,000 ha per year (Abrol et al., 1973) and an area of about 7.00 lakh ha has been estimated to have been made useless because of salinity and alkalinity in Uttar Pradesh (Bhumbla, 1978).

STUDY SITE AND METHODS

The area under study experiences tropical climate with its elements having marked seasonal fluctuations (Dudgeon, 1920). The yearly average incident solar radiation equals 1.2 x 10⁶ K cal/m². July through October is the monsoon season when more than 85 per cent of total annual precipitation is received (Singh, 1981). Average annual precipitation is 1100 mm with 68 as the climatic index for effective precipitation. The winter extends from November through February and is characterised by dry, cool days, and occasional showers due to south east monsoon. May and June are hottest months.

The soil is of saline-alkali type (Richards, 1954). The surface soils are characterised by white, greyish or fluffy white deposits of salt during the major part of the year. The encrustation consists of sodium chloride and sodium sulphate. The efflorescence at places is so thick that few graminoids are able to grow (Choudhri and Varshney, 1979). The surface soil is virtually impermeable to water. The rate of infiltration ranges between 0.30 to 1.4 ml per day. The saturated hydraulic conductivity ranges between 1 and 1.6 ml cm⁻¹ day⁻¹ with the intrinsic permeability between 5.1262 x 10⁻¹ⁱ and 18.2998 x 10⁻¹¹ mol per cm². The C/N of the surface soil approximates unity during monsoon period (Singh, 1985). The calcic zone beneath the surface contains calcareous nodules which extends to variable depth in the profile.

METHODS

Total precipitation was estimated from the rain water collected in cemented and non-cemented meter square troughs specially designed with edges raised ten inches high. Runoff was estimated from the difference between the amount of water collected in bottles below from these tanks. Lower value in non-cemented troughs represented infiltration.

Reported value of potential nitrogen fixation in the area by blue-green algae (Singh 1961) was taken as the BGA fixation of the element. Rain water and runoff were analysed for estimation of nitrogen contribution through these vectors to the system. Microbial contribution except that due to blue-green algae was estimated by incubation of soil with powdered plant material for a period of 120 days at field capacity in the laboratory. Nutrient removal through grazing was estimated from crop removal in grazed and non-grazed areas of known dimensions.
Total nitrogen of soil, plant and runoff suspensions was determined by micro-kjeldahl digestion. The moist soil was treated with KMnO₄ and dilute H₂SO₄, followed by treatment with reduced iron powder for reduction of NO₃ to NH₄ (Olsen, 1929).

Remaining information was obtained by difference equations. (Hopkinson & Day, 1977).

OBSERVATION AND DISCUSSION

Vegetation: Although the area is potentially capable of supporting dry deciduous forest vegetation, the present physiognomy however, due to land degradation under human influence, is represented by scattered greenery interspersed by barren spots of variable dimensions. The greenery comprises mostly of graminoids with a few herbs and still fewer shrubs scattered here and there. Optimum vegetative growth occurs during monsoon period. Subsequently, increase in total soil moisture stress results in accumulation of salts in the surface layers of the profile with a concomitant simplification of the community structure due to elimination of the salt sensitive species. Even though the system represents an extension of the granary of the sub-continent the potential level of bio-productivity is not possible to be accomplished because of constraints characteristically associated with the edaphic environment. With increasing total soil moisture stress subsequent to monsoon period the primary producers are subsequent to acute internal water deficit and this tells adversely on the process of photosynthesis (Rabinowitch, 1945; Kramer, 1963). This is reflected in the loss of biomass even for salt tolerant facultative halophytes October onward. At moisture content below permanent wilting percent, leaf expansion stops, photosynthesis lowered and roots being close to the limited available water become a dominant sink for assimilates (Brouwer and de Witt, 1969). Biomass synthesized during this period, if any, is invested in the perennation process only. The perennial salt tolerant plants remain dormant over the long spell of dry period with minimum shoot volume and rejuvenate at the advent of the monsoon when total soil moisture stress is lowered (Choudhari & Varshney, 1979).

Blue-green algae appear on these soils subsequent to the first few showers of monsoon and continues growth activity until mid October. During the peak growing season the fresh algal biomass averages between 44 and 56 Kg ha⁻¹ (Roger and Reynaud, 1978). Subsequently, the algal mat is rolled up along with the drying surface layer of soil and finally disintegrated into minute fragments which are blown away by the hot and desiccating winds of summer months. Perrenation of these algal propagules continues as aerobiological flora under extreme desiccation till the advent of the monsoon rains (Singh, 1985).
N-Cycling in a Salt Affected Terrestrial Ecosystem

**Nitrogen Dynamics**

**Inputs and outputs:** Nitrogen in the soil comes from the atmosphere via rain and biological fixation (Viranen and Miettinen, 1963). The biological fixation involves reduction of molecular nitrogen to ammonia. The micro-organisms involved in the fixation process are free living bacteria and blue-green algae. During lush growth phase these algae have been reported to have the potential to fix as much as 90 Kg ha\(^{-1}\) of nitrogen per year (Singh, 1961). Input, flow and output of nitrogen involve various pathways (Fig. 1). Identification of seven nodes yielded a network model (Fig. 2). The average values for rain input, bacterial fixation and BGA fixation have been estimated to be 11.96, 20.29 and 89.76 Kg ha\(^{-1}\) yr\(^{-1}\), respectively.

**Conservation:** Equations developed on the basis of the network model yielded a positive remainder of 1.08 kg ha\(^{-1}\) yr\(^{-1}\). According to this there should have been a piling up of this element in the ecosystem at completion of every annual cycle. Since that does not happen in reality this unaccountable nitrogen has been envisaged to be conserved in an immobilized form in a flux between the atmosphere and the soil system. The aerobiology contains a number of algae dominated by Cynobacteria majority of which are known to be implicated in the fixation of nitrogen in soil. The key factor in this flux is moisture. When moisture is available the spores and propagules settle down to the terrestrial environment and continue lush growth till the advent of the dry period subsequent to monsoon season.

**System deficit:** The real value of nitrogenous material for fertility depends on the rate of its transformation into a chemically available form (Choudhri and Prasad, 1971). The added nitrogen to soil from biological fixation is converted to elemental forms through microbial action (Hermansen and Kolenbrander, 1965). The basic processes of mineralization i.e. ammonification and nitrification are confined to the surface layer of soil which are subjected to periodic inundation and drying during monsoon period and remain dry for the major part of the year subsequent to monsoon (Raming and Rhoades, 1963). Nitrification being an oxygen dependent process hardly continues during waterlogged phase. Thus the process of nitrification in the ecosystem is restricted to a limited number of days. During summer months when temperature is high and moisture content in the profile drops below permanent wilting point, nitrification ceases and nitrogen is lost from the ecosystem as ammonia. Under ideal conditions of temperature, moisture and pH the potential nitrification capability of the ecosystem has been worked out to be 0.0104 Kg ha\(^{-1}\) yr\(^{-1}\), to 30 cm depth in the profile. Low permeability further enhances runoff loss with denitrification acting as an additive process to account for loss of the element through capillary pores as upward movement of water due to evaporation brings more mineral nitrogen up from the moist soil below. Volatilization constitutes the third avenue for loss of this element from the system. NH\(_3\) is lost in a slow but steady rate over a long period facilitated by high pH high temperature and prevailing dry conditions.

### Table 1: Flow averages of N in the ecosystem with operation of each annual cycle.

<table>
<thead>
<tr>
<th>Flow Kg. ha(^{-1}) yr(^{-1})</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. N(_{B}) 83.19</td>
<td>N lost to atmosphere as NH(_3) gas detrit</td>
</tr>
<tr>
<td>*2. N(_{B}) 11.61</td>
<td>N contribution of the system to the detritus sub-system.</td>
</tr>
<tr>
<td>*3. N(_{B}) 20.79</td>
<td>N to cover crop from soil</td>
</tr>
<tr>
<td>*4. N(_{B}) 8.54</td>
<td>N to permanent sink via run-off.</td>
</tr>
<tr>
<td>*5. N(_{B}) 122.21</td>
<td>N input to the system from atmosphere via rain, BGA and bacteria.</td>
</tr>
<tr>
<td>6. N(_{B}) 3.00</td>
<td>N detritus feed-back.</td>
</tr>
<tr>
<td>7. N(_{B}) 17.29</td>
<td>N to atmosphere via denitrification.</td>
</tr>
<tr>
<td>*8. N(_{d}) 3.87</td>
<td>N from mechanically disintegrated dead organic matter during dry part of the year.</td>
</tr>
<tr>
<td>9. N(_{d}) 8.21</td>
<td>N to detritus sub-system from cover crop as standing dead O.M.</td>
</tr>
<tr>
<td>10. N(_{d}) 0.47</td>
<td>N to detritus sub-system from grazed component as droppings</td>
</tr>
<tr>
<td>*11. N(_{d}) 8.24</td>
<td>N to permanent sink via cattle grazing</td>
</tr>
<tr>
<td>*12. N(_{d}) 12.08</td>
<td>N to the system by cover crop as standing dead material.</td>
</tr>
<tr>
<td>*13. N(_{d}) 8.71</td>
<td>N contribution to the grazed component by the cover crop</td>
</tr>
<tr>
<td>14. N(_{d}) 1.08</td>
<td>Immobile in the dynamic flux between aerobiological and terrestrial algal flora</td>
</tr>
</tbody>
</table>

* Items 2, 5 & 8, 10, 13 were analysis based. Rest was obtained through equations.
Concluding Comments: Input interactions, release by heterotrophic utilization and uptake of the nutrient by green plants in the system are in dynamic equilibrium. There is no continuous addition of nitrogen to the system at the completion of each annual cycle simply because accumulation of biomass is not possible. The heterotrophic metabolism of the monsoon period and the mechanical disintegration of the dry period together equal production process in the system.

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