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**Review Article**

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# Precision Nitrogen Management in Crop Production

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**ABSTRACT**

Precision nitrogen management is a management practice where the optimum amount of nitrogen (N) is supplied according to the demand of the crop. It is the best management practice that is used to protect and conserve natural resources, as nitrogen is most important for crop production and an excess amount of nitrogen can easily escape into the environment, resulting in groundwater pollution, eutrophication dead zones and other harmful effects. It is environmentally friendly as it controls environmental pollution by reducing the excess use of N fertilizer. The loss of N fertilizer mainly occurs due to leaching, runoff, volatilization, denitrification and nitrogen fixation. In Nepal, there is a high loss of nitrogen as farmers use fertilizers haphazardly. This loss is minimized by using different decision support tools. Different tools used for N fertilizer management are LCC, SPAD and the Green Seeker optical sensor tool. These tools help to determine the demand of N by the crop and fertilizer can be used according to it. These tools have high efficiency and can be easily and effectively used.
**Keywords:** precision, crop, nitrogen, fertilizer, tools

## INTRODUCTION

### Background

Precision nitrogen management is the important management practice that matches the amount of nitrogen supply to the crop with the exact amount that the crop demands to perform its activity. This is the technique that is heavily backed by science. The scientific studies will constantly change the data and recommendations for nitrogen application. It is the best management practice that is used to protect and conserve natural resources, as nitrogen is most important for crop production and excess amounts of nitrogen can easily escape into the environment, resulting in groundwater pollution, eutrophication, dead zones and other harmful effects.

Precision N management is considered environmentally friendly as there will be excess reduction in nitrogen and runoff with the adoption of this practice. The farmer will have to apply less nitrogen, which will positively affect in crop production and saves money. Precision N management practice is used where there is high pollution level in the environment and field as nitrogen is used in less amount that makes less pollution. There are many barriers in this management practices, like it requires specific calculation of nitrogen to be used in the field whichrequires new equipment, and farmers also need to have more knowledge about how to use and when to use so that nitrogen loss can be minimized.

Site specific nutrient management practices are mainly used for nitrogen application to make sure the nitrogen are applied in the right rate source placement and to match the timing of nutrient supply to nutrient demand.

Leaching is the process of loss of water-soluble plant nutrients from the soil due to rain and irrigation. Nutrient applied in the soil is lost due to heavy rain and irrigation. Runoff mainly occurs when rainfall intensity is more than the infiltration capacity of the soil. Runoff is limited on soils which has high infiltration capacity (Examveda, 2021). Volatilization is a chemical process that occurs on soil surface when ammonium from urea or ammonium containing fertilizers is converted to ammonia gas at high PH. Denitrification is a soil microbial process that produce and consume the potent greenhouse gas nitrous oxide (NO) which compete for nitrate with plants and remove nutrients.

Nitrogen is the largest input used by the farmers in crop production. Farmers apply nitrogen in order to increase the production. Excessive amount of nitrogen applied in the field causes weed problems and could result in lodging, delayed maturity and more disease problems in the crop (Diacono *et al*., 2013). This has led to greater nitrogen loss through volatilization, denitrification, runoff and leaching. Low amount of N applied in the field does not meet the demand of N by the crop and excess amount of N leads to losses. For the minimization of N losses, N fertilizer should be applied according to the time and the needs of the crops.

Nitrous oxide creates 310 times the global warming potential of carbondioxide and its emissions are affected by poor nitrogen management in intensive crop production which is major source for it (Mohanty *et al*., 2025). The potential for enrichment of ground and surface waters with nitratesincreases with excessive N fertilizer applications which causes eutrophication in aquatic ecosystem (Jat *et al*., 2013). Efficient nutrient-management always supply plant nutrients in adequate quantities to sustain maximum crop productivity and profitability and minimizes environmental impacts of nutrient use (Jat and Gerard, 2014). For effective nutrient management practices, it requires knowledge of the interactions between the soil, plant and environment.

The Agriculture Perspective Plan (APP, 1995-2014) has shown that fertilizer use has been increased from 31 kg nutrient/hectare in the base year (1995) to 131 kg nutrient/hectare by the end of 2015. Similarly, Agriculture Development Strategy (2015-2034) has also highlighted the low use of fertilizer as the major reason for low productivity and commercialization. Based on the total consumption of chemical fertilizer in FY 2065/66 the fertilizer and nutrient use per hectare was 2.29 kg and 1.03 kg which has significantly increased over the years and has reached to 96.62 kg and 50.68 kg respectively (Bista *et al*., 2016). The consumption level is very low compared to that targeted by Agriculture Perspective Plan (APP). Fertilizer use of 147 kg/ha, 176 kg/ha, 166 kg/ha and 101 kg/ha has been reported in India, Bangladesh, Pakistan and Sri Lanka respectively in 2009 (Bista *et al*., 2016).

4R Nutrient Stewardship is the important practice of applying nutrients to the plants using the Right Source, at the Right Rate, at the Right Time, and in the Right Place to achieve optimal crop productivity with minimum environmental impacts. The 4R approach helps to increase crop yield, reduce fertilizer cost, protect soil and water and promote sustainable agriculture. It balances crop production and environmental protection.

**Objectives**

To know the precision nitrogen management practices in crop production.

To know about nitrogen management tools and techniques.

To know the impact of high and low nitrogen applied in field in crop growth

To review and collect information from various research papers in relation to nitrogen management practices in Nepal.

**Methodology**

This paper, "Precision Nitrogen Management In Crop Production" has been prepared through a deep study on the basis of 4R Nutrient Stewardship principles with modern tools and field practices. and compiling all the relevant information/data to meet our objectives. During the study, different study materials were used. The methodology illustrated by Pandit *et al*., 2025 was also reviewed and evaluated. Secondary data were reviewed and collected. Journals, research article, books from google scholar, scopus etc upto 2025 were reviewed to complete this paper. The papers published by Nepal government, newspaper articles, department of agriculture, annual books were also referred during the review.


(Roberts, T. L., 2010)

**Figure 1**. Precision nitrogen management framework

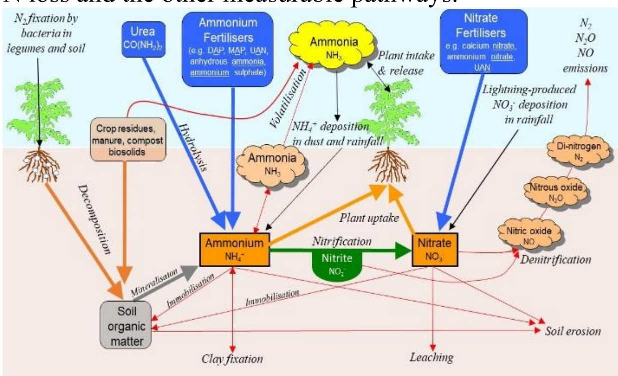
Precision nitrogen management uses various tools such as LCC, SPAD, Green seeker, nutrient expert model, crop simulation model etc. for collecting information about spatial and temporal differences within the field in order to match inputs according to site specific field conditions (Diacono *et al*., 2013).

**Nitrogen Pathways**

The cycling of nitrogen (N) through the soil, water and air is complicated. Solid, liquid and gaseous forms of N that are interrelated by variety of processes; some biologically driven other purely chemical. A range of soil properties, crop growth and environmental conditions (moisture content, temperature, wind speed) all come to determine whether N will be lost and from which pathway and at what rate.

**Nitrogen loss mechanism from the field**

If there were no N losses from fertiliser N applied to the soil-plant system, then the amount of N taken up by the crop or left in the soil at harvest would equal that which was put there at the start of the season, plus that mineralised from soil organic matter during the season. We know N losses occur because many studies using isotopically-labelled N fertiliser were not able to account for all of the N applied when measurements of plant and soil were conducted at harvest. From a large number of Australian cropping studies, an average of 28% of the 15N applied to a crop was not found at the end of the crop (range: 0–94%) (Barton *et al*., 2022). There are a range of potential loss pathways that can contribute to the overall loss figure. Volatilisation, leaching and runoff can be measured directly. Denitrification is usually deduced by difference after measuring the total N loss and the other measurable pathways.




(Barton *et al*. 2022)

**Figure 2.** Major pathways of the soil nitrogen cycle and loss mechanism.

**Leaching and runoff:**

Leaching losses of N usually occur when soils receive more incoming water (rain or irrigation) than they can hold. Nitrate (NO3-) in the soil solution moves with water as it moves through the soil. Ammonium (NH4+) is a positive charge and is in the negative sites on the clay in the soil. This makes the (NH4+) forms of N leach very little in clay. In coarse-textured sand and in some muck soils, ammonium forms of N leach (Vitosh and Silva, 1994).

Nitrate containing fertilizers such as Urea and Ammonium nitrate are more susceptible to leaching loss as they are applied in the field. Urea gets converted into nitrate within two weeks in the spring season, and then leaching loss occurs. Similarly, anhydrous ammonia converts into nitrate very slowly due to initial toxic effects on the soil microbes, which are responsible for the conversion of ammonium –N to nitrate (Nielsen, 2006).

Surface runoff is the primary pathway of loss of N to lakes and rivers. It is reported that surface runoff has been decreased by reducing tillage practices and also by maintaining cover crop residue. Krutz *et al*. (2009) reported that a rye cover crop has helped to reduce runoff volume by 1.4 fold and sediment loss by 4.7 fold as compared with bare soil. Van Vliet *et al*. (2002) told that, as compared with no relay crop, intercropping silage corn with a relay crop of Italian ryegrass reduced annual runoff by 53% and sediment loss by 74%. Winter cover crop reduces runoff and thus decreases the nitrate (NO3) loss (Zhu *et al*., 1989).

The cropping system has greatly affected annual runoff. More runoff was observed in wheat/fallow than in three double-cropping systems. Wheat/cotton has reduced annual runoff by 23%, 43% and 29% in 2007, 2008 and 2009, respectively, as compared with wheat/fallow. The wheat/soybean runoff has been decreased by 51% and 65% in 2007 and 2009, as compared with wheat/fallow (Jioa *et al*., 2012).

**Volatilization:**

Volatilization is the loss of nitrogen from ammonium to ammonia gas and then it is released to the atmosphere. Volatilization losses are usually more in manure and urea fertilizers which are applied in surface and is not incorporated (by tillage or by rain) into the soil. The volatilization loss is high at higher soil PH and at hot and windy conditions. As soil PH increases from 6.5 to 7.5, then volatilization losses double from 10 to 20 per cent. As with leaching and denitrification, volatilization represents a big loss of N for crop production and a possible negative environmental effect (Penn State Extension, 2021). Urease enzymes within the soil and plant residues convert the urea component to free ammonia gas. The risk of volatilization drops to zero if a half-inch or more of rain occurs within the first 24 hours after surface application (Pessarakli, M. 1999).

**Denitrification:**

Denitrification may be a process where bacteria convert soil nitrate (NO3) into nitrogen (N) gases that are lost from the soil. Bacteria break down organic matter to produce carbon dioxide, water and energy in the presence of oxygen in normal aerated soils (Cox *et al*., 2015). But in very wet soils, oxygen is rapidly depleted, so bacteria use nitrate instead of oxygen for respiration. Usually, the source of the nitrate determines when denitrification losses may occur. In N-fertilized summer crops such as sorghum, losses can be large if heavy rains waterlog the soil during hot conditions soon after planting.

N loss occurs when there is microbial attack from naturally occurring bacteria in the soil strip oxygen from the nitrate which produces gases that escape to the air and cause a loss upto 60% from the applied nitrogen. Denitrification mainly occur under four conditions, that is in wet or poorly drained soil, in compaction, in warm soil temperatures and in readily decomposable organic matter. These four conditions cause the oxygen level to drop in the soil and activate the bacteria to denitrify the soil to live. The losses occur as gases, nitrogen gas, nitric oxide or nitrous oxide.

**Table 1.** Estimated denitrification losses influenced by soil temperature and days of saturation

| Soil temperature (degree F) | Days Saturated | Loss (% of total N applied) |
|---|---|---|
| 55-60 | 5<br>10 | 10<br>25 |
| 75-80 | 3<br>5<br>7<br>9 | 60<br>75<br>85<br>95 |

Source: Ferguson, T.S., 2014

Table 1 shows the relation of soil temperature, days of saturation, and loss of nitrogen. It has been shown that at higher temperatures and higher saturated days there is high nitrogen loss. From the table it can be seen that, at 55-60 degrees Fahrenheit and 5 saturated days the nitrogen loss is 10%. Similarly, at 75-80 degrees Fahrenheit and 9 saturated days, the nitrogen loss is 95%.

**Nitrogen fixation:**

Nitrogen fixation is a process where atmospheric nitrogen gets converted by either a natural or an industrial means to a form of nitrogen such as ammonia. Most of the nitrogen comes from the atmosphere by microorganisms to form into ammonia, nitrates and nitrates which is used by plants.

The N losses take place N fixation as ammonium fixation by clay minerals. The amount of N applied in the field in the form of urea goes more in reduced zone of the soil than the top soil due to higher clay content of sub soil and convert to organic N or unavailable N, thereby fixes nitrogen and plants cannot utilize that N effectively.

Ammonium fixation by clay minerals is high in subsoil than that of top soil. In soils with considerable 2:1clay content, inter layer fixed NH4+ typically accounts for 5-10% of total nitrogen in the surface soil and upto 20-40% of the nitrogen in the subsoil. Ammonium fixation is low in highly weathered soil due to present of low amount of 2:1 clay. Nitrogen in the O and A horizons are immobilized in forest soils due to ammonium fixation (Brady, 2008).

Relationship between plant growth and nitrogen supply

Increase in supply of nitrogen increases yield until it is limited by other factors. With the deficiency of nitrogen in the crop the yield is very low and with increasing nitrogen supply the yield slowly increases. With the optimum supply of nitrogen, the yield will be maximum and when nitrogen fertilizer is over supplied then the yield slowly decreases and loss of nitrogen becomes more.

**Relationship between soil nitrogen supply and fertilizer N application**

Crop yield can be obtained through soil nitrogen supply and fertilizer nitrogen supply. Very low yield is obtained from soil nitrogen supply. For higher yield fertilizer nitrogen is most important. The graph has shown that yield can only increase with the fertilizer nitrogen supply.

**Need for using precision N management**

Precision N management is the technique that the nitrogen is used in the field exactly in that amount the crop demands for. The loss of nitrogen can be minimized through the proper application of the nitrogen in the field. The nitrogen loss from the field is mainly due to leaching, runoff, denitrification, volatilization, nitrogen fixation.

Precision nitrogen management is considered as environmentally friendly as there will be excess reduction in nitrogen and runoff with the adoption of this practice. It has high efficiency. It is very efficient to every farmer carrying out crop production activity. For higher crop production efficiency is very important. It is very cost-effective for the farmer to adopt. The farmer will have to apply less nitrogen which will positively affect in crop production and save money.

Precision nitrogen management practice is used where there is high pollution level in the environment and the field as nitrogen is used in less amount that makes less pollution. There are many barriers in this management practices like it requires specific calculations of nitrogen to be used in the field, requiring new equipment, and farmers also need more knowledge about how to use and when to use, so that nitrogen loss can be minimised.

Precision nitrogen management helps to increase the nitrogen uptake by the plant thereby increasing the nitrogen use efficiency without any yield penalty. It helps farmers practice more sustainable agriculture by having a sufficient rate of nitrogen when the crops need it and at a particular time by reducing the risk of losing the harvest. So, the need of using precision N management practices is very important as it is familiar to the farmers and farmers can use N in an optimum amount.

**Precision N management tools and techniques**

**SPAD (Soil Plant Analysis Development)**

SPAD is a portable device which allows instant measurement of chlorophyll content of the leaf. It has a sensor which emits two frequencies of light red at 60 nanometers and infrared at 940 nanometers. The chlorophyll absorbs red light but not infrared. This difference in absorption allows introducing the chlorophyll content of the leaf.

Chlorophyll meters are used to guide the nitrogen management by monitoring leaf N status in agricultural systems (Xiong *et al*., 2015). SPAD chlorophyll meter helps to understand the N present within the leaves and this helps to determine at which stage the nitrogen is deficient within the crop (Baral *et al*., 2021). For semi-dwarf indica rice varieties, critical SPAD values usually ranges from 32 to 37.5. To guide N application using SPAD meter, two approaches has got to be followed. First one is when SPAD value is less than the set critical reading, and the other is when the sufficiency index falls below 0.90 in rice. SPAD meter-based N management has helped to increase NUE (45-110%) as compared with farmers field level fertilizer practices.

SPAD meter is a simple device which has a display, four buttons for easy operations, and an off switch which allows it to be turned on or off. There is a handle bar which has a chamber inside which sensors are pressed, working with a SPAD meter. The SPAD meter handle is pressed without leaf in it to calibrate. Once the meter reads blank, then it is ready to use. The leaf is choosed and then reading is taken.

SPAD meter helps to understand the N present in the leaf and this will determine when and how much N to be applied to the crop. It gives correct reading of N content in the leaf. This meter needs technique to use and is very expensive. Poor farmers cannot use SPAD meter in the field.

**LCC (Leaf Color Chart)**

Leaf color chart is a diagnostic plastic strip device that is used for tracking the nitrogen status of a rice leaf. At different growth stages, there is close link between leaf chlorophyll content and leaf N content over different growth stages. The LCC depicts gradients of green hues that are based on the wavelength characteristics of rice leaves, from yellowish-green to dark green, with a scale value from 1 to 1.5. The critical LCC value of Basmati, inbred and Hybrid rice cultivars are 3, 4 and 5, respectively (Sukla *et al*., 2004). LCC guided N control has expanded yield by 0.31 mt ha-1 as compared with farmers level practices (Marahatta, 2017).

Leaf N status of rice is related to photosynthetic rate and biomass production, and it is a sensitive indicator of changes in crop N demand within a growing season. A tool to rapidly assess leaf N status and thereby guide the application of fertilizer N to maintain an optimal leaf N content can consequently be vital for achieving high rice yield with effective N management.

LCC is especially used to monitor leaf N status from tillering to panicle initiation stage (USAID, 2021). Farmers' preferences and frequency of visits by farmers to their fields and their knowledge of critical growth stages for N application help in taking decision about which tools to use. The real-time option is usually preferred when farmers lack sufficient understanding of the critical stages for optimal timing of fertilizer N.

**Steps to use the LCC:**

10 disease-free rice plants or hills are randomly selected from a field with a uniform plant population.

1.Top most fully expanded leaf from each hill or plant is chosen. The middle part of the leaf is placed on a chart and compare the leaf color with the color panels of the LCC. Do not destroy the leaf.

2. Leaf color is measured under the shade of our body, because direct sunlight affects leaf color readings. If possible, the same person should take LCC readings at the same time of the day every time.

3. The average LCC reading for the selected leaves is now determined.

Plants without nitrogen application become yellowish. With this more complicated option, farmers monitor the rice leaf color at 7- to 10-day intervals from tillering to about 5−10 days after panicle initiation. Farmers usually apply N fertilizer if the leaves become more yellow-green than a critical threshold value indicated on the LCC. Leaf color is typically monitored a total of four to six times per cycle. For the effective use of real-time N management requires the selection of an N dose and a critical threshold LCC color that ensure two to three N applications in an average yielding field or year. Rice crop leaves turn yellow rapidly, if there is more crop N demand in the field resulting in more N applications and causing more N fertilizer in use. Rice leaves require less N fertilizer and leaves remain green for a longer time in fields and years with below average growth, hence this leads to less N fertilizer in use. The critical threshold value is usually adjusted for cultivars and crop establishment method. Threshold value for cultivars with yellowish leaves should be more yellow green than that for cultivars with inherently dark green leaves (USAID, 2021).

**Green seeker**

Green seeker is an active light source optical sensor tool which is used to measure plant biomass. The GS measures normalized difference vegetation index (NDVI), a unit that is primarily based totally at the reflectance at red and near infrared (NIR) regions. NDVI is an empirically derived vegetation index associated with leaf area index that predicts biomass and yield (Baral *et al*., 2021).

The principle behind NDVI is that red-light is absorbed by chlorophyll within the plant and near-infrared light is mirrored by the plant's leaf. The plant that is growing vigorously has low red-light reflectance and high close to infrared reflectance and hence this makes high NDVI values. There is a presence of a sensing element in the tool, and once the sensing element activates, it emits red and infrared light and then the tool measures the amount of each that is reflected. To observe the reading, the sensor should be held 60-120 cm higher than the crop canopy, and then the trigger should be pulled. This will give the proper reading.

NDVI measured at the panicle initiation level definitely correlates with rice grain yield. GS-guided N fertilizer application will increase N recovery efficiency by 6–22%, and agronomic efficiency by 5–12 kg grain kg-1 N applied over conventional practice without any yield penalty. Using the response index calculated from NDVI, a definite N fertilization time is known, while not a penalty on the yield.

**Urea briquette:**

Urea briquette fertilizer is a simple physical modification of ordinary urea fertilizer. It consists of huge distinct particles of urea containing 46% nitrogen. Urea briquettes are oval-shaped super granules of urea having a weight of 1-2 g prepared by compaction using briquette/pellet making machine. Urea briquette is mainly deep placed in the soil. Urea deep placement helps to save urea fertilizer upto 65% and increases grain yield upto 50% as compared to split-applied N in the field. Urea briquettes are superior to sulphur-coated urea, neem cake-coated urea and prilled urea in terms of yield and N uptake performance (Manikyam *et al*., 2020).

Urea briquettes are generally placed at 7-10 cm at the rate of one urea super granule. The labor cost and lack of awareness to farmers discourage them from adopting this practice as this practice is a very efficient method for NUE. Continuous operation type and non-continuous injector type applicators have been used for deep placement of urea briquettes in the transplanted rice. The continuous operation type applicators were found to be labor saving but problems like metering and depth of placement make this applicator less efficient than manual placement. The non-continuous injector-type urea briquette applicators are less labour-saving as compared to continuous operation type applicators (Nayak *et al*., 2017).

Weed infestation is very less in urea briquette applied field than that of prilled urea applied in the field. There will be less pollution in the environment due to fertilizer use, no leaching.

**Urea deep placement**

Urea deep placement is an innovative, simple, but laborious and low-cost technology where ammonical N fertilizer are placed in the reduced zone of soil in the form of briquette. It is a technology that increases the efficiency of nutrient delivery of crops by placing fertilizer directly into the root zone. Deep placement increases nutrient uptake by crops by using less fertilizer than that of surface broadcasting, as it minimises loss of N due to runoff and ammonia volatilization (CINDY M. COX, 2015).

Urea deep placement helps to save urea fertilizer upto 65% and increases grain yield upto 50% as compared to split applied N in the field. Urea deep placement preserves nitrogen in the soil in the form of ammonium, which is less mobile than nitrate and increase nitrogen available to rice for a longer period of time. Poorly developed roots can get nutrients easily and there is less use of fertilizer.

**Summary:**

In Nepal, the application of N is haphazard, that is, people are applying N fertilizer without any proper manner and techniques. Nitrogen is the most used fertilizer by farmers in order to increase production. Low amount of application of N fertilizer does not fulfil the demand of N to the crop, and excess amount of application of N fertilizer leads to the loss of N in more amount. Precision nitrogen management is an environmentally friendly management practice which helps to reduce the use of N in more amount and hence reduces the loss of N from the field and reduces environmental pollution. Table 2 shows the contributing factors and precision management strategies of the N loss pathway in detail.

The different tools that are used for precision N management practices are LCC, SPAD, Green Seeker optical sensor tool, urea briquettes, etc. These tools are useful in taking decision when and how much N to apply in the field. These tools determine the amount of N in the crop, and hence the N fertilizer is applied according to the reading taken from these tools.

Nitrogen plays an important role in increasing the yield of the crop. As the N fertilizer increases, the yield also increases until other factors do not affect and with optimum application of N fertilizer yield becomes maximum. But over supply of N fertilizer slowly decreases the yield of the crop and results in losses of nitrogen.

Leaching loss of N occurs when soils have more incoming water than the soil can hold. Surface runoff is the loss of N to lakes and rivers. Volatilization loss occur form ammonium to ammonia gas and goes to the atmosphere. It mainly occurs if the soil PH increases from 6.5 to 7.5. Denitrification loss occurs where bacteria convert soil nitrate into nitrogen gases that are lost from the soil. Similarly, nitrogen loss occurs due to nitrogen fixation, where the nitrogen goes into reduced form and changes into an unavailable form and due to this plant cannot use nitrogen and it gets lost.

LCC, SPAD and Green seeker optical sensor tools are used to monitor the N status of the crop. These tools help to know the status of N in the leaf of the crop. Due to this nitrogen can be managed properly. This will help to reduce the application of nitrogen in the field and increases the nitrogen use efficiency. Similarly, these tools have high efficiency and can be used by the farmers for proper application of fertilizer and minimize the loss of N from the field.

**Table 2.** Summary Table of N loss pathway

| N Loss Pathway | Contributing Conditions | Precision / 4R Management Strategy |
|---|---|---|
| Volatilization ($NH_3$ gas) | Surface applied urea fertilizer, High soil pH and temperature, Low rainfall after application, Windy conditions | Incorporate urea into the soil, Use urease inhibitors, Apply before rainfall, Use slow-release/controlled-release fertilizers |
| Leaching (nitrate movement down soil) | Sandy/coarse soils with high infiltration, Heavy rainfall or excessive irrigation, High nitrate concentrations below root zone | Apply correct rates based on soil test, Split N applications, Use slow-release fertilizers, Better irrigation scheduling to match crop need |
| Denitrification ($NO_3^- \rightarrow N_2/N_2O$ gas) | Saturated/waterlogged soils, Poor drainage, Warm temperatures, High organic carbon (food for microbes) | Improve drainage, Avoid over-irrigation, Use nitrification inhibitors, Adjust timing (avoid heavy rains after N application) |
| Runoff | Heavy rainfall soon after fertilizer application, Steep slopes or compacted soils, Bare surfaces without vegetation | Avoid fertilizer before rain, Use cover crops or residues, Contour farming and buffer strips, Place fertilizer near roots |
| Immobilization (temporary microbial storage) | High carbon-to-nitrogen crop residues (e.g., straw), High microbial activity, Aerated soils | Adjust fertilizer timing, Band N fertilizer near roots, Combine with residue management |

Whetton *et al*., 2022; Mezbahuddin *et al*., 2020

## CONCLUSION

In Nepal, fertilizers come from foreign country that is Nepal do not have its own fertilizer producing factory. Fertilizers come in limited quantity. Due to this farmers cannot get sufficient number of fertilizers in time. And when farmers get fertilizers during cropping period, they apply fertilizers haphazardly. Blanket fertilizer recommendations, especially for nitrogen can lead to the overuse of fertilizers, pollution and increased cost of cultivation. They apply more amount of fertilizer in single crop without any calculation and techniques. This has made the more loss of N from the field. Urea briquette which is applied as deep placement is most effective for N management because it has high NUE and there is less loss of N from the field. But it is very laborious and requires more time. Similarly, Green seeker optical sensor has high efficiency and gives proper reading but in context of Nepal, farmers are poor and unskilled so they cannot buy and use it effectively. SPAD also has high efficiency but it is very expensive to buy and farmers are poor and unskilled so that they cannot use it effectively. LCC is cheap to buy and has high efficiency and can easily be used by farmers as it does not require skilled manpower to use.

So, in context of Nepal LCC can be the best tool for farmers for effectively managing N fertilizer.

## CONFLICT OF INTEREST

The author here declares there is no conflict of interest in the publication of this article.

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