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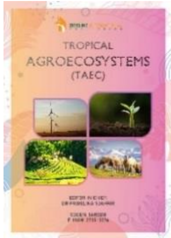

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RESEARCH ARTICLE

COMPARATIVE STUDY OF EVALUATION OF SOIL FERTILITY STATUS IN RICE ZONE, MORANG

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ABSTRACT

A study was conducted in the rice zone of Morang district to examine soil fertility status and the most limiting nutrient in the research area in accordance with rice cultivation requirements. Hundred samples were collected from two different locations of Ratuwamai Municipality ward number 6 and 8 at depth of 0-15 cm from surface soil. Samples were analyzed to find texture, pH, Nitrogen, Phosphorus, Potassium and Soil Organic Matter (SOM). Statistical tools were used to analyze the data. The most limiting nutrient in rice fields were determined by comparing the observed value with the standard requirement for rice fields. From analysis, it was revealed that, nitrogen content was found medium. Phosphorus was low in ward 6 whereas medium in ward 8. Potassium was high in ward 8 whereas medium in ward 6. SOM was low due to less application of organic fertilizer. Majority sample were of acidic probably due to more use of urea. Thirty percent samples of ward 8 were neutral and with equal alkalinity in both wards. Majority of sample was sandy loam except in ward 8 where ten percent sample was clayey loam. Both wards show equal behavior of loamy soil. Nutshell, majority of samples were of low fertility. Nitrogen and Potassium was most limiting as per the rice cultivation requirement with optimum soil pH. Various extension works regarding the importance of soil fertility management, sustainable soil management, optimum application of organic and inorganic fertilizers and the techniques to enhance the soil fertility status is required.

KEYWORDS

Evaluation, Fertilizer, Limiting nutrient, Soil Fertility, Rice Cultivation.

1. INTRODUCTION

1.1 Background information

Since the development of the civilization, agriculture has been the way of living to the mankind. Nepal being an agrarian country, majority of people (65.6%) is directly involved in Agriculture sector (MoALD, 2075). Agriculture contributes about 31.7 % of GDP, which contributes major role in Nepalese Economy (MOF, 2074/75). Rice (*Oryza sativa* L. var. *indica)* is the vital crop in the country's food security accounting nearly 44% of the total food grain production and holds about 20% share in national agricultural GDP (MOAD, 2016). Geographically, rice is grown in all agro ecological zones ranging from the terai (100-300 masl), valleys and foothills (300-1000 masl) to the high mountains (1500-3050 masl).

Morang, a district under Province No. 1, earlier was a district of Koshi zone of Eastern Development Region. The district covers an area of 1855 km^2 (716 sq. mil). Ratuwamai Municipality is the site under study. It is formed by the union of six village development committee; namely Sijuwa, Itahara, Jhurkiya, Mahadeva, Govindapur (Ward No. 1, 3, 4 & 7) and Baradanga (Ward No. 1, 4, 5 & 7). The area of Ratuwamai Municipality is 142.15 km^2 (54.88 sq. mil). Among which Ward No. 6 & 8 is under study and covers 45 km^2. Total population of the municipality is 55,380. Total area under this zone is 4500 ha. The annual rainfall is about 2623mm and temperature varies from 17^0 to 31^0 C. With the implementation of this project the farmers were more encouraged to utilize the fallow lands (Morang R. Z., 2018). Due to continuous hot and humid days during spring and monsoon season rice cultivation practice is more prevalent in this district. However, in some parts of the district Boro rice is also cultivated (Morang R. Z., 2018).

Soil is a dynamic complex substances consists of minerals, soil organic matter (SOM), water and air(Vishal , Narahari, & Punit, 2009)(Flores-Magdaleno, Mancilla-Villa, Mejia-Saenz, Olmedo-Bolantilde, & Bautista-Olivas, 2011). Soil quality includes mutually interactive attributes of physical, chemical and biological properties, which affect many processes in the soil that make it suitable for agricultural cultivation (Rakesh, Rakesh, & Brijesh, 2012). The texture, structure colour etc. are important soil physical parameters. Similarly, soil reaction (pH), organic matter, macro and micro-nutrients etc. are also important soil chemical parameters. These properties play important role for the soil fertility and determined after soil testing(Brady & Weil, 2005). In Southern Africa, the

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most limiting factor to agricultural productivity is soil fertility (Ramaru et al., 2000). The evaluation of soil fertility includes the measurement of available plant essential nutrients and estimation of capacity of soil to maintain a continuous supply of plant nutrients for a crop. Soil is the greatest treasure that human have acquired free of cost and is one of the most valuable natural resource of the world (Brady & Weil, 2005). Soil properties vary spatially and temporally from a field to a larger region scale, and are influenced by both intrinsic (soil formation factors, such as soil parent materials) and extrinsic factors (soil management practices, fertilization and crop rotation)(Cambardella & Karlen, 1999).

Humans are dependent on plants as their food source and soil is the primary medium for plant growth. It is the source of nutrient element to the plants (Kharal, 2017). Soil, being the source of infinite life is the most crucial and precious natural resource, and not a renewable in short period. Sustainable crop production requires a good understanding of the fertility status of the soil in order to impose appropriate nutrient management strategies (Khadka, et al., 2018). Before the introduction of modern high yielding cultivars, net nutrient removal by rice crop was small and even poor soil had the capacity to supply sufficient nutrients to sustainable low yield levels of traditional cultivars (Doberman, Sheehy, Cassaman, & Mamaril, 1998). Fertility is one of the vital factors of soil productivity which is directly related to the loss or gain of plant nutrients (Magar, 2015). The role of plant nutrients in crop production is well established. The nutrients have to be available for the crops in quantities as required for a yield target. Any limiting or deficient nutrient will limit the crop growth. So, it will be better to understand the soil fertility status to develop proper soil management strategies helping in designing the planning crop cultivation in proposed area (STSS, 2000).

1.2 Statement of the problem

As per the information provided from the rice zone office, Morang, it has been experienced that there is quite decline in rice production in Morang district(Morang R. Z., 2018). Rice production and productivity in Morang has not risen up as expected(Khadka, Lamichhane, Tiwari, & Mishra, 2017). But the mouth to be fed has been increasing at greater rate and hence the demand for rice too. Therefore, a good agricultural practices and sound soil condition is very much crucial for increment in rice production (MoAC & FAO, 2011). Late monsoon, lack of proper irrigation source, lack of labors and declining in soil fertility are found to be major constraints for the rice production in Nepal (Pokhrel, 2002). However declining soil fertility ranks in top for Morang district of Nepal (Morang R. Z., 2018). Land is becoming a scarce resource due to immerse agricultural and demographic pressure. Irrational use of chemical fertilizers, which is major factor for soil degradation. Farmers of Morang are highly dependent upon the use of chemical fertilizers, mostly urea and DAP for rice production(Bhandari, Bhattarai, & Bista, 2017). Majority of the people use the livestock waste and other green manures either as a fuel or forage for livestock. The excessive N fertilizer application leads to soil pollution (Tilman, Cassaman, & Matson, 2002).

The problems like soil quality deterioration and fertility decline are prevalent all over the world (Harden, 2001). Farmers have been cultivating their land and managing their soil and fertilizers by communicating with their neighbors in a traditional way since very long, where agriculture extension service is lacking. Soil testing services approaches are quite less or even not at all. An unseen factor playing important role for making soil alive is soil fertility. Apart from various challenges in soil system, soil fertility improvement has become a major concern day to day. For sustainable soil management and crop production, evaluation of soil fertility must be a routine work (Khadka, Lamichhane, Tiwari, & Mishra, 2017). The Intensive farming has led to the decreasing use of organic matter like crop residues and farmyard manure (FYM)/compost. Also, farmers are unable to use the recommended dose of chemical fertilizers due to unavailability, high cost, and a reduction of subsidies to support farmers in the agricultural sector (Rawal, Bhandari, Chalise, & Khadka, 2015).

It was found that neither soil analysis nor field trials have been conducted in the potential rice growing regions of rice zone. The manure and fertilizer dosages suggested in this area are based on the experience of the technicians, farmers and literature available. According to International Fertilizer Industry Association (IFA, 1992) for targeted yield of 1 ton/ha of rice took 20.0 N while for 4 ton/ha yield, N consumption reaches up to 80.0. Inadequate practices of soil conservation and nutrient management contribute to the nutrient depletion soil fertility (Rawal, Bhandari, Chalise, & Khadka, 2015).

1.3 Rationale of the study

Soil is the foundation of agricultural production and for enhancing efficacy of the agricultural research; future research strategy should be built based on the soil fertility status of the farm. Availability of plant macronutrients like Nitrogen, Phosphorous and Potassium status along with the soil reaction status can be reflected in soil fertility analysis(Brady & Weil, 2000). Because of the general lack of detailed soil fertility surveys, only examples of N, P, K deficiencies is provided in various region rather than exact problem (Doberman, Sheehy, Cassaman, & Mamaril, 1998).The physical, chemical and biological characteristics of the soil keep on changing upon the long period of cultivation(Bear, F. E., 1964). Recent focus is directed towards sustainability of any system. Nepal is facing serious problem of soil quality decline as a result of recent changes in agricultural practices and increasing resource constraints with little scientific knowledge. Despite agro-climatic conditions, every year of flood in district hampers soil fertility to a greater extent. Since rice production is the main source of economy of marginal farmers, one can easily know importance of this research. The amounts of depleted nutrients from the soil should determine the dosage of manures and fertilizers. Assessing soil fertility is important to help identify strategies with less environmental impact in order to achieve more sustainable agricultural systems(Khaki, Honarjoo, Davatgar, Jalalian, & Golsefidi, 2017). Nutrient analysis of the soil helps in recommendation of soil fertility management(Khaki, Honarjoo, Davatgar, Jalalian, & Golsefidi, 2017). Evaluation of soil fertility is the most critical point for long-term planning in a specific area (Khadka, et al., 2018).

1.4 Objectives

1.4.1 General objective

- The general objective of this study was to evaluate the soil fertility status of command areas of rice zone in Morang district

1.4.2 Specific objectives

- To evaluate and characterize the soil physio-chemical properties of command areas of rice zone
- To find out the most limiting nutrient of rice field of the command areas of rice zone

1.5 Scope and limitations of the study

1.5.1 Scope of the study

The outcomes of this study will

- help to recognize the potential areas for rice production in rice zone.
- help to find out the corrective measures for improving the fertility status of the rice growing field.
- help to demarcate the most limiting nutrient as per the requirement of rice production
- help the concerned stakeholdersfor making policy in soil fertility management and Integrated Nutrient Management (INM).

The main output of the study may be useful for farmers, future researchers, policy makers and entrepreneurs, as the findings provides a guideline to refine the strategies and programs in supporting and promoting rice production particularly in the study area.

1.5.2 Limitations of the study

Apart from the various efforts made to obtain reliable and accurate information/data from the lab analysis of soil fertility parameters, certain limitations of the study were recognized.

- The findings of the study may not be relevant and may vary to other geographical situations and locations of the country.as the study was carried out on limited samples. So, the findings will be useful only to similar areas and conditions.

- Selected factors were only accounted in this study, considering the limitations of cost and time as researcher and as a student had not enough time and budget to investigate large samples in a shorter period of time.

2. Literature Review

2.1 Production status of rice in Nepal

Production status of rice in Nepal in last 5 decades has found to be increased nearly 2.2 times from 2.1 million tons in 1961-63 to 4.8 million tons in 2010-15. Beside this, production of rice grew at the rate of 1.8% per annum which was below the population growth rate of 2.3% per annum (ABPSD, 2015). It was found that the recent production status of rice from 2070/71 to 072/73, there is continuous decline in cultivation area as well in production. But after that there has been found to slight increased production. This production and productivity actually is not enough for the country (Pokhrel, 2002).

Table 1: Production status of rice in Nepal from (2070-2075)(MOF, 2074/75)

Year	Area (ha)	Production (mt)	Productivity (tones/ha)	Avg. price (Rs. /kg)
2070/71	1486951	5047047	3.39	18
2071/72	1425346	4788612	3.36	20
2072/73	1362908	4299078	3.15	22
2073/74	1552469	5230327	3.37	22
2074/75	1469545	5151925	3.50	24

Source: Ministry of Finance, 2074/75

2.2 Production status of rice in Morang

From the ancient times, Rice is the main agricultural crop which is being produced in this district. Rice production is the major source of economy to the marginal people of the district. Rice production status in this district is continuously fluctuating. The continuous change in climate and the modification of rice producing environment has affected the rice farmers of Morang. Beside this, involvement of farmers towards other field has also accounted in less production of rice. Recent studies revealed that most of the rice growing field are used for pond construction and fish farming.

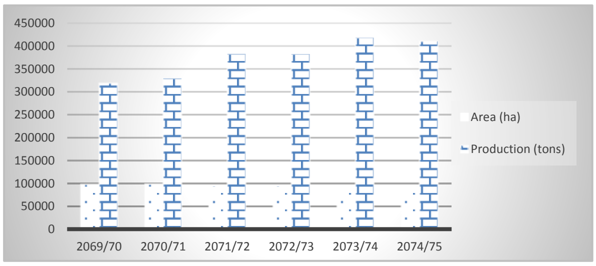

Figure 1: Rice production in Morang district

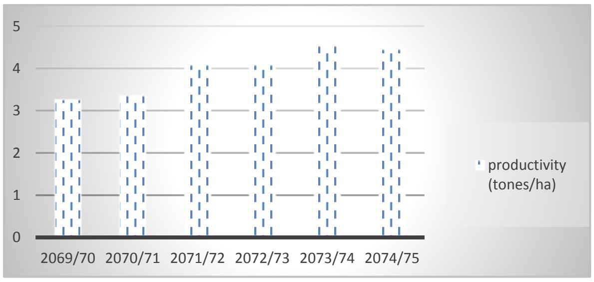

Figure 2: Rice productivity in Morang district

2.3 Favourable environment for Rice Production

Average temperature ranging 20⁰C to 27⁰C is considered best for growing rice as it is a tropical cereal crop. Below 15˚C, germination hampers, so, the minimum temperature for raising crop should be above. Annual rainfall of 175-300 cm is considered most suitable for rice cultivation. It also needs flooded conditions with the depth of water varying over 25 mm at the time of transplanting to as much as 150 mm for 10 weeks of the growing period. Clayey loam soil in monsoon land with slight low pHof 5-6.5 is considered to be best for rice cultivation as water retention capacity of the soil is very high. Rice needs a leveled surface to enable the fields to be flooded at least during the growing period. Rice cultivation is extremely labor- intensive, therefore, requires more labor in comparison to other cereal crops(CDD, 2015). In case of Morang district, during rice growing (summer) season, temperature extends up to 40̊ C maximum and 20̊ C minimum. The annual rainfall is 1400mm and relative humidity is 50%. Soil of terai, especially Morang district has sandy loam, clayey loam and clayey texture. The soil is fertile with pH range 5.5-7.5(DADO, 2073).

2.4 Requirement of Nutrient for rice crop

For rice, sixteen vital nutrients are needed for normal growth and completion of life cycle. In our context, Rice needs relatively large amounts of nitrogen (N), i.e. 50kg/ha for traditional rice varieties and 160 for improved varieties with good irrigation facility: phosphorus followed by Nitrogen i.e. 40kg/ha for local and 60-80kg/ha for improved varieties; and potassium i.e. 30-40kg/ha for traditional varieties and 60-120kg/ha(Khadka, Yajna Gajadhar, 2017). Such nutrients are referred to as primary nutrients as they usually are depleting from the soil first and plants use these nutrients in large amounts for their growth and survival. Most frequently supplied to plants in fertilizers(Witt & Dobermann, 2002). Secondary nutrients are usually found enough in the soil so fertilization is not always needed; these are calcium (Ca), magnesium (Mg) and sulfur (S). Other nutrients essential for rice plant growth which are needed in only very small quantities, are called micronutrients include zinc (Zn), iron (Fe), manganese (Mn), Boron (B), Molybdenum (Mo)(Johnson, Raun, & Hattey, 2000).

2.5 Historical Aspects of Soil Fertility

Interest on soil fertility seems to be originated with the development of agriculture. By Roman times, many soil fertility management practices were in use. These included manuring, liming, crop rotations, and fallowing to build up the supply of available nutrients. During the middle of nineteenth century to the twentieth century significant progress was made in the evaluation of soil fertility and its improvement with the addition of manures and fertilizers. Jean Baptiste Boussingault (1802-1882) quantified nutrients in manures applied to field plots and prepared balance sheets showing inputs and outputs in the harvested crop. At about same time, Justus Von Liebig (1803-1873) propounded the law of minimum, which states that yield of a crop in the field was in direct relation to the essential plant nutrient present in the minimum quantity. By 1855, it was established that (i) crops require both phosphorus (P) and potassium (K), (ii) non-leguminous crops require a supply of nitrogen (N) for their growth and development, and (iii) soil fertility can be maintained by means of mineral fertilizers and manures. Later, many long-term fertilizer experiments established around the world convincingly showed remarkable benefits from the use of animal manures and fertilizers, fallowing and green manuring, and depletion of soil fertility with concomitant yield reductions due to continuous cropping without addition of manures or fertilizers.

2.6 Soil Fertility Evaluation

Nutrient management practices formulated to achieve economically optimum plant performance as well as minimal leakage of plant nutrients from the soil-plant system can only be optimized after soil fertility evaluation (Dalal & Subba Raao, 2006). Thus, soil fertility evaluation is a central feature of modern soil fertility management. The fundamental purpose of soil fertility evaluation is to quantify the ability of soils to supply nutrients for plant growth (Singh & Ryan, 2015).

Soil fertility evaluation can be carried out using a range of field and laboratory diagnostic and a series of increasingly sophisticated empirical and /or theoretical models that quantitively relate indicators of soil fertility to plant response (Dalal & Subba Raao, 2006). The diagnostic techniques include chemical and biological soil tests, visual observations of plant growth for nutrient deficiency or toxicity symptoms and chemical analysis of plant tissues.

2.7 Soil Fertility and Soil Productivity

Soil productivity is a measure of the ability of soil to produce a particular crop or sequence of crops under a specified management system (Singh & Ryan, 2015). Optimum nutrient status alone will not ensure soil productivity (Bear, 1965). Factors such as soil moisture and temperature, soil physical conditions, soil acidity and salinity and biotic stresses (disease, insects, and weeds) can reduce the productivity of even the most fertile soils (Havlin, Beaton , Tisdale, & Nelson, 2010). Thus, soil productivity is affected by a range of factors. Some, such as climate (including rainfall, evaporation, solar radiation, temperature and wind) are beyond farmers' past and present activities (Havlin, Beaton , Tisdale, & Nelson, 2010). Soil fertility affects as well as gets affected by the choices that farmers make regarding agricultural production, fertilization, and soil and water conservation regimes. Soil productivity, therefore, encompasses soil fertility plus all the other factors affecting plant growth, including soil management (Dalal & Subba Raao, 2006).

2.8 Factors affecting soil fertility

2.8.1 Climate

Temperature and rainfall are key features of climate, which affect agricultural productivity, is defined as the prevailing weather conditions over an area (IPCC, 2001). Agriculture production depends on rainfall and atmospheric temperature (ICIMOD/UNEP, 2007). Areas with sufficient rainfall will have greater weathering and greater leaching of soil nutrients and organic matter, and also the enhanced decomposition of organic materials in soils. Less decomposition leads to low fertility status. Temperature influences vegetation cover which in turn influences soil organic matter and the activity of organisms in soil (Sherchan et al., 2007).

2.8.2 Water retention capacity

Water holding capacity refers to the quantity of water that the soil is capable of storing for use by the plant (Brady & Weil, 2000). Soil water is held in, and flows through, the pore spaces in soils. Water holding capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems (Brady & Weil, 2000). The ability os soil to provide water for plants is an important fertility characteristic (RCEP, 1996). 00

2.8.3 Cation Exchange Capacity (CEC)

Cation exchange capacity is defined as the sum total of the exchangeable cations that a soil can adsorb (Brady & Weil, 2000). It is used as a measure of soil fertility, nutrient retention capacity to protect groundwater from cation contamination (Brady & Weil, 2000). It buffers fluctuations in nutrient availability and soil pH (Bergaya and Vayer, 1997). Clay and organic matter (humus) are the main sources of CEC (Peinemann et al., 2002). The higher the CEC, the greater the potential fertility of that soil (Brady & Weil, 2000).

2.8.4 Soil reaction(pH)

Soil pH is an important chemical parameter as it helps in ensuring availability of plant essential nutrients(Deshmukh, 2012). Soil pH has a profound effect on nutrient availability and hence soil fertility(Uriyo, Mongi, Chowdhury, Singh, & Semoka, 1979). Soil pH influences the rate of plant nutrient release by weathering, the solubility of all materials in soil and the amounts of nutrients ions on the cation exchange sites(Trohel & Thompson, 1993). The best pH range for Nitrogen availability is 6-8 and that of potassium is 6-10 and the activity of phosphorus increase from 6.5-7.5 and decrease from 7.5-8.5 and increases again from pH 8.5-10(Yadav R. , 2013).

2.8.5 Soil organic matter (SOM)

Organic matter has a vital role in agricultural soil. It supplies plant nutrient, improve the soil structure, water infiltration and retention, feeds soil micro-flora and fauna, and the retention cycling of applied fertilizer(Johnston, 1986). Soil organic matter acts as a conditioner by improving soil structure, moisture content and ion retention, besides being an important source of some nutrient elements such as N, P, K, S, Zn(Uriyo, Mongi, Chowdhury, Singh, & Semoka, 1979). The organic fraction of N constitutes 5% of total Nitrogen in the soil and that of P generally constitutes 20 – 80% of total P in surface horizons(Brady & Weil, 2000).

2.8.6 Nutrient interaction

Excessive amounts of K reduce uptake of Mg and it is possible to induce or aggravate Mg deficiency by the liberal use of potash(Davies, Eagle, & Finney, 1993). Application of P fertilizers at high rates has been found to reduce Zn availability in soils(Foth, 1990).The availability of one nutrient may be affected by the amount of other nutrient elements in the soil(Bear, F. E., 1964).

2.8.7 Level of N, P, K, S and Zn in soil and forms available

Nitrogen (N) is one of the key plant nutrients and most frequently deficient of all nutrients (Havlin, Beaton , Tisdale, & Nelson, 2010). In Nepal, paddy consumes the largest portion of the total amount of fertilizers sold (Thapa, 2010).Low nitrogen supplying capacity by the soils call for large additions of nitrogen to soils as fertilizers to meet the N needs of high yielding non-leguminous crops such as rice, maize, sorghum and finger millet(Foth, 1990). The quantity of N in surface soils generally ranges from 0.02 – 0.25% and is closely related to the amount of soil organic matter (SOM) which makes up approximately 5%(Singh, Singh, Pandey, & Mishra, 2006).The forms of nitrogen available for plant nutrition are: (a) Organic nitrogen associated with the soil humus, (b) ammonium nitrogen fixed by certain clay minerals, and (c) soluble inorganic ammonium and nitrate compounds(Mowo et al., 2006).

Phosphorus (P) is second only to nitrogen in frequency of use as fertilizer nutrient(Trohel & Thompson, 1993). Plants utilize P in the forms of $HPO42^{-}$ and $H2PO4^{-}$. Soils generally contain 0.02 – 0.2% means total P(Brady & Weil, 2000).

Potassium (K) in the soil occurs as potassium ions in mineral structure and as hydrated K ions either in solution or adsorbed on cation exchange sites(Trohel & Thompson, 1993). The K content expressed as K2O ranges between 0.05 and 3.5% for mineral soils(Bear, F. E., 1964).

Sulphur is an essential nutrients for plant growth due to its presence in proteins, glutathione, phytochelatins, thioredoxins, chloroplast membrane lipids, and certain coenzymes and vitamins (Takahashi , Kopriva, Giordano, Saito , & Hell, 2011). The sulphur is a component of organic matter released after their mineralization (Havlin, Beaton , Tisdale, & Nelson, 2010).

Zinc exist in soil solution as $Zn2^{+}$, as an exchangeable Zn. Zinc is required in early stage of plant and its deficiency causes Khaira disease. Its concentration ranges from 10-30 ppm (average 50ppm)(Brady & Weil, 2000).

2.9 Management of Fertilizer in rice

2.9.1 Management of Nitrogenous Fertilizer in rice

The most and frequent system of applying fertilizers in Nepal is broadcasting method. The three-split dose of application of nitrogenous fertilizer is hardly being practiced.Generally, urea is top dressed in agricultural field. The production and productivity of the rice is highly dependent on the amount of nitrogenous fertilizer. The losses could be assumed by very high in rice farming system of Nepal. For proper response, three-split dose i.e. one third in basal dose, one third in panicle initiation stage and remaining doze at grain filling stage should be practiced(Khaki, Honarjoo, Davatgar, Jalalian, & Golsefidi, 2017). On an irrigated field condition, the recommended dose of nitrogen for rice is 100kg/ha whereas for unirrigated 60kg/ha.

2.9.2 Management of Phosphorus Fertilizer in rice

Whole dose of phosphorus should be applied at basal dose for efficient production(Lan, Lin, Wang, Zhang, & Chen, 2012). The range of application of phosphorus fertilizer may vary between 60-80 kg/ha. For traditional (local variety) and unirrigated field 40 kg/ha P_2O_5 will usually be enough and 60-80 kg/ha will be optimum for improved varieties with proper irrigation facility. The solubility of phosphorus ion in the soil is very much dependent on the soil reaction (pH) level of the soil and is greatest at pH 6-7.

2.9.3 Management of Potassium Fertilizer in rice

Application of 25-30 kg/ha of potassium is sufficient for traditional variety in an unirrigated condition, but improved varieties with irrigated condition justify an application up to 50 kg/ha. On most soils, potassium fertilizer should be applied as a basal dressing, but on free-draining sandy soils where leaching possibilities is high, half should be basal and half top dressed(Doberman, Sheehy, Cassaman, & Mamaril, 1998).

2.9.4 Management of secondary macro nutrients and micronutrients in rice

Because of the use of high yielding and improved varieties, reduced use of organic matter, and use of sulphur-free fertilizers, sulphur deficiency is becoming more widespread in rice. Especially on high pH soils, zinc, manganese and iron deficiencies occur fairly(Dass, et al., 2017). Because of the intensification of rice production, secondary macronutrient and micronutrient deficiencies are becoming more common, and it is important to identify and correct them wherever there is need(Khadka, Yajna Gajadhar, 2017).

2.10 Losses of Nutrient from soil

The major contributing factors for nutrient loss from the soil are Crop removal, leaching and soil erosion (Brady & Weil, 2000). Rice variety yielding 5t/ha removes 110 kg of N, 34 kg of P and 156 kg of K and 200gm of Zn (Tisdale, Nelson, Beaton, & Halvin, 1993).

2.11 Nutrient uptake and concentration

Usually N, P and K are mainly taken up during active vegetative growth for high photosynthetic activity(Roy, Flinck, & Blair, 2006). The pattern of nutrient uptake follows a sigmoid (S – shaped) curve in most cases, being first low in the early stages of crop growth, increasing rapidly when dry matter production is maximum and then declining towards crop maturity (Bear, F. E., 1964). The critical time at active tillering of rice for N application is typically about midway between 14 days after transplanting (DAT) or 21 days after sowing (DAS) and panicle initiation(Bear, 1965).

2.12 Fertilizer use in Morang and its recommendation for rice

Rice growers of Morang are not much acquainted with the use of Chemical fertilizers. They use 115 kg/ha Urea, 95 kg/ha DAP and 17 kg/ha Potash which is equivalent to 70 kg/ha N. 43 kg/ha P, 10 kg/ha K (Bhandari, Bhattarai, & Bista, 2017).

Table 2: Recommendation dose of fertilizer of rice in terms of nutrients

Name	Compost fertilizer (t/ha)	Recommended fertilizer dose by nutrient (kg/ha)	NPK Ratio		
		Nitrogen	Phosphorus	Potassium	
Rice (irrigated)	6	100	30	30	3.3:1:1
Rice (rainfed)	6	60	20	20	3:1:1

Source:(AICC, 2016)

2.13 Soil sampling techniques and selection

A scientific assessment is possible through detailed physical, chemical and biological analysis of the soils (Khaki, Honarjoo, Davatgar, Jalalian, & Golsefidi, 2017). It is necessary to assess the capacity of a soil to supply nutrients in order to supply the remaining amounts of needed plant nutrients (total crop requirement - soil supply). Thus, soil testing laboratories are considered nerve centers for nutrient management and crop production systems (FAO, 2008).The health of soils can be assessed by the quality and stand of the crops grown on them. However, this is a general assessment made by the farmers.

2.13.1 Soil sampling

A carefully designed sampling plan is required to provide reliable samples for the purpose of fulfilling the objective of the study or research. The plan needs to address the site selection, depth of sampling, type and number of samples, details of collection, and sampling and sub-sampling procedures to be followed (Motsara & Roy, 2008) Soil survey field and laboratory method manual, NRCS, 2009). The most important phase of soil analysis takes place not in the laboratory but in the field where the soil is sampled. Soil property vary from place to place(Khadka, et al., 2018). Efforts should always be made to take the samples in such a way that they are fully representative of the field. Only 1–10 g of soil is used for each chemical determination and this sample needs to represent as accurately as possible the entire surface 0–22 cm of soil, weighing about 2 million kg/ha (FAO, 2008).

2.13.2 Selection of sampling unit

Before the actual sampling, a visual survey of the field is must. The variation in slope, colour, texture, management and cropping pattern by traversing the field should be noted. The field should be demarcated into uniform portions, each of which must be sampled separately. Where all these conditions are similar, one field can be treated as a single sampling unit. Such a unit should not exceed 1–2 ha, and it must be an area to which a farmer is willing to give separate attention. The sampling unit is a compromise between expenditure, labour and time on the one hand, and precision on the other (FAO, 2008). Hence, the sampling unit describes the success of the fulfillment of the objective.

2.14 Laboratory analysis

2.14.1 Total nitrogen

Nitrogen is one of the key plant nutrients and the most frequently deficient of all nutrients (Havlin, Beaton , Tisdale, & Nelson, 2010). Total N includes all forms of inorganic N, such as NH_4, NO_3, NH_2 (urea) and the organic compounds such as proteins, amino acids and other derivatives. Depending on the form of N present in a particular sample, a specific method is to be adopted for determining the total N value. The modified Kjeldahl method is adopted with the use of salicylic acid of Devarda's alloy. At the end of digestion, all organic and inorganic salts are converted into ammonium form, which is distilled and estimated by using standard acid.

The Procedure is:

- Weigh 1 g of soil sample. Place in Kjeldahl flask.
- Add 0.7 g of copper sulphate, 1.5 g of K_2SO_4 and 30 ml of H_2SO_4.
- Heat gently until frothing ceases. If necessary, add a small amount of paraffin or glass beads to reduce frothing.
- Boil briskly until the solution is clear and continue digestion for at least 30 minutes.
- Remove the flask from the heater and cool, add 50 ml of water, and transfer to a distilling flask.
- Place accurately 20-25 ml of standard acid (0.1M HCl of 0.05M H_2SO_4) in the receiving conical flask so that there will be an excess of at least 5 ml of the acid. Add 2-3 drops of methyl red indicator. Add enough water to cover the end of the condenser outlet tubes.
- Run tap water through the condenser.
- Add 30 ml of 35 percent NaOH in the distilling flask ins such a way that the contents do not mix.
- Heat the contents to distill the ammonia for about 30-40 minutes.
- Remove the receiving flask and rinse the outlet tube into the receiving flask with a small amount of distilled water.
- Titrate excess of acid in the distillate with 0.1M NaOH.
- Determine blank on reagents using the same quantity of standard acid in a receiving conical flask.

2.14.2 Available phosphorus

Spectrometer is used to measure the amount of phosphorus available in soil samples. Altogether 5 different soil phosphorus extractants: M_1, Mehlich-3 (M3), Bray, Oslen and AB-DTPA are widely used (Morgan, 2017). In Oslen's method, the extraction reagent is 0.5M sodium bicarbonate ($NaHCO_3$) solution at a pH of 8.5, which was first developed and described by Oslen et al. (1954). The original procedure required that 5 g soil be shaken for 30 minutes in 100 ml extraction reagent containing 1 teaspoon of carbon black (Darco G-60). The use of carbon black is eliminated the color in the extract. This procedure was recently modified so that the use of carbon black was eliminated (Watanabe & Oslen, 1965).

2.14.3 Available potassium

Flame Photometer is used for measuring potassium available in the soil sample collected. The principle underlying this is that a large number of element when excited in the flame, emit radiation of characteristics wavelength (Hasanuzzaman, 2018). The excitation cause one of the outer electrons of the neutron atoms to move to an outer orbit of higher energy level of the atoms may be excited sufficiently to lose an electron completely from the attractive force of nucleus where excited atom return to lower energy level, light at characteristics wavelength is emitted.

Excited atoms of ions give line radiation at very definite wavelengths (Doberman, Sheehy, Cassaman, & Mamaril, 1998). The flame photometer employees a relatively low temperature excitation and measures with a photocell the emission intensity which is proportional and to concentration in selected wavelength and for this red filter is used (Thakur, Baghel, Sharma, Sahu, & Amule, 2012).

2.14.4 Soil Reaction (pH)

Soil pH is an important chemical parameter as it helps in ensuring availability of plant essential nutrients (Deshmukh, 2012). Soil pH is usually measured potentiometrically in slurry using an electronic pH meter. H^+ sensitive electrode and a reference electrode are required with combination electrodes that contain the H^+ sensitive electrode and the reference electrode being most commonly used (Brady & Weil, 2005). pH is a measure of the soil acidity or basicity measured on a scale from 0 to 14, with a pH of 7.0 neutral point that is neither acidic nor basic. Because pH is a tenfold change in H^+ ion concentration (Jones, 2001). Most nutrients are available in the pH range of 5.5-6.5(Peters, Nathan, & Laboski, 2012).

2.14.5 Soil texture

Texture is one of the most important property of soils as it affects water retention, nutrient availability, pore space, slope stability aeration and erosion susceptibility(Brady & Weil, 2005). Soil texture or particle size distribution is a stable soil characteristic which influences physical and chemical properties of the soil. The sizes of the soil particles have a direct relationship with the surface area of the particles. Two common procedures are used for particle size analysis or mechanical analysis is the hydrometer method or the pipette gravimetric method.

2.14.6 Organic matter (OM) content

Various methods can be used to estimate the available organic matter content in the soil sample. Loss of weight on ignition can be used as a direct measure of the organic matter contained in the soil. It can also be expressed as the content of organic matter contained in the soil. It can also be expressed as the content of organic carbon in the soil. It is generally assumed that on an average organic matter contains about 58% organic carbon (Khadka, Yajna Gajadhar, 2017). Organic carbon can be estimated by volumetric and calorimetric methods. Soil organic matter can be used as an index of N availability (potential of a soil to supply N to plants) because the content of N in the soil organic matter is relatively constant (MOA, India, 2011).

3. Materials and Methods

3.1 Study area

3.1.1 Location map of study area

The research was purposively carried out in rice growing fields under Prime Minister Agriculture Modernization Project (PMAMP), Project Implementation Unit (PIU), Rice-zone in Morang district. The command areas under this project in fiscal year 2075/76 were Ratuwamai Municipality ward number 6 and 8.

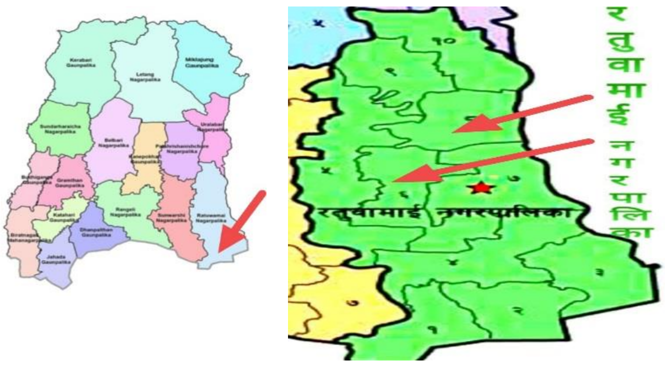

Figure 3: Map showing study area

3.1.2 Climate

The climate of the study area is predominantly tropical. Data presented in table 2 shows that the year-round average temperature was found to be above 20^{0}C. The highest temperature of 38^{0}C was recorded in the month of June and lowest temperature of 15^{0}C was recorded in the month of February with an average annual temperature of 27^{0}C.

Table 3: Annual temperature (^{0}C) range of Morang district in 2019 A.D.

Month	Maximum	Average	Minimum
January	28	22	18
February	27	20	15
March	33	26	20
April	36	30	24
May	36	31	26
June	38	33	29
July	36	32	28
August	35	30	27
September	34	29	26
October	32	28	23
November	30	26	20
December	26	22	17
Average	33	27	23

Source: www.worldweatheronline.com

Figure in Table 3 depicts the average range of annual temperature of Morang district in 2019 A.D. The highest rainfall (130.21) was recorded in the month of August and no rainfall was recorded in the month of January and December with an average annual rainfall of 37 mm.

Table 4: Average annual rainfall (mm) of Morang district in 2019 A.D.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Avg.
0	0.45	1.18	25.95	45.09	71.46	110.77	130.21	60.54	2.1	0	0.1	37

Source: www.worldweatheronline.com

3.2 Sample and sampling technique

At least of 5 years of rice cultivating field were selected for the sample taking.Zig-Zag method was used to take sample from 0-15 cm depth of the surface soil. Altogether 100 (one hundred) soil samples were collected from different rice cultivating fields of rice-zone, Ratuwamai Municipality, Morang district. The number of soil sample from Ratuwamai Municipality Ward Number 6 was 50 and from Ratuwamai Municipality Ward Number 8 was 50. The samples were purposively selected.

3.3 Research instruments/design

Various nature of instruments was used in order to collect soil sample in the field, and to measure physio-chemical properties of soil in the laboratory. Different nature of spades and augers were used in accordance with the type of land for collection of soil sample. Similarly, soil packing polythene was used to place the soil samples. Different chemicals and lab equipment were used in lab during qualitative as well as quantitative data evaluation of soil.

Table 5: Parameters and methods adopted for the laboratory analysis

Parameters	Analysis methods
Soil Texture	Hydrometer Method (Gee and Bauder, 1986)
Soil pH	Digital pH Meter (Cottenie*et al.,* 1982)
Organic Matter Content	Grahams' Calorimetric Method (Graham, 1948)
Nitrogen	Kjeldahl Distillation(Bremmer & Mulvaney, 1982).
Phosphorus	Modified Oslen's Method (Olsen , Cole , Watanabe, & Dean, 1954)
Potassium	Ammonium Acetate Extraction Method (Pratt, 1965) using Flame Photometer

3.4 Data and data types

Both the primary and secondary data were chosen for the interpretation of the study. Primary data were collected from the field from direct observation as well as lab analysis and measurement. And the secondary data were obtained from the review of related literature available in online journal or in library. Data related to soil physio-chemical properties were obtained from the Regional Soil Laboratory, Jhumka, Sunsari. All soil physio-chemical data including pH, Soil Organic Matter, Nitrogen, Phosphorus and Potassium were quantitative data whereas soil texture was qualitative.

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3.5 Data analysis techniques

3.5.1 Characterization of soil resource

MS-Excel Office 16, was used for data entry. Both the qualitative and quantitative data of soil physio-chemical parameters were entered into MS-Excel and were analyzed giving standard rating for each soil physio-chemical parameter as low, medium and high.

Table 6: Standard ratings of soil parameters

Soil Physio-chemical parameters	Low	Medium	High
OM content (%)	<=2.5	2.51-5.0	>=5
Nitrogen (%)	<=0.1	0.11-0.20	>=0.20
Phosphorus (kg/ha)	<=30	30.1-55	>=55
Potassium (kg/ha)	<=110	110.1-280	>=280

Source: Shahu, 2015

3.5.2 Determination of the most limiting nutrient

For the proper recommendation of the dose of nutrient to be applied, one must need the available amount of nutrient present already in the soil. Standard rating only helps to characterize the soil but it may not be an accordance with the exact rice requirement. Therefore, the obtained soil parameters data are compared with the optimum range of rice requirement in order to find which nutrient is most limiting factor for the development of rice growth.

Table 7: Optimum value of soil test for rice cultivation at depth 0-15 cm

Soil Parameters	Optimum Range
Soil pH	5.0-6.5
Soil organic matter content (%)	2.0-3.5
Available Nitrogen (%)	>0.2
Extractable Phosphorus (ppm)	>10
Extractable Potassium (ppm)	>188

Source: Ponnamperuma (1981)

Available phosphorus and available potassium in kg/ha were converted into extractable P and extractable K in ppm i.e. in mg/kg by following conversion formula (Lui, Li, & Gazula, 2016).

Extractable phosphorus (ppm) = phosphorus pentoxide (kg/ha)/ (2×2.2913)

Extractable potassium (ppm) = potassium oxide (kg/ha)/ (2×1.2046)

The data of all soil parameters of soil samples were compared with optimum soil fertility requirement for rice production. The limiting nutrients according to second objective of this study are assessed and compared among the two wards of study area, rice zone, Morang.

3.5.3 Nutrient index value (NIV)

For more precision, determination of nutrient index value (NIV) of different locations of study areas is must for soil fertility evaluation(Parkers, Nelson, Winter , & Miles, 1957).

The nutrient index value is calculated by the formula (Ramamoorthy & Bajaj, 1969)

NIV = (% of samples rating low×1+% of samples rating medium×2+ % of samples rating high×3)/100

Technique of result interpretation of NIV value

Index Value, Low (L) <1.67, Medium (M) 1.67-2.33, High (H)>2.33; (Shetty, Y., Nagamma, M., & M., 2008);(Pathak, 2010);(Kumar , Sidharam , & Srinivasamurthy, 2013)

4. Results and Discussions

4.1 Nutrient Status of soil in study area

4.1.1 Total nitrogen status

The results under status of nitrogen were found varied from one site to another site. The rating of nitrogen was given as low, medium and high as shown in the table 8. In Ratuwamai Municipality Ward Number 6, majority (44%) of samples were found as medium, 36% as low and few (20%) as high in total nitrogen content. The value of total nitrogen from lab analysis varied from 0.00% to 0.40% with an average value 0.13% in those samples. In Ratuwamai municipality Ward Number 8, 48% of samples were measured as low, 36% as medium and 16 % as high. The value was varied from 0.00% to 0.50 % with an average value 0.12%.

Nitrogen is one of the most important plant nutrients and the most frequently deficient of all nutrients (Havlin, Beaton , Tisdale, & Nelson, 2010). The most imperative element for proper growth and development of plants which significantly increases and enhances the yield and its quality by playing a vital role in biochemical and physiological functions of plant is Nitrogen(Havlin, Beaton , Tisdale, & Nelson, 2010). It helps to assimilate carbon in plant, increase protein content, increase photosynthesis, increase water proportion, decrease calcium content in plant cell, help in seed formation and increase the quality of seed(Chaudahary, 2015). Those areas which have low status should be applied with full dose (100%) of the recommended nitrogen dose, whereas 75% of the recommended dose in medium status might be sufficient (Joshy & Deo, 1976)

Table 8: Total nitrogen status of the study area in rice zone Morang (A)

Municipality Rating	Range (%)	Ratuwamai Ward No. 6 (%) (n=50)	Ratuwamai Ward No. 8 (%) (n=50)
Low	<0.1	36	48
Medium	0.1-0.2	44	36
High	>0.2	20	16
Total		100	100

Table 9: Total nitrogen status of the study area in rice zone Morang (B)

Municipality	Ratuwamai Ward No. 6 (n=50)	Ratuwamai Ward No. 8 (n=50)
Mean	0.13	0.12
Max.	0.40	0.50
Min.	0.00	0.00
Std. Deviation	0.10	0.12
Std. Error	0.01	0.02
CV (%)	74.74	95.95

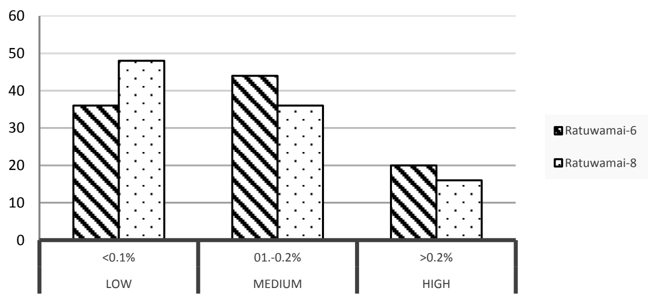

Figure 4: Bar graph showing status of total soil nitrogen ofstudy area in rice zone Morang

4.1.2 Available soil phosphorus status

The available soil phosphorus content of study area, rated as low, medium and High. In Ratuwamai municipality Ward Number 6, 52% of sample were found as low, 38% as medium and 10% as high in phosphorus content. The available phosphorus value was varied from 12 kg/ha to 78 kg/ha with an average value 33.42 kg/ha. Whereas, in Ratuwamai municipality Ward Number 8, 46% of the sample were low, 32% of samples were medium and 22% of the samples were high in available phosphorus content. The available phosphorus value was varied from 8kg/ha to 97kg/ha with an average value of 38.76kg/ha.

Phosphorus is present in all living tissue and is particularly concentrated in the younger parts of the plant and in the flowers and the seed (Olsen , Cole , Watanabe, & Dean, 1954). Phosphorus plays an important role in energy transformation and metabolic processes in plants(Rai, et al., 2012). For sustenance, growth and development of plants, Phosphorus (P), major nutrient element, perform vital functions(Lan, Lin, Wang, Zhang, & Chen, 2012). It involves in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next (Ahmed, Zaidi, Khan, & Oves, 2011). The area having low, medium and high status, 100%, 60% and 40%, respectively of recommended phosphorus dose should be applied in the area of need(Joshy & Deo, 1976).

Table 10: Available soil phosphorus status of the study area in rice zone Morang (A)

Municipality	Range (Kg/ha)	Ratuwamai Ward No. 6 % (n=50)	Ratuwamai Ward No. 8 % (n=50)
Rating			
Low	<31	52	46
Medium	31-55	38	32
High	>55	10	22
Total		100	100

Table 11: Available soil phosphorus status of the study area in rice zone Morang (B)

Municipality	Ratuwamai Ward No.6 (n=50)	Ratuwamai Ward No. 8 (n=50)
Mean	33.42	38.76
Max.	78.00	97.00
Min.	12.00	8.00
Std. Deviation	16.82	25.33
Std. Error	2.38	3.58
CV (%)	50.34	65.34

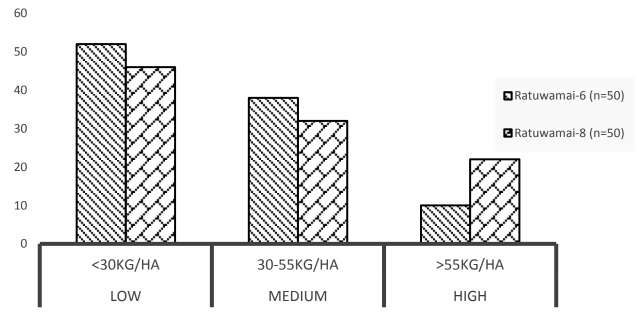

Figure 5: Bar graph showing status of available soil phosphorus of study area in rice zone, Morang

4.1.3 Available potassium status

The available potassium status of the Ratuwamai municipality ward number 6 shows 36% of samples were found as low, 46% as medium and 18% as high. The value of available phosphorus was varied from 34kg/ha to 507kg/ha with an average of 179.82kg/ha in those samples. In Ratuwamai municipality ward number 8, 10% of samples were found as low, 48% as medium and 42 % as high in available potassium status. The value was varied from 42kg/ha to 750kg/ha with an average value 267.21kg/ha.

Potassium is not an integral part of any major plant component but it plays a key role in a vast array of physiological process vital to plant growth from protein synthesis to maintenance of plant water balance (Sumithra , Ankalaiah, Rao, & Yamuna , 2013). It is one of the vital nutrient elements required for plant growth and physiology. In general, K increases tillering, grain size and weight, and disease resistance.(Sumithra , Ankalaiah, Rao, & Yamuna , 2013) In rice plants, about 75% of plant K remains in leaves and stems and stems, and the rest is translocated to grains(Hasanuzzaman, 2018) Beside a constituent of the plant structure, potassium also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism, and enzyme activation (Hasanuzzaman, 2018). The area having low, medium and high status, 100%, 60% and 40%, respectively of recommended phosphorus dose should be applied in the farm (Joshy & Deo, 1976).

Table 12: Available soil potassium status of the study area in rice zone Morang (A)

Municipality	Range (Kg/ha)	Ratuwamai Ward No. 6 (n=50)	Ratuwamai Ward No. 8 (n=50)
Rating			
low	<110	36	10
medium	110-280	46	48
high	>280	18	42
Total		100	100

Table 12: Available soil potassium status of the study area in rice zone Morang (B)

Municipality	Ratuwamai Ward No. 6 (n=50)	Ratuwamai Ward No. 8 (n=50)
Mean	179.82	267.21
Max.	507.00	750.00
Min.	34.00	42.00
Std. Deviation	138.03	143.16
Std. Error	19.52	20.25
CV (%)	76.76	53.58

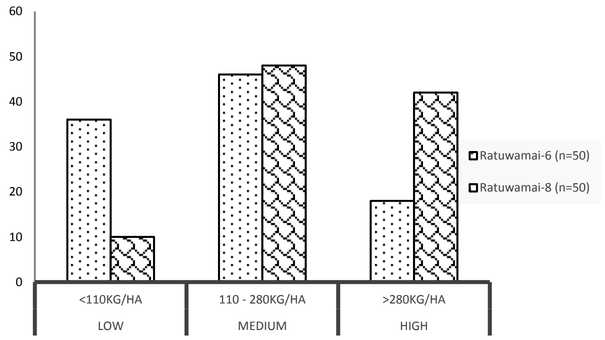

Figure 6: Bar graph showing status of available soil potassium of study area in rice zone, Morang

4.1.4 Soil organic matter (SOM) status

It is found that 68% samples of Ratuwamai municipality ward number 6 were found as low, 32% as medium and none as high in soil organic matter content. The value of SOM was varied from 0.16% to 4.50% with an average value 2.12% in those samples. In Ratuwamai municipality ward number 8, 76% of samples were found as low and 24% as medium and none of the samples were found to be high in SOM content. The value of SOM was varied from 0.80% to 3.40% with an average value 2.02% in those samples.

Soil Organic Carbon (SOC) is the dominant component of soil organic matter, which is an important source of carbon for soil processes and a sink for carbon sequestration (Noppol , Nathsuda, & Ryusuke, 2017). Organic matter has a vital role in agricultural soil. It supplies plant nutrient, improve the soil structure, water infiltration and retention, feeds soil micro-flora and fauna, and the retention cycling of applied fertilizer(Johnston, 1986). An extremely important component of soil is the soil organic matter (SOM). SOM provides nutrients for crops as it decomposes and contributes to the cation exchange complex necessary for holding applied nutrients in the soil(FAO, 2014). Soil aggregation is improved by increased organic matter content and hence has a role in maintaining soil structure, drainage and aeration; all of which are necessary for good crop yields(Tisdale, Nelson, Beaton, & Halvin, 1993). Soil organic matter also plays a role in increasing moisture retention and consequently the drought tolerance of the crop (FAO, 2014).

Table 13: Soil organic matter (SOM) status of the study area in rice zone Morang (A)

Municipality / Rating	Range (%)	Ratuwamai ward No. 6 (%) (n=50)	Ratuwamai ward No. 8 (%) (n=50)
low	<2.5	68	76
medium	2.5-5.0	32	24
high	>5.0	00	00
Total		100	100

Table 14: Soil organic matter status of the study area in rice zone Morang (B)

Municipality	Ratuwamai ward No. 6 (n=50)	Ratuwamai ward No. 8 (n=50)
Mean	2.12	2.02
Max.	4.50	3.40
Min.	0.16	0.80
Std. Deviation	0.97	0.67
Std. Error	0.14	0.10
CV (%)	46.02	33.46

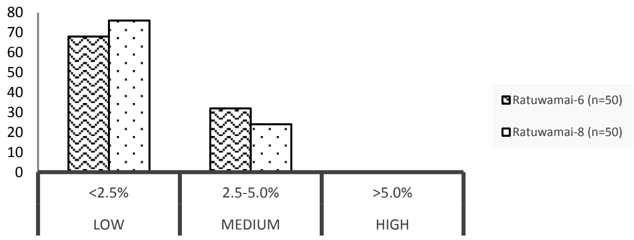

Figure 7: Bar graph showing status of soil organic matter of study areas in rice zone Morang

4.1.5 Soil reaction (pH) status

It was found that 76% of samples were found as acidic (low), 16% as medium (neutral) and 8% as high (alkaline) in pH in Ratuwamai municipality ward number 6. The pH value was varied from 3.8 to 8.3 with an average of 5.88 in those samples. In Ratuwamai municipality ward number 8, 62% of samples were found as low (acidic), 30% as medium (neutral) and 8% as high (alkaline) in pH status. The pH value was varied from 4.5 to 8.5 with an average value of 6.13 in those samples.

Growth and biomass yield (Neina, 2019). Soil pH has an enormous influence on soil biogeochemical processes in natural environment, is therefore described as "master soil variable " that influences myriads of soil biological, chemical, and physical properties and processes that affect plant. Soil reaction is the degree of acidity or alkalinity of the soil. Soil pH is an important chemical parameter as it helps in ensuring availability of plant essential nutrients(Deshmukh, 2012). Availability of plant nutrients from soil differs with soil acidity and soil alkalinity(Bear, F. E., 1964). Essential plant nutrients become available in different way in accordance to the different soil reaction condition (Prajapati, 2018).

Table 15: Soil pH status of the study area in rice zone Morang (A)

Municipality	Range (pH)	Ratuwamai ward No. 6 (%) (n=50)	Ratuwamai ward No. 8 (%) (n=50)
Rating			
Acidic (low)	<6.5	76	62
Neutral (medium)	6.5-7.5	16	30
Alkaline (high)	>7.5	08	8
Total		100	100

Table 16: Soil pH status of the study area in rice zone Morang (B)

Municipality	Ratuwamai ward No. 6 (n=50)	Ratuwamai ward No. 8 (n=50)
Mean	5.88	6.13
Max.	8.30	8.50
Min.	3.80	4.50
Std. Deviation	0.96	0.93
Std. Error	0.14	0.13
CV (%)	16.38	15.11

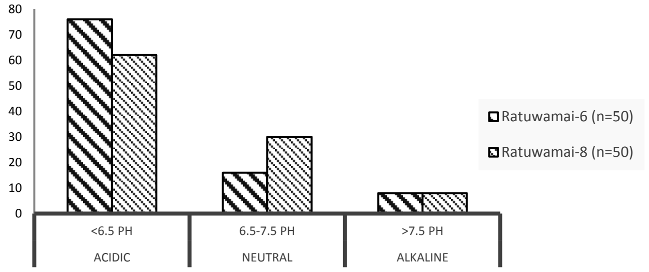

Figure 8: Bar graph showing status of soil pH of study area in rice zone, Morang

4.1.6 Soil texture status

In Ratuwamai municipality ward number 6, 34% of samples were loamy textured, 60% of samples were found as sandy loam soil and 6% as clayey loam in soil texture. It was revealed that 34% of samples were found to as loamy, 56% as sandy loam and 10% as clayey loam texture in Ratuwamai municipality ward number 8.

Water holding capacity, permeability, irrigation requirement and erodibility like factors are highly related to the soil texture of the field(Brady & Weil, 2005). Soil texture has an extremely significant influence on the physical and mechanical behaviors of the soil (Roy, Flinck, & Blair, 2006).

Table 17: Soil texture status of study area in rice zone Morang (A)

Municipality / Texture	Ratuwamai ward No. 6 (%) (n=50)	Ratuwamai ward No. 8 (%) (n=50)
loamy	34	34
sandy loam	60	56
clayey loam	6	10
Total	100	100

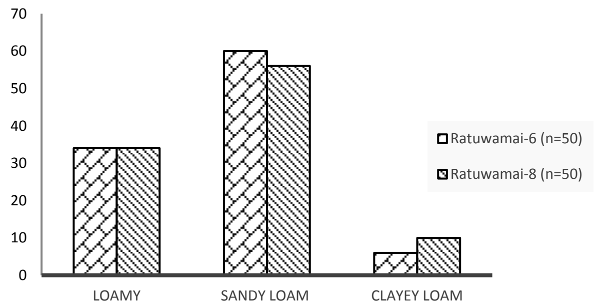

Figure 9: Bar graph showing status of soil texture at study areas in rice zone Morang

4.1.7 Overall fertility status of soil

In Ratuwamai municipality ward number 6, 54% of samples were found to be low, 35% as medium and 11% as high in all six soil fertility parameters whereasin Ratuwamai municipality ward number 8, 48% of samples were found as low, 34% as medium and 18% as high in all soil fertility parameters.

Soil fertility refers to the ability of soil to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality(Bear, F. E., 1964). The above explained six soil parameters were estimated and based on mode value; overall fertility status rating.

From the result obtained, it is clearly revealed that majority of samples of all location of command areas of rice zone, Morang were found to be low content.

Table 18: Overall fertility status of the study area in rice zone Morang

Municipality / Overall Fertility Rating	Ratuwamai ward No. 6 (%) (n=50)	Ratuwamai ward No. 8 (%) (n=50)
Low	54	48
Medium	35	34
High	11	18
Total	100	100

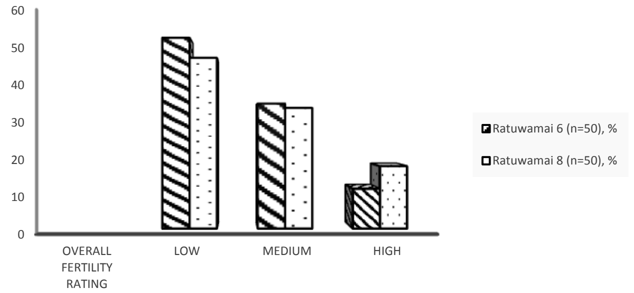

Figure 10: Bar graph showing overall fertility status of the study areas

4.2 Optimum nutrient requirement and nutrient status in rice fields

The data obtained from the field analysis may not be in accordance with the requirement of rice cultivation as the assessment of soil physio-chemical parameters of the study area only helps to characterize the soil. So, comparing the assessed soil nutrient with the optimum requirement nutrient for rice cultivation will help to determine which nutrient factor is most limiting factor for the production of qualitative and quantitative rice production. The data obtained is highly dependent on the field condition and the amount of nutrient being added before the crop removal.

4.2.1 Available soil nitrogen status

Comparing the optimum soil nitrogen requirement for rice cultivation with assessed total soil nitrogen status of the study area, it was revealed that 86% and 84% of the soil sampling locations Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8 were found to be limiting. This clears that ward number 8 was found to be somewhat better in nitrogen level in soil as required by rice than ward number 6.In plants, much of nitrogen is used in chlorophyll molecules, which are essential for photosynthesis and further growth, when nitrogen is in limiting amount, it will limit the plant growth (Chaudahary, 2015). The production and productivity of the rice crop is highly dependent on the amount of nitrogen present and being added upon requirement(Tisdale, Nelson, Beaton, & Halvin, 1993).

Table 19: Available soil nitrogen status as per the requirement of rice in the study areas

Variable Municipality	Rating	Range (%)	Ratuwamai ward no. 6 (%) (n=50)	Ratuwamai ward no. 8 (%) (n=50)
Available soil Nitrogen	Limiting Optimum	<0.2 >0.2	78 22	84 16
Total			100	100

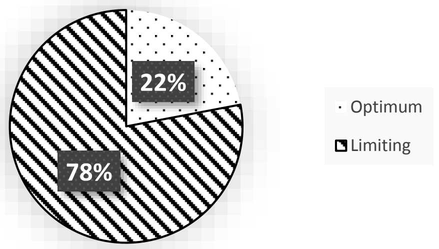

Figure 11: Pie-chart showing status of available nitrogen as per requirement of rice in Ratuwamai Municipality ward number 6

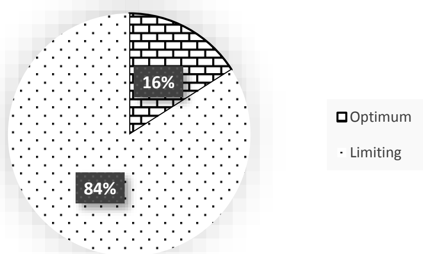

Figure 12: Pie-chart showing status of available nitrogen as per requirement of rice in Ratuwamai Municipality ward number 8

4.2.1 Available soil phosphorus status

Comparing the optimum soil phosphorus requirement for rice cultivation with assessed total soil phosphorus status of the study area, it was revealed that 78% and 64% of the soil sampling locations in Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8 respectively were found to be limiting. Ward Number 8 is found to be slightly better phosphorus level in soil as required by rice over ward number 6.

At optimum plant nutrition, the rice crop (straw plus grain) takes up around 6.4 kg P_2O_5 (2.8 kg P) per ton of grain yield (4.4 kgP_2O_5 in grain and 2.0 kg P_2O_5in straw)(Ahmed, Zaidi, Khan, & Oves, 2011).Thelong-term (14-year) application of P fertilizer is essential to maintain soil P availability and higher rice grain yield under nitrogen (N) supply in a soil(Lan, Lin, Wang, Zhang, & Chen, 2012).Continuous application of chemical fertilizer (N, P, and K) increased soil inorganic and organic P significantly(Doberman, Sheehy, Cassaman, & Mamaril, 1998), but the application of the chemical fertilizer together with compost accelerated the decrease in the soil organic P fraction, due to enhanced microbial activity(Lan, Lin, Wang, Zhang, & Chen, 2012).

Table 20: Status of available soil phosphorus as per the requirement of rice in the study area.

Variable Municipality	Rating	Range (ppm)	Ratuwamai ward no. 6 (%) (n=50)	Ratuwamai ward no. 8 (%) (n=50)
Available soil phosphorus	Limiting Optimum	<10 >10	78 22	64 36
Total	100	100		

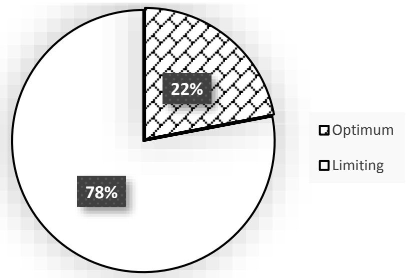

Figure 13: Pie-chart showing status of available soil phosphorus as per the requirement of rice in Ratuwamai Municipality ward number 6

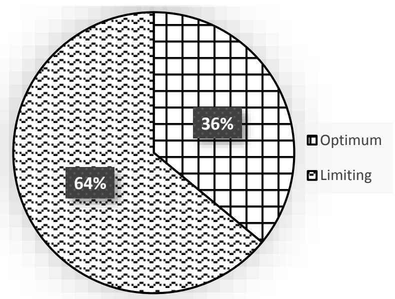

Figure 14: Pie-chart showing status of available soil phosphorus as per the rice requirement in Ratuwamai Municipality ward number 8

4.2.3 Available potassium status

Comparing the optimum soil potassium requirement for rice cultivation with assessed total soil potassium status of the study area, it was revealed that 86% and 90% of the soil sampling locations in Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8 respectively were found to be limiting. However, Ward number 6 was found to be slightly better potassium level in soil over Ward number 8 as per requirement of rice.

In rice plants, K participates in many enzymatic and physiological processes; notably in the opening and closing of stomata(Gebreslassie , 2016). Generally, potassium is usually taken up earlier than nitrogen and phosphorus by plants and uptake increase faster than dry matter production(Gebreslassie , 2016). This means that potassium accumulates early in the growing period and then is translocated to other plant parts

(Gebreslassie , 2016). So, it becomes most important to improvethe status of soil potassium for proper growth of rice plant.

Table 21: Status of available soil potassium as per requirement of rice in the study area.

Variable Municipality	Rating	Range (ppm)	Ratuwamai ward no. 6 (%) (n=50)	Ratuwamai ward no. 8 (%) (n=50)
Available soil potassium	Limiting Optimum	<188 >188	86 14	90 10
Total			100	100

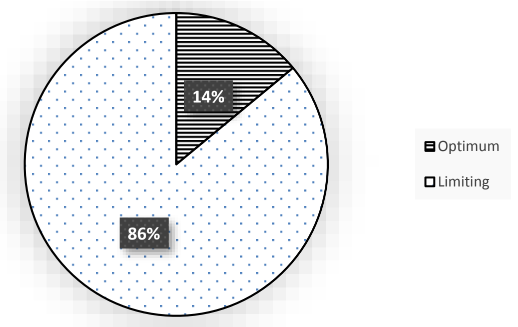

Figure 15: Pie-chart showing status of available soil potassium as per requirement of rice in Ratuwamai Municipality ward number 6

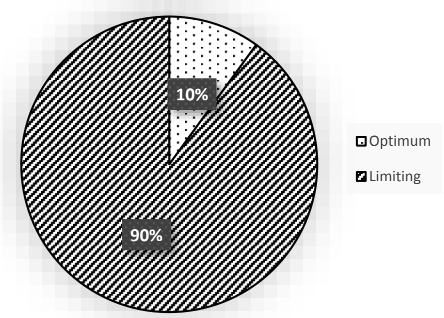

Figure 16: Pie-chart showing status of available soil potassium as per requirement of rice in Ratuwamai Municipality ward number 8

4.2.4 Available soil organic matter

By comparison of assessed soil organic matter status of the study areas with the available soil organic matter as per requirement of rice, it was revealed that 60% and 46% of the sampling locations in Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8 respectively were found to be limiting. Ward number 8 with 54% of samples was found to be measuring optimum level slightly better than of other 3 ward number 6.

Manures and other organic sources are used to improve soil fertility and soil organic matter content and to provide micronutrients and other growth factors not normally supplied by inorganic fertilizers(Havlin, Beaton , Tisdale, & Nelson, 2010). Application of these materials may also enhance microbial growth and nutrient turnover` in soil(Noppol , Nathsuda, & Ryusuke, 2017). SOM is the key to soil fertility and productivity not only for rice cultivation but for other overall improvement in physical, chemical and biological conditions of soil(FAO, 2014). It helps to make good soil health and provides its sustainable use for agriculture and rice production (Prajapati, 2018).

Table 22: Status of the Soil Organic Matter (SOM) as per requirement of rice in the study area

Variable Municipality	Rating	Range (%)	Ratuwamai ward no. 6 (%) (n=80)	Ratuwamai ward no. 8 (%) (n=60)
Available soil organic matter	Limiting Optimum	<2.0;>3.5 2.0-3.5	60 40	46 54
Total		100		100

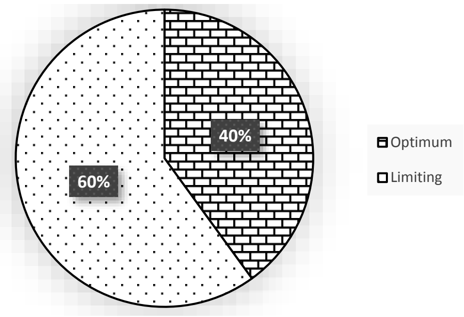

Figure 17: Pie-chart showing status of SOM as per requirement of rice in Ratuwamai Municipality ward number 6

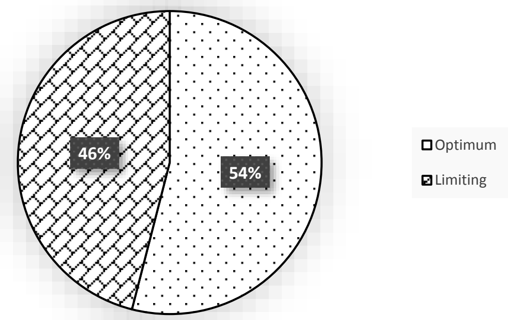

Figure 18: Pie-chart showing status of SOM as per requirement of rice in Ratuwamai Municipality ward number 8

4.2.5 Soil reaction (pH) status

Considering optimum range of soil pH requirement of rice cultivation, it was revealed that 40% and 44% of the soil sampling locations in Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8 respectively were found to be limiting whereas in ward number 6, majority (60%) of samples were found to be optimum in pH level as per requirement for rice production which states potential area for greater amount of rice production.

As pH increases at a higher rate in the soil, the availability of other nutrients to the crop is reduced to greater extent i.e. hampers soil fertility and hence the production(Anderson, Nilsson, & Saetre, 2000). It was found that application of nitrogenous chemical fertilizers like urea, DAP etc. was high because of which acidity of soil was hampered(Foth, 1990).

Table 23: Status of the soil pH as per requirement of rice in the study area

Variable Municipality	Rating	Range (pH)	Ratuwamai ward no. 6 (%) (n=50)	Ratuwamai ward no. 8 (%) (n=60)
Soil pH	Limiting Optimum	<5.0;>6.5 5.0-6.5	40 60	44 56
Total			100	100

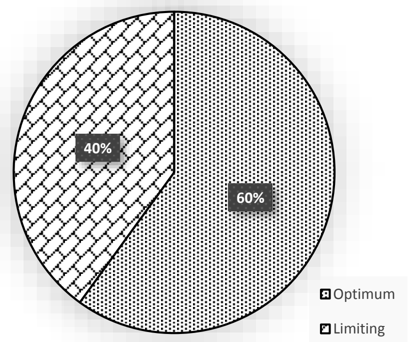

Figure 19: Pie-chart showing status of soil pH as per requirement of rice in Ratuwamai Municipality ward number 6

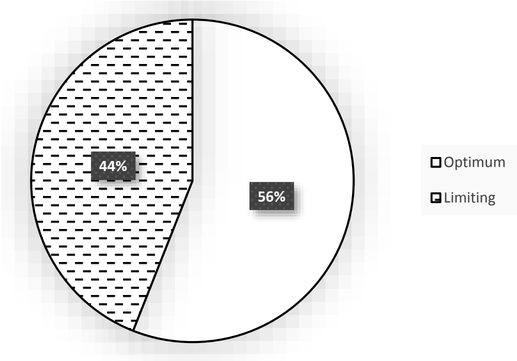

Figure 20: Pie-chart showing status of soil pH as per requirement of rice in Ratuwamai Municipality ward number 8

4.3 Nutrient index value of study areas

4.3.1 NIV of Ratuwamai Municipality ward number 6 (n=50)

From calculation of nutrient index value (NIV) of measured soil parameters, it was revealed that OM and phosphorus status with value 1.32 and 1.58 respectively found to be low in content while nitrogen and potassium status with value 1.74 and 1.82 respectively found to be medium.

The mode value of nutrient index status of measured soil physio-chemical properties of Ratuwamai Municipality ward number 6, nutrient status was found to be low in overall soil fertility status.

Table 24: NIV summary of Ratuwamai Municipality ward number 6

Parameters	Low (%)	Medium (%)	High (%)	NIV	Remarks
OM (%) Nitrogen (%) Phosphorus (kg/ha) Potassium (kg/ha)	68 40 52 36	32 46 38 46	0 14 10 18	1.32 1.74 1.58 1.82	Low Medium Low Medium

4.3.2 NIV of Ratuwamai Municipality ward number 8 (n=50)

From calculation of nutrient index value of measured soil parameters, it was revealed that SOM status with NIV 1.24 was found to be low, nitrogen and phosphorus status with NIV 1.68 and 1.76 respectively were found to be medium, while potassium status with NIV 2.32 was found to be high.

The mode value of nutrient index status of measured soil physio-chemical properties of Ratuwamai Municipality ward number 8, nutrient status was found to be medium in overall soil fertility status.

Table 25: NIV Summary of Ratuwamai Municipality ward number 8

Parameters	Low (%)	Medium (%)	High (%)	NIV	Remarks
OM (%) Nitrogen (%) Phosphorus (kg/ha) Potassium (kg/ha)	76 48 46 10	24 36 32 48	0 16 22 42	1.35 1.68 1.60 1.93	Low Medium Medium High

5. Conclusions

Nitrogen content was found medium in both the locations of Ratuwamai Municipality ward number 6 and Ratuwamai Municipality ward number 8. Phosphorus content was found low in Ratuwamai Municipality ward number 6 whereas medium in Ratuwamai Municipality ward number 8. Potassium was high in Ratuwamai Municipality ward number 8 whereas medium in Ratuwamai Municipality ward number 6. SOM was low in all locations due to no application of organic fertilizer in the study areas. Majority of soil sample taken from both the wards were of acidic nature. However, 30% of the samples of Ratuwamai Municipality ward number 8 was found to be neutral in nature and both wards shown of equal contribution of alkaline soil samples. It is probably due to higher application of Urea & DAP, majority of samples shown acidic nature. Majority of soil sample was sandy loam texture in all locations except Ratuwamai Municipality ward number 8 where 10% of soil sample found as clayey loam textured. Both wards show equal behavior of loamy soil. In overall scenario, majority of soil samples in all study sites were of low fertility status.

Nitrogen and Potassium was found as most limiting nutrient as per the rice cultivation requirement. The pH was found most suitable (optimum) soil parameter in all locations as per rice cultivation requirement. Soil Organic Matter (SOM) was found deficient in great extent in majority of samples of all locations.

The prepared soil data base is very useful for fertilizer recommendations for different crops to economize their production. The crops may suffer from the deficiency and toxicity stress of the particular determined such nutrients during cultivation. The proper nutrient management should be adopted especially for these nutrients during cultivation. Similarly, soil fertility variation is very high in the majority of nutrients due to various intrinsic and extrinsic factors. Keeping one season fallow before starting any experiment is advisable for reducing error in the experimentation due to soil fertility variation.

References

ABPSD. 2015. Statistical Information on Nepalese Agriculture. Kathmandu, Nepal: Ministry of Agriculture and Cooperatives.

Ahmed, M., Zaidi, A., Khan, M., Oves, M. 2011. Biological Importance of Phosphorus and Phosphate Solubilizing Microbes. Nova Science Publishers, pp. 50-62.

AICC. 2016. Krishi Diary. Hariharbhawan, Lalitpur: Agriculture Information and Communication Centre.

Anderson, S., Nilsson, S. I., Saetre, P. 2000. Leaching of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in more humus as affected by temperature and pH. In Soil Biology and Biochemistry, Vol. 32, pp. 1-10.

Bear, F. 1965. Soil in relation to crop growth. London: Reinhold Publishing Corporation.

Bear, F. E. 1964. Chemistry of the soil, Second Edition. New Dehli: Oxford and IHB Publishing Corporation.

Bhandari, D. R., Bhattarai, D., & Bista, D. R. 2017. Status of Chemical Fertilizer Use for Rice in Nepal. In Rice Science and Tecnology in Nepal (pp. 384-393). Hariharbhawan, Lalitpur: Crop Development Directorate.

Brady, N., Weil, R. 2000. The Nature and Properties of Soils, Thirteenth edition. New Jersey: Prentice Hall, Incorporation.

Brady, N., Weil, R. 2005. The Nature and Property of Soil. New Jersey: Prentice-hall, inc.

Bremmer, J., Mulvaney, C. 1982. Nitrogen Total Methods of Analysis. In A.L., Chemical and Microbiological Properties, pp. 595-624. Madison.

Burrough, P. A., McDonnell, R. A. 1998. Principle of geographic information systems.

Cambardella, C. A., & Karlen, D. L. 1999. Spatial analysis of soil fertility parameters. Precision Agriculture, vol. 1, no. 1, pp. 5-14.

CDD. 2015. Rice varietal mappind in Nepal; implication for development and adoption. Hariharbhawan, Lalitpur: New Era Offset Press.

Chaudahary, B. P. 2015. Nitrogen Nutrition in Rice. Indian Journal of Plant Science, pp. 28-37.

DADO. 2073. Yearly Agricultural Development Program and Statistical Book. Lahan: Janak Offset Printers.

Dalal, R. C., Subba Raao, A. 2006. Fertility Evaluation Systems. In Encyclopedia of Soil Science (Second Edition ed.). FL., USA: CRC Press, Boca Raton.

Dass, A., Chandra, S., Uphoff, N., Choudhary, A. K., Bhattacharyya, R., Rana, K. S. 2017. Agronomic fortification of rice grains with secondary and micronutrients under differing crop management and soil moisture regimes in the north Indian Plains. Paddy and Water Environment, pp. 745-760.

Davies, D., Eagle, D., Finney, J. 1993. Soil Management. United Kingdom: Farming Press.

Deshmukh, K. K. 2012. Studies on chemical characteristics and classifications of soils from Sangammer areas, Ahmadnagar District, Maharastra. Rasayan Journal of Chemistry, vol. 1, no. 5, pp. 74-85.

Doberman, A., Sheehy, J., Cassaman, K., Mamaril, C. 1998. Management of Phosphorus, Potassium and Sulphur Intensive Irrigated Lowland Rice. Field Crop Research, pp. 113-118.

FAO. 2008. Guide to Laboratory Establishment for plant nutrient analysis. Rome: Food and Agriculture Organization.

FAO. (2014). The Importance of Soil Organic Matter. Food and Agriuculture Science, pp. 417-422.

Flores-Magdaleno, H., Mancilla-Villa, O. R., Mejia-Saenz, E., Olmedo-Bolantilde, M. C., Bautista-Olivas, A. L. 2011. Heavy metals in agricultural soils and Irrigation wastewater of Mixquiahuala, Hidalgo, Mexico. African Journal of Agricultural Research, vol. 6, no. 24, pp. 5505-5511.

Foth, H. 1990. Fundamentals of soil science, Eighth edition. New york: John Wiley and sons, Incorporation.

Gebreslassie, H. B. 2016. Effect of Potasium Fertilizer on Crop Production. Journal of Natural Science Research, pp. 6-7.

Haifa. 2016. Retrieved from www.haifa-group.com.

Harden, C. 2001. Soil erosion and sustainable mountain development: experiments, observations and recommen- dations from the Ecuadorian Andes. Mountain Resource Development, vol. 21, pp. 77-78.

Hasanuzzaman. 2018. Potassium: A Vital Regulator of Plant Responses and. Journal of Agronomy.

Havlin, H. L., Beaton, J. D., Tisdale, S. L., Nelson, W. L. 2010. Soil fertility and fertilizers - An introduction to nutrient management. New Delhi, India: PHI Learning Private Limited.

Johnson, G., Raun, W., Hattey, J. 2000. Oklahoma Soil Fertility Handbook, Fifth Edition. Department of Plant and Soil sciences Oklahoma agricultural Experiment Station Oklahoma Cooperative Extension Service.

Johnston, A. E. 1986. Soil organic matter, effects on soils and crops.

Jones, J. B. 2001. Laboratory Guide for Conducting Soil Tests and Plant Analysis. CRS press, Taylor and Fransic Group, LCC.

Joshy, D., Deo, G. P. 1976. Fertilizers Recommendations for Major crops of Nepal.

Khadka, D., Lamichhane, S., Bhurer, K. P., Chaudhary, J. N., Ali, M. F., Lakhe, L. 2018. Soil Fertility Assessment and Mapping of Regional Agricultural Research Station Parwanipur, Bara, Nepal. Journal of Nepal Agricultural Research Council, Vol. 4, pp. 33-47.

Khadka, D., Lamichhane, S., Tiwari, D. N., Mishra, K. 2017. Assessment of Soil Fertility Status of National Rice Research Program, Hardinath, Dhanusha, Nepal. International Journal of Agriculture and Environment Science, vol. 3, no. 1, pp. 86-105.

Khadka, Y. G. 2017. Management of Organic and Inorganic Fertilizer for Rice Production in Nepal. Hariharbhawan, Lalitpur: Crop Development Directorate.

Khadka, Yajna Gajadhar. 2017. Management of Organic and Inorganic Fertilizer for Rice Production in Nepal. In M. N. Paudel, D. R. Bhandari, M. P. Khanal, B. K. Joshi, P. Acharya, & K. H. Ghimire, Rice Science and Technology in Nepal (pp. 351-357). Hariharbhawan, Lalitpur: Crop Development Directorate.

Khadka, Yajna Gajadhar. 2017. Management of Organic and Inorganic Fertilizer for Rice Production in Nepal. Khumaltar, Lalitpur: Crop Development Directorate.

Khaki, B. D., Honarjoo, N., Davatgar, N., Jalalian, A., & Golsefidi, H. T. 2017. Assessment of Two Soil Fertility Indexes to Evaluate Paddy Fields for Rice Cultivation. Sustainability.

Kharal, S. 2017. Evaluation of Soil Fertility in Different Land Use Systems of Dhading, Nepal. Rampur, Chitwan.

Kumar, K. S., Sidharam, P., Srinivasamurthy, C.A. 2013. Soil fertility status and nutrient index for primary nutrients in Western Ghats and Coastal Karnataka under different agro-ecological systems. Asian Journal of Soil Science, vol. 12, no. 2, pp. 314-319.

Lan, Z., Lin, X., Wang, F., Zhang, H., Chen, C. 2012. Phosphorus Availability and Rce Grain Yield in a Paddy Soil. Bio Fertil Soils, vol. 49, pp. 579-588.

Leghari, S. J., Wahocho, N. A., Laghari, G. M., Laghari, A. H. 2016. Role of Nitrogen for Plant Growth and Development: A review. Advances in Environmental Biology, pp. 209-218.

Lui, G., Li, Y., & Gazula, A. 2016. Conversion of Parts per Million on Soil Test Reports to Pounds per Acre. Florida: IFAS extensions, University of Florida.

Magar, S. S. 2015. Assessment of Soil Fertility Status under differernt Cropping Systems and Fertility Distribution of Gunjanagar VDC, Chitwan, Nepal Using Geographical Information System. Rampur.

MoAC, FAO. 2011. Disaster Risk Management Plan.

MoAD. 2015. Rice Varietal Mapping in Nepal: Implecation for Development and Adoption. Hariharbhawan, Lalitpur: Crop Development Directorate.

MOAD. 2016. Statistical Information on Nepalese Agriculture. Kathmandu: MOAD.

MoALD. 2075. Krishi Diary. Kathmandu: Ministry of Agriculture and Livestock Development.

MOF. 2074/75. Trend of Rice Production, Ministry of Finance. Kathmandu: Government of Nepal.

Morang, R. Z. 2018. Baseline Survey Report on Rice Zone. Bargachhi, Morang, Nepal: PMAMP, Rice Zone, Morrnag.

Morang, R. Z. 2018. Baseline Survey Report on Rice Zone. Bargachhi, Morang, Nepal: PMAMP, Rice-Zone, Morang.

Morgan, T. 2017. Nutrition of Florida Citrus Trees, 2nd Edition. USA: IFAS extension.

Motsara, M. R., Roy, R. N. 2008. Guide to laboratory establishment for plant nutrient analysis. In Fao Fertilizer and Plant Nutrition Bulletin 19.

Mowo, J. G., Janssen, B. H., Oenema, O., German, L. A., Mrema, J. P., Shemdoe, R. S. 2006. Soil fertility evaluation and management by smallholder farmer communities in northern Tanzania. Agriculture, Ecosystems and Environment, 116(1–2), 47–59. https://doi.org/10.1016/j.agee.2006.03.021

Neina, D. 2019. The Role of Soil pH in Plant Nutrition and Soil Remediation. Hindawi Applied and Environmental Soil Science.

Noppol, A., Nathsuda, P., Ryusuke, H. 2017. Practices sustaining soil organic matter and rice yield in a tropical monsoon region. Soil Science and Plant Nutrition, pp. 274-287.

Olsen, S. R., Cole, C. V., Watanabe, F. S., Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate.

Parkers, F., Nelson, W., Winter, E., Miles, Z. 1957. The Broad Interpretation and Application of Soil Test Summaries. Agronomy Journal, vol. 43, no. 3, pp. 103-112.

Pathak, H. 2010. Trend of fertility status of Indian soils. Current advances in Agricultural Sciences, vol. 2, no. 1.

Peters, J., Nathan, M., Laboski, C. 2012. pH & Lime Requirement. Recommended Chemical Soil Test Procedures for The North Central Region. North Central Region Publications.

Pokhrel, T. (2002). Rice Development Program in Nepal. FAO.

Prajapati, M. 2018. Comparative Study on Soil Fertility Status of Sweet Orange Orchards of Three VDCs (Tinkanya, Jalkanya and Ratanchura). Rampur: Agriculture and Forestry University.

Rai, S., Chopra, A. K., Chakresh, P., Dinesh, K., Renu, S., Gupta, P. M. 2012. Comparative study of some physiological parameters of soil irrigated with sewage water and canal water of Dehradun city. Archives of Applied Science Research vol. 3, no. 3, pp. 318-325.

Rakesh, K., Rakesh, K. S., Brijesh, Y. 2012. Vertical distribution of physio-chemical properties under different topo-sequence in soils of Jharkhand, India. Journal of Agricultural Physics vol. 3, no. 2, pp. 28-34.

Ramamoorthy, B., Bajaj, J. C. 1969. Available nitrogen, phosphorus and potassium status of Indian soils. Fertilizer News, pp. 14.

Rawal, N., Bhandari, N., Chalise, D., Khadka, D. 2015. Assessment of Soil Fertility Management Practices of Wheat in Western Terai of Nepal. Journal of Institute of Agriculture and Animal Science, pp. 33-34: 105-114.

Roy, R., Flinck, A., Blair, G. 2006. Plant Nutrition for Food security. Rome.

Shetty, V., Y., Nagamma, M. S., M., D. K., M., J. S. 2008. Fertility status in arecanut garden soils of karnataka. Karnataka Journal of Agricultural Science, vol. 21, no. 4.

Singh, B., Ryan, J. 2015. Managing Fertilizers to Enhance Soil Health. International Fertilizer Industry Association (IFA), Paris, France, pp. 23.

Singh, S. K., Singh, S. S., Pandey, V. D., Mishra, A. K. 2006. Factors modulating alkaline phosphatase activity in the diazotrophic rice-field cyanobacterium, Anabaena oryzae. World Journal of Microbiology and Biotechnology.

STSS. 2000. Soil Fertility Survey and Mapping of Mahottari District. Hariharbhawan, Lalitpur: HMG/MOAC, Department of Agriculture, Soil Testing and Service Section.

Sumithra, S., Ankalaiah, C., Rao, D., Yamuna, R. T. 2013. A case study on physio-chemical characteristics of soil around industrial and agricultural area of yerraguntla, Kadapa District, A. P. India. International Journal of Geological Earth and Environment Science, vol. 3, no. 2, pp. 28-34.

Takahashi, H., Kopriva, S., Giordano, M., Saito, K., Hell, R. 2011. Sulfur assimilation in photosynthetic organisms: molecular functions and regulations of transporters and assimilatory enzymes. Annual Review of Plant Biology, vol. 62, pp. 157-184.

Thakur, R., Baghel, S., Sharma, G., Sahu, P., Amule. 2012. Training Program on Advances in Agro-technologies for Improving Soil, Plant adn Atmosphere Systems, Laboratory Manual. Jabalpur 482 004 (M.P.): Deparment of Soil Science & Agicultural Chemistry, Jawarlala Nehru Krishi Vishwa Vidyalaya.

Thapa, M. 2010. Factors affecting Fertilizer use Efficiency in Dry Season Paddy Production in Makwanpur district, Mid-hill, Nepal. Agronomy Journal of Nepal, Vol. 1.

Tilman, D., Cassaman, K. G., Matson, K. A. 2002. Agricultural Sustainability and Intensive Production Practice.

Tisdale, S., Nelson, W., Beaton, J., Halvin, J. 1993. Soil Fertility and Fertilizers, Fifth edition. New York: MacMillan Publishing Company.

Trohel, F., Thompson, L. 1993. Soils and soil fertility, Fifth Edition. New York: Oxford University Press.

Uriyo, A., Mongi, H., Chowdhury, M., Singh, B., Semoka, J. 1979. Introductory Soil Science. Dar es Salaam: Tanzania Publishing House.

Vishal, D. J., Narahari, N. P., Punit, R. R. 2009. Physio-chemical properties of four farm site soils inarea surrounding Rajkot, Gujrat, India. International Journal of Chemical Technical Research, vol. 1, no. 3, pp. 709-713.

Watanabe, F., Oslen, S. 1965. Test of an Ascorbic Acid Method for Determining Phosphorus in Water and NaHCO3 Extracts from Soil. Soil Science Society of America Journal.

Witt, C., Dobermann, A. 2002. A Site-Specific Nutrient Management Approach for Irrigated, Lowland Rice in Asia. Better Crops International, vol. 16, no. 1, pp. 20–24.

Yadav, M. 2017. Provinance 2 of Nepal. Research Gate.

Yadav, R. 2013. A Textbook on Tropical and sub-tropical soil. Kathmandu: Western Book Publishing and Printers.