STRENGTHENING AGRO-ECOSYSTEMS RESILIENCE FOR CLIMATE CHANGE ADAPTATION TO IMPROVE FOOD AND NUTRITION SECURITY (TCP/NEP/3701)

Soil report on the nutrient balance, organic matter and soil carbon

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INTRODUCTION

Soils are integrated components of ecosystem (croplands, pasturelands, woodlands etc.) as a precious assets of nature for all life on earth. Soil is a base to prosperous agriculture but deteriorated due to many reasons: land clearing, deforestation, over grazing, surface mining, industrial wastes, and careless management. Further, climate has a significant effect on crop growth, production and productivity, quality and economic returns. Soil is constantly changing and always responding to changes in the environmental factors, along with the influences of man and land use.

The biggest challenge for agriculture over the coming decades will be to meet the world's increasing demand for food in a sustainable manner. Therefore, good land management decision is needed for sustainable and resilient agriculture systems. In fact, agriculture has been considered as the backbone of the national economy, food security of the country and livelihood of farm families. It implies all activities which need to be undertaken for crop production, like land preparation, soil fertility, crop varieties, sowing, inter-culture practices, bio-rational pest management and harvesting of crops with least disruption to the environment. It is necessary to produce crops maintaining soil fertility with balanced fertilization, ensuring healthy agro-ecosystem with biological diversity and conservation of all organisms for getting good ecosystem services from generation to generation. For all these, the basic requirement is soil sampling analysis and application of the results for maintaining sound agro-ecosystem and bio-diversity. In this line, FAO had declared the year 2015 as the "International Soil Year" and 5th December as World Soil Day with an aim to raise awareness about the importance of healthy soil and their sustainable management for protection for this precious natural resource.

OBJECTIVES

- To study the farmers knowledge on the importance of balanced use of nutrients for crop production.
- To determine the status of soil and calculate index of nutrient availability of farmers' fields.
- To predict the probability of profitable response to fertilizer.
- To recommend fertilizer needs of crops to maintain soil fertility and sustain food productivity.
- To maintain judicious use of input, i.e. reducing unnecessary costs and help in soil fertility management.
- To share technology generated for nutrient use efficiency and promote environment quality.

METHODOLOGY

Soil fertility is an important ecosystem services for cultivation of any type of crop. Crop yield is largely dependent on the soil in which the crop grows. So, before cultivation, it is very important to check the soil for its nutrients. Therefore, semi-structured questionnaire was prepared, shared with FAO office for suggestion and improvement, and face to face interview was administered among randomly selected farmers in Dang, Gulmi and Marpha including farmers as follows.

Dang	Gulmi	Marpha
1. Ragauja (N=23)	1. Balkot (N=21)	1. Gharapjing (N=6)

2. Sunepani (N=20) 3. Santinagar (N=25)	2. Lumcha (N=17) 3. Pipaldhara (N=16)	2. Marpha (N=6) 3. Pangling (N=10)
Total: 68	Total: 54	Total: 22

Similarly, soil sampling is the vital step for analysis, which were collected following soil testing standards from farmers' fields as representatives of the selected areas. It was done when there was no crop in the field, before growing of the next crop and prior application of manures and fertilizers. For this, surface litter was scraped away without disturbing soil, V-shaped cut up to 15 cm depth, and soil slices collected in plastic bucket moving in a zig-zag manner from each sampling unit in the Dang districts. In Gulmi and Mustang, the soil samples were taken from the Citrus and Apple field before the manuring on the crops. The soil samples were taken from the three depths i.e 0-15 cm, 15-30 cm and 30-60 cm depths. Ten soil samples were collected from homogenous sampling units, mixed them thoroughly, which were divided into four units and two opposite units were selected each time so that the final composite sample of half kg (one sampling unit) was selected. Thus collected samples kept in cloth bags, well labeled, brought in Soil Testing Laboratory in Pokhara, Kaski. Soil analysis was done for major primary nutrients N, P, K, including soil pH and organic matter.

RESULTS

Farmers' survey

Farmer's perception on the soil fertility status of the soil

Farmers were interviewed from the three project districts i.e Dang (120), Gulmi (120) and Mustang (60) to know their perception on the soil fertility status of soil. In total 54.9% of the farmers perceived that the soil in the field was fertile followed by the somewhat fertile (32.8%), highly fertile (9.6%) and least (2.7%) perceived as not fertile. There results from the districts was contrasting showing that the majority of the farmers from the Dang districts perceived the soil are somewhat fertile whereas in the Gulmi and Mustang districts majority of farmers perceived as fertile shown in Table 2.

Table 2. Farmers perception on the soil fertility status of the soil in the project districts

S.N	Soil fertility status	Dang	Gulmi	Mustang	Total	P value
1.	Fertile	38 (31.9%)	77 (67.5%)	46 (76.7%)	161 (54.9%)	< 0.001
2.	Highly fertile	0 (0.0%)	28 (24.6%)	0 (0.0%)	28 (9.6%)	
3.	Not fertile	6 (5.0%)	2 (1.8%)	0 (0.0%)	8 (2.7%)	
4.	Somewhat fertile	75 (63.0%)	7 (6.1%)	14 (23.3%)	96 (32.8%)	

Agricultural Cropping practices

We found that the around 68% of the farmers followed the both cropping practices i.e. mono-cropping and mixed cropping. In the case of the Gulmi and Mustang districts very few number of the farmers follows the sole mono-cropping practices. This shows that the farming practices followed by the farmers in the research areas shows the potentiality to increase the crop diversification which helps to conserve the ecosystem services.

Table 3. Cropping practices followed by the farmers in the project districts

S.N	Cropping practices	Dang	Gulmi	Mustang	Total	P value
1.	Mono cropping	26 (21.8%)	0 (0.0%)	3 (5.0%)	29 (9.9%)	< 0.001
2.	Mixed cropping	13 (11.0%)	29 (25.4%)	21 (35.0%)	63 (21.5%)	
3.	Both	80 (67.2%)	84 (73.7%)	34 (56.7%)	198 (67.6%)	

Nutrients management:

The results shows that the overall the more than 90% of the farmers use the compost for the nutrients management in all three districts. The use of the chemical fertilizers also contribute more than 50% in the nutrients management practices. The use of the green manure and cover crops for the nutrients management was not found in practices by the farmers in the study areas but the farmers in the mustang used cover crops as a practices. We concluded that the agricultural practices could be changed incorporating the different nutrients management practices for the nutrients management in the study districts.

Table 4. Nutrient management practices adopted by the farmers in the project districts

S.N	Nutrients management	Dang	Gulmi	Mustang	Total	P value
1.	**Compost**					
	Yes	117 (98.3%)	99 (86.8%)	54 (90.0%)	270 (92.2%)	< 0.001
	No	2 (1.7%)	15 (13.2%)	6 (10.0%)	23 (7.8%)	
2.	Ch**emical fertilizers**					
	Yes	79 (66.4%)	66 (57.9%)	30 (50.0%)	175 (59.7%)	< 0.001
	No	40 (33.6%)	48 (42.1%)	30 (50.0%)	118 (40.3%)	
3.	**Green manure**					
	Yes	2 (1.7%)	0 (0.0%)	3 (5.0%)	5 (1.7%)	0.053
	No	117 (98.3%)	114 (100.0%)	57 (95.0%)	288 (98.3%)	
4.	**Cover crops**					
	Yes	1 (0.8%)	0 (0.0%)	19 (31.7%)	20 (6.8%)	< 0.001
	No	118 (99.2%)	114 (100.0%)	41 (68.3%)	273 (93.2%)	
5.	**Mulching**					
	Yes	109 (91.6%)	114 (100.0%)	58 (96.7%)	281 (95.9%)	0.005
	No	10 (8.4%)	0 (0.0%)	2 (3.3%)	12 (4.1%)	
6.	**Conservation tillage**					
	Yes	0 (0.0%)	0 (0.0%)	44 (73.3%)	44 (15.0%)	< 0.001
	No	119 (100.0%)	114 (100.0%)	16 (26.7%)	249 (85.0%)	
7.	**Others practices**					
	Yes	10 (8.4%)	0 (0.0%)	1 (1.7%)	11 (3.8%)	0.002
	No	109 (91.6%)	114 (100.0%)	59 (98.3%)	282 (96.2%)	

Soil analysis

Crop production and its yield is a function of four major factors, i.e. yield = f (crop, soil, climate and management). Fertilizer recommendation therefore varies with crop cultivar, specific site of

cultivation, temperature variability and required necessary inputs of crop production). For this, soil testing and analysis are interpreted like low, to very high which is easily understood by the growers.

Soil pH

Hydrogen ions present in the soil decide pH value of the soil. It is a measure of the acidity or basicity in

soils, which affects the availability of plant nutrients. Soil pH status and values of soil sample analyses are presented in Tables 1a (Dang, $1b_{1\text{-}3}$ (Gulmi) and $1c_{1\text{-}3}$ (Marpha). which in general reflects that the samples were acidic in nature in Dang, moderately acidic to neutral in Gulmi and neutral to basic in Marpha. Table 2a (Dang, $2b_{1\text{-}3}$ (Gulmi) and $2c_{1\text{-}3}$ (Marpha) represents the statistical values (minimum, maximum, standard deviation and mean) of sampled sites.

Table 1a. Soil pH status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Soil pH	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Acidic	21	91.00	20	100.00	24	96
2	Neutral	2	9.00	0	0.00	1	4

Table $1b_1$. Soil pH status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	2	9.52	3	14.29	2	9.52
2	Neutral	19	90.48	18	85.71	19	90.48

Table $1b_2$. Soil pH status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	10	58.82	12	70.59	11	64.71
2	Acidic	1	5.88	0	0.00	1	5.88
3	Neutral	6	35.30	5	29.41	5	29.41

Table $1b_3$. Soil pH status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	5	31.25	4	25.00	6	37.50
2	Neutral	11	68.75	12	75.00	9	56.25
3	Basic	0	0.00	0	0.00	1	6.25

Table $1c_1$. Soil pH status of Gharapjing sampled sites, Marpha, 2020 (N=6)

SN	Soil pH	0-15 cm	15-30 cm	30-60 cm

		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Basic	6	100.00	6	100.00	6	100.00

Table 1c$_2$. Soil pH status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Basic	6	100.00	6	100.00	6	100.00

Table 1c$_3$. Soil pH status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Neutral	1	10.00	0	0.00	0	0.00
2	Basic	9	90.00	10	100.00	10	100.00

Table 2a. Soil pH values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	5.10	4.70	4.80
2	Maximum	6.50	6.30	6.50
3	Standard deviation	0.40	0.46	0.34
4	Average	5.94	5.83	5.47

Table 2b$_1$. Soil pH status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	6.40	6.40	6.40
2	Maximum	7.40	7.40	7.40
3	Standard deviation	0.29	0.32	0.32
4	Average	6.98	7.01	6.97

Table 2b$_2$. Soil pH status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	5.10	5.60	5.20
2	Maximum	7.40	7.50	7.50
3	Standard deviation	0.59	0.52	0.60
4	Average	6.41	6.41	6.26

Table 2b$_3$. Soil pH status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	6.30	6.40	6.20
2	Maximum	7.40	7.30	7.60
3	Standard deviation	0.38	0.29	0.38

4	Average	6.79	6.81	6.78

Table $2c_1$. Soil pH status of Gharapjing sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	8.20	8.30	8.20
2	Maximum	8.50	8.40	8.50
3	Standard deviation	0.10	0.05	0.1
4	Average	8.33	8.33	8.37

Table $2c_2$. Soil pH status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	8.20	7.90	7.90
2	Maximum	8.50	8.50	8.50
3	Standard deviation	0.13	0.22	0.22
4	Average	8.32	8.32	8.32

Table $2c_3$. Soil pH status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	7.50	8.00	7.60
2	Maximum	8.60	8.90	8.80
3	Standard deviation	0.37	0.26	0.36
4	Average	8.27	8.5	8.44

Soil OM and C

OM is a measure of use of FYM and OC as measure of organic matter available in the soil, and the C:N ratio (carbon present in the soil to the ration of nitrogen present in the soil) lying in favorable range >2% and <30% for bacteria growing properly within this limit. The analyses of soil samples of the sampled sites in three districts are presented in Table 3a (Dang), $3b_{1-3}$ (Gulmi) and $3c_{1-3}$ (Marpha). Findings showed that over 80% samples with medium level of OM in Dang, which was slightly better in majority of the surveyed farmers of Sunapani VDC than other two VDCs. It was very low to low in Gulmi, and low to very high in Marpha, respectively. Respective statistical values of three survey districts are given in Table 4a (Dang), $4b_{1-3}$ (Gulmi) and $4c_{1-3}$ (Marpha).

Table 3a. Soil OM status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	OM	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	8.70	0	0.00	4	16.00
2	Medium	21	91.30	19	95.00	20	80.00
3	High	0	0.00	1	5.00	1	4.00

Table $3b_1$. Soil OM status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent

1	Very Low	5	23.81	6	28.57	3	14.29
2	Low	16	76.19	15	71.43	18	85.71

Table 3b$_2$. Soil OM status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	10	58.82	9	52.94	10	58.82
2	Low	7	41.18	8	47.06	7	41.18

Table 3b$_3$. Soil OM status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	12.50	4	25.00	4	25.00
2	Low	14	87.50	12	75.00	12	75.00

Table 3c$_1$. Soil OM status of Gharapjomg sampled sites, Marpha, 2020 (N=6)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	High	2	33.33	2	33.33	1	16.67
2	Very High	4	66.67	4	66.67	5	83.33

Table 3c$_2$. Soil OM status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	0	0.00	3	50.00	3	50.00
2	High	5	83.33	3	50.00	3	50.00
3	Very High	1	16.67	0	0.00	0	0.00

Table 3c$_3$. Soil OM status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	3	30.00	0	0.00	0	0.00
2	Medium	1	10.00	2	20.00	2	20.00
3	High	4	40.00	4	40.00	6	60.00
4	Very High	2	20.00	4	40.00	2	20.00

Table 4a. Soil OM and C values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	2.33	1.35	2.54	1.47	1.42	0.82
2	Maximum	4.79	2.78	5.24	3.04	6.17	3.58

3	Standard deviation	0.70	0.41	0.63	0.37	1.15	0.67
4	Average	3.48	2.02	3.71	2.15	3.51	2.03

Table 4b$_1$. Soil OM and C values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.83	0.48	0.70	0.40	0.70	0.40
2	Maximum	2.15	1.25	1.89	1.10	2.09	1.21
3	Standard deviation	0.35	0.20	0.36	0.21	0.35	0.20
4	Average	1.25	0.73	1.25	0.73	1.33	0.77

Table 4b$_2$. Soil OM and C values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.56	0.33	0.50	0.29	0.70	0.40
2	Maximum	1.56	0.90	1.49	0.86	1.89	1.10
3	Standard deviation	0.26	0.15	0.32	0.19	0.37	0.21
4	Average	0.98	0.57	0.98	0.57	1.09	0.63

Table 4b$_3$. Soil OM and C values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.83	0.48	0.43	0.25	0.50	0.29
2	Maximum	1.76	1.02	2.49	1.44	1.69	0.98
3	Standard deviation	0.23	0.13	0.45	0.26	0.32	0.18
4	Average	1.21	0.70	1.20	0.69	1.17	0.68

Table 4c$_1$. Soil OM and C values of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	9.26	5.37	9.12	5.29	1.59	0.92
2	Maximum	14.47	8.39	14.90	8.64	11.29	6.55
3	Standard deviation	1.79	1.04	2.15	1.25	3.64	2.11
4	Average	11.08	6.43	11.34	6.57	8.97	5.20

Table 4c$_2$. Soil OM and C values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	5.64	3.27	3.04	1.76	3.18	1.84
2	Maximum	11.43	6.63	9.26	5.37	7.96	4.62
3	Standard deviation	2.10	1.22	2.30	1.34	2.01	1.16

4	Average	7.45	4.32	5.75	3.33	5.50	3.19

Table 4c$_3$. Soil OM and C values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	2.46	1.43	2.75	1.60	2.89	1.68
2	Maximum	15.92	9.23	24.60	14.27	14.61	8.47
3	Standard deviation	4.49	2.61	7.18	4.16	3.83	2.22
4	Average	6.90	4.00	10.81	6.27	7.44	4.31

To predict nutrient need of crops soil test is performed and calibrated against the response of crops, and thus interpretation and evaluation of the soil test values primarily form the basis for fertilizer recommendations especially major nutrients; like N, P, K.

Soil N

Nitrogen is an essential constituent of amino acids, nucleic acids, nucleotides and chlorophyll; and it promotes rapid plant growth. Both NH4+ and NO3- forms can be taken up and metabolized by plants. Soil sample analyses showing soil N status and N values of Dang, Gulmi and Marpha are presented in Table 5-6a (Dang), 5-6b$_{1-3}$ (Gulmi) and 5-6c$_{1-3}$ (Marpha). The findings of soil sample analysis indicates that the values range low-high in Dang, low-medium in Gulmi and low- high in Matpha sample sites.

Table 5a. Soil N status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	N	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	-	-	-	-	2	8.00
2	Medium	18	78.26	13	65.00	12	48.00
3	High	5	21.74	7	35.00	11	44.00

Table 5b$_1$. Soil N status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	20	95.24	21	100.00	21	100.00
2	Medium	1	4.76	0	0.00	0	0.00

Table 5b$_2$. Soil N status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	17	100.00	17	100.00	17	100.00

Table 5b$_3$. Soil N status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	N	0-15 cm	15-30 cm	30-60 cm

		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	16	100.00	15	93.75	16	100.00
2	Medium	-	00.00	1	6.25	-	00.00

Table 5c$_1$. Soil N status of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	0	0.00	0	0.00	1	6.25
2	High	6	100.00	6	100.00	5	93.75

Table 5c$_2$. Soil N status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	0	0.00	2	33.33	2	33.33
2	High	6	100.00	4	66.67	4	66.67

Table 5c$_3$. Soil N status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	4	40.00	2	20.00	2	20.00
2	High	6	60.00	8	80.00	8	80.00

Table 6a. Soil N values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	0.12	0.13	0.07
2	Maximum	0.24	0.26	0.31
3	Standard deviation	0.03	0.03	0.06
4	Average	0.17	0.18	0.18

Table 6b$_1$. Soil N values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.04	0.03	0.03
2	Maximum	0.11	0.09	0.10
3	Standard deviation	0.02	0.02	0.02
4	Average	0.06	0.06	0.07

Table 6b$_2$. Soil N values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.03	0.02	0.03
2	Maximum	0.08	0.07	0.09
3	Standard deviation	0.01	0.02	0.02

4	Average	0.05	0.05	0.05

Table 6b$_3$. Soil N values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.04	0.02	0.02
2	Maximum	0.09	0.12	0.08
3	Standard deviation	0.01	0.02	0.02
4	Average	0.06	0.06	0.06

Table 6c$_1$. Soil N values of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.46	0.46	0.08
2	Maximum	0.62	0.75	0.56
3	Standard deviation	0.061	0.11	0.18
4	Average	0.54	0.57	0.45

Table 6c$_2$. Soil N values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.28	0.15	0.16
2	Maximum	0.57	0.46	0.40
3	Standard deviation	0.11	0.12	0.10
4	Average	0.37	0.29	0.27

Table 6c$_3$. Soil N values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.12	0.14	0.14
2	Maximum	0.80	1.23	0.79
3	Standard deviation	0.23	0.36	0.20
4	Average	0.35	0.54	0.38

Soil P

Like N, P plays important functions in energy storage and transfer and the maintenance of membrane integrity. Soil P status and P values shows that 88% of the farmers' of Santinagar, 73.9% in Ragauja and 45% in Sunepani VDCs are having low status of P in their fields (Table 7a), among them, the lowest mean P value (20.58 P) was recorded in Santinagar, while the highest P value was obtained in soil samples from Ragauja VDC (Table 8a). Similarly, soil P values ranged very low-very high in Gulmi (Table 7-8b$_{1-3}$) and low- high in Marpha, low-medium in Pangling and medium- very high in Gharpjong and sampled sites (Table 7-8c$_{1-3}$). The uptake of phosphorus by the plant occurs in the form of HPO42- and H2PO4- ions from the soil solution. The major functions are. (Gulmi) and 5-6c$_{1-3}$ (Marpha)

Table 7a. Soil P status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	P	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)

		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	17	73.91	9	45.00	22	88.00
2	Medium	1	4.35	3	15.00	1	4.00
3	High	5	21.74	8	40.00	2	8.00

Table 7b$_1$. Soil P status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	9.52	1	4.76	3	14.39
2	Low	11	52.38	9	42.86	10	47.62
3	Medium	5	23.81	8	38.10	6	28.57
4	High	1	4.76	2	9.52	1	4.76
5	Very High	2	9.52	1	4.76	1	4.76

Table 7b$_2$. Soil P status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	11.76	2	11.76	5	29.41
2	Low	7	41.18	5	29.41	4	23.53
3	Medium	4	23.53	4	23.53	6	35.30
4	High	3	17.65	5	29.41	2	11.76
5	Very High	1	5.88	1	5.88	0	

Table 7b$_3$. Soil P status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	3	18.75	2	12.50	2	12.50
2	Low	7	43.75	7	43.75	4	25.00
3	Medium	2	12.50	2	12.50	6	37.50
4	High	3	18.75	5	31.25	4	25.00
5	Very High	1	6.25	0	0.00	0	0.00

Table 7c$_1$. Soil P status of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	2	33,33	4	66.67	3	50.00
2	High	3	50.00	0	0.00	1	16.67
3	Very High	1	16.67	2	33.33	2	33.33

Table 7c$_2$. Soil P status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	P	0-15 cm	15-30 cm	30-60 cm

		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	33,33	2	33.33	3	50.00
2	Medium	3	50.00	4	66.67	2	50.00
3	High	1	16.67	0	0.00	1	16.67

Table 7c_3. Soil P status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	4	40.00	3	30.00	3	30.00
2	Medium	6	60.00	7	70.00	7	70.00

Table 8a. Soil P values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	1.00	4.56	3.00
2	Maximum	582.16	119.58	138.04
3	Standard deviation	152.70	39.49	31.88
4	Average	72.99	51.48	20.58

Table 8b_1. Soil P values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	3.38	6.98	1.83
2	Maximum	241.44	122.41	225.99
3	Standard deviation	55.14	29.62	47.51
4	Average	41.51	36.43	35.40

Table 8b_2. Soil P values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	5.95	7.50	1.83
2	Maximum	114.68	159.51	96.65
3	Standard deviation	34.89	39.44	29.42
4	Average	41.60	49.33	32.72

Table 8b_3. Soil P values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	4.41	1.83	5.44
2	Maximum	124.99	107.98	86.86
3	Standard deviation	33.84	33.91	24.57
4	Average	38.13	40.99	39.87

Table 8c_1. Soil P values of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	33.10	33.1	33.10

2	Maximum	136.20	137.2	171.90
3	Standard deviation	40.33	53.5	55.94
4	Average	70.14	67.6	85.15

Table 8c_2. Soil P values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	15.80	15.80	15.80
2	Maximum	102.50	50.50	67.80
3	Standard deviation	32.29	13.05	21.93
4	Average	38.90	30.23	33.13

Table 8c_3. Soil P values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	15.80	15.80	15.80
2	Maximum	50.50	33.10	33.10
3	Standard deviation	11.70	8.36	8.36
4	Average	27.92	27.91	27.91

Soil K

Soil samples analyses for K status and K value revealed quite different than N and P, i.e. over 80% of the soil samples from Raguaja and Sunepani, and over 955% soil samples from Santinagar VDCs of Dang showing high K status (Table 9-10a), K mean value was also the highest from soil samples of Santinagar. K status ranged low to very high in all three sample sites of Gulmi (Table 9-10b_{1-3}) and Marpha (Table 9-10c_{1-3}). Potassium in the form of the K+ ion can be taken up readily by plant roots from the soil solution. Potassium controls water loss from plants as the K+ ion plays a crucial role in opening and closing of stomata.

Table 9a. Soil K status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	K	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	-	-	1	5.00	-	-
2	Medium	4	17.39	3	15.00	1	4.00
3	High	19	82.61	16	80.00	24	96.00

Table 9b_1. Soil K status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	1	4.76	1	4.76	2	9.52
2	Low	7	33.33	10	47.62	10	47.62
3	Medium	7	33.33	9	42.86	8	38.10
4	High	5	23.81	0	0.00	0	0.00
5	Very High	1	4.76	1	4.76	1	4.76

Table 9b$_2$. Soil K status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	0	0.00	1	5.88	1	5.88
2	Medium	10	58.82	13	76.47	13	76.47
3	High	5	29.41	2	11.76	3	16.67
4	Very High	2	11.76	1	5.88	1	5.88

Table 9b$_3$. Soil K status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	1	6.25	0	0.00	1	6.25
2	Low	2	12.50	5	31.25	5	31.25
3	Medium	9	56.25	9	56.25	8	50.00
4	High	4	25.00	1	6.25	1	6.25
5	Very High	0	0.00	1	6.25	1	6.25

Table 9c$_1$. Soil K status of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	0	0.00	0	0.00	1	16.67
2	Low	2	33.33	3	50.00	4	66.66
3	Medium	4	66.67	2	33.33	1	16.67
4	High	0	0.00	1	16.67	0	0.00

Table 9c$_2$. Soil K status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	0	0.00	0	0.00	1	16.67
2	Low	4	66.66	3	50.00	3	50.00
3	Medium	1	16.67	3	50.00	2	33.33
4	Very High	1	16.67	0	0.00	0	0.00

Table 9c$_3$. Soil K status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	20.00	5	50.00	4	40.00
2	Medium	6	60.00	3	30.00	5	50.00
3	High	0	0.00	1	10.00	0	0.00

4	Very High	2	20.00	1	10.00	1	10.00

Table 10a. Soil K values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	227.58	14.94	233.05
2	Maximum	867.64	841.91	893.65
3	Standard deviation	179.69	195.61	168.99
4	Average	481.23	425.50	596.93

Table 10b$_1$. Soil K values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	45.20	33.21	21.22
2	Maximum	602.76	692.69	680.70
3	Standard deviation	147.52	144.92	137.01
4	Average	204.79	145.12	127.71

Table 10b$_2$. Soil K values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	117.15	105.16	51.20
2	Maximum	632.73	572.78	392.93
3	Standard deviation	151.88	123.48	88.84
4	Average	294.18	238.46	196.49

Table 10b$_3$. Soil K values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	21.22	57.19	15.23
2	Maximum	494.84	500.84	632.73
3	Standard deviation	133.98	117.82	158.12
4	Average	219.81	188.71	180.85

Table 10c$_1$. Soil K values of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	98.60	69.10	39.00
2	Maximum	216.90	499.20	211.50
3	Standard deviation	47.25	163.41	57.12
4	Average	150.10	168.08	103.93

Table 10c$_2$. Soil K values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	55.10	60.50	29.60

2	Maximum	1114.00	232.50	176.10
3	Standard deviation	420.11	62.10	54.56
4	Average	266.52	119.67	97.02

Table $10c_3$. Soil K values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	71.20	52.40	60.50
2	Maximum	649.70	663.10	518.50
3	Standard deviation	209.75	198.61	135.30
4	Average	219.76	179.74	170.90

MANAGEMENT STRATEGY

1. Soil physical, chemical and biological indicators of farm soils have been observed in terms of its productive capacity by working on the yield difference between organic and conventional farms. The major quality indicators of soil is presented in Table 11. In this study, the main purpose of the soil sampling is for efficiency of nutrient inputs to maximize crop production and sustain soil fertility.

Table 11. Soil quality indicators

SN	Soil properties	Indicators
1	**Biological property indicator** (These all together enrich soil and support in all aspects of plant growth and production)	Microbial biomass Carbon Microbial biomass Nitrogen Enzyme activities Soil macro-organisms (arthropods) Soil micro-organisms (pathogens) Earthworms
2	**Chemical property indicator** (These all together support in availability of nutrient, microorganisms activity and plant growth)	Soil pH Soil organic matter content Available Nitrogen Available Phosphorus Available Potassium Cation exchange capacity Micro nutrients (Ca, Mg, Al, Mn, Zn, Br, Na, Fe) Redox potential
3	**Physical property indicator** (These all indicators together support in aeration, mobility of water, root penetration and soil fertility)	Soil texture Soil structure Bulk density Soil porosity Soil color Soil moisture Soil temperature Soil water holding capacity

Source: Anukwonke, 2014.

2. The N-P-K in balanced form plays important role in plant growth, crop yield and productivity. Their deficiency in plants are clearly identified by plant deficiency symptoms (Figure 1) and based on soil analyses are recommended in balanced form not to exceed their quantity otherwise may result toxicity to plant and change soil characteristics as well.

		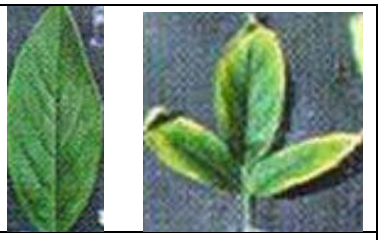
Nitrogen (Left: Normal & Right: Deficiency)	Phosphorus (Left: Normal & Right: Deficiency)	Potash (Left: Normal & Right: Deficiency)

Figure 1. Main nutrients (N, P, K) for crop plants showing normal growth and deficiency symptoms

3. Every farmer has his own management practice, which influences nutrient availability and plant growth. There are also many trace elements, whose deficiency symptoms are expressed by plants, which differ from one field to another, and can be diagnosed in growing plants. The pH neutrality indicates availability of nutrients to plants. In the Figure 2, the gray area depicts a neutral pH of soil, when all nutrients are soluble and mostly available to plants. The pH scale ranges from 0 to 14 with pH 7 as the neural point. So maximum availability of nutrient to plants is the way to rather than just using fertilizers in the crop fields.

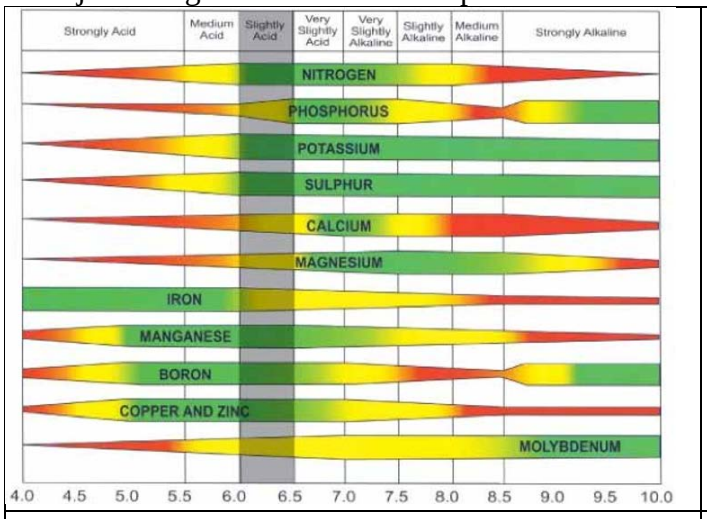	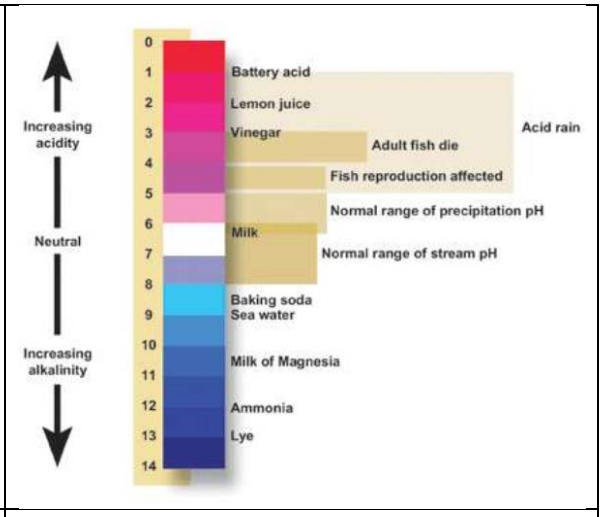
Nutrient availability at different pH of soil	pH range 0-14 with different color comparator

Figure 2. Effects of the soil pH on transfer of nutrients from soil to the plants through roots

4. Plant growing in fertile soil is reservoir of nutrients which are essential elements required for plant growth, production and productivity. Their available forms, mass (%) in dry plant tissue and key functions are summarized in Table 12.

Table 12. Fertile soil with reservoir of nutrients essential for plant growth, production and productivity

SN	Element	Form primarily absorbed by plants	Mass (%) in dry tissue	Major functions
	Macronutrients			
1.	Carbon	CO_2	45	Major component of plant's organic compounds
2.	Oxygen	CO_2	45	Major component of plant's organic compounds
3.	Hydrogen	H_2O	6	Major component of plant's organic compounds
4.	Nitrogen	NO_3^-, NH_4^+	1.5	Component of nucleic acids, proteins, hormones, chlorophyll, coenzyme
5.	Potassium	K^+	1	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
6.	Calcium	Ca^{2+}	0.5	Important in formations and stability of cell walls and in maintenance of membrane structure and permeability, activates some enzyme; regulates many responses of cells to stimuli
7.	Magnesium	Mg^{2+}	0.2	Component of chlorophyll; cofactor and activator of many enzymes
8.	Phosphorus	$H_2PO_4^+$, HPO_4^{2-}	0.2	Component of nucleic acids, phospholipids, ATP, several coenzymes
9.	Sulfur	SO_4^{2-}	0.1	Component of proteins, coenzymes
	Micronutrients			
1.	Chlorine	Cl^-	0.01	Requiring for water splitting step of photosynthesis & water balance
2.	Iron	Fe^{3+}, Fe^{2+}	0.01	Components of cytochromes; cofactor of some enzymes, needed for photosynthesis
3.	Manganese	MN^{2+}	0.005	Active in formation of amino acids; activates some enzymes, required for water splitting step of photosynthesis
4.	Boron	$H_2BO_3^-$	0.002	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall formation
5.	Zinc	ZN^{2+}	0.002	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
6.	Copper	Cu^+, Cu^{2+}	0.001	Compound of many redox and lignin-biosynthetic enzymes
7.	Nickle	Ni^{2+}	0.001	Cofactor of enzyme functioning in nitrogen metabolism

8.	Molybdenum	MoO_4^{2-}	0.0001	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

Source: Huang et al., 2008.

5. Use of FYM/Poultry manure Vermi-compost is always beneficial to plants and soils in many aspects. This has been exemplified with the use of Vermi-compost and comparing with chemical fertilizers (Table 13).

Table 13. Farm soil properties under vermi-compost and chemical fertilizer

SN	Chemical and biological properties of soil	Vermi-compost	Chemical fertilizers
1.	Availability of nitrogen (kg/ha)	256.0	185.0
2.	Availability of phosphorus (kg/ha)	50.5	28.5
3.	Availability of potash (kg/ha)	489.5	426.5
4.	Azatobacter (1000/gm of soil)	11.7	0.8
5.	Phospho-bacteria (100,000/kg of soil)	8.8	3.2
6.	Carbonic biomass (mg/kg of soil)	273.0	217.0

Source: Suhane, 2007.

6. Effect of climate in agriculture especially in crop production, and pest problems has been realized all over the world. The impacts of climate change on agriculture is listed in Table 14.

Table 14. Climate change impacts on agriculture

SN	Climate event	Possible impact on agriculture
1.	Warmer and fewer cold days and nights	Increased yields in colder environments
2.	Warmer and more frequent hot days and nights over most land areas (virtually certain)	Decreased yields in warmer environments Increased insect pest outbreaks
3.	Warm spells and heat waves increasing in frequency over most land areas (very likely)	Reduced yields in warmer regions due to heat stress Increased crop damage due to wildfire
4.	Heavy precipitation events increasing in frequency over most areas (very likely)	Heavy precipitation events increasing in frequency over most areas (very likely)
5.	Drought-affected area increases (likely)	Increase in land degradation and soil erosion Lower yields from crop damage and failure Increased risk of wild*fi*re, loss of arable land Salinization by irrigation/irrigation water
6.	Intense tropical cyclone activity increases (likely)	Damage to crops, storages, and agricultural infrastructure
7.	Extremely high sea levels increase in incidence (excludes tsunamis) (likely)	Salinization of irrigation water, loss of arable land, and increase in migration

Source: FAO, 2008.

7. Emphasis has been given on improving the use efficiency of fertilizers through the 4R nutrient stewardship principle, i.e. effective use, i) Right source, ii) Right rate, iii) Right time, iv) Right placement. However, important factors for controlling efficiency of fertilizer application are numerous: i). The nature of crop and its variety, ii). Method and time of application of fertilizer, iii). Crop management, iv). Cropping system, v). Chemical composition of soil and its pH, vi). Organic matter content of the soil, vii). Physical condition including drainage, aeration, etc., viii). Weather conditions, ix). Soil moisture, and x). Balance of nutrients. All these have to be taken care for efficient utilization of nutrients.

Recommendations

It has revealed that pH value range more acidic to (Dang) to towards basic (Marpha), soil organic contents variable, slighter better in Sunapani and C:N ratio in higher range, and major nutrients NPK are not in balanced forms as perceived from the study of three district sampled sites.

As general recommendation, one aspect, fertilizers are suggested depending upon the amount of nutrients available in the soil as well as requirement of the crop. For example, i) if available soil nutrients are very low in soil test, then increase the dose of fertilizer by 50%, ii) if available soil nutrients are low, increase the dose of fertilizer by 25%, iii) if available soil nutrients are medium or slightly more than medium, no need to change the fertilizer dose and amount of application, iv) if available soil nutrients are very high, reduce the dose of fertilizer by 50% and v) if available soil nutrients are high, reducing the dose of fertilizer by 25%, etc. However, based on the overall management strategies, the recommendations are made as follows:

- Proper crop selection, reduced tillage practices and crop residue utilization, discarding of tillage sequence that reduces loss of soil or water and disturbance to soil structure.
- Sub-soil improvement with terrace and contour bunds, agroforestry practices, levelling or horizontal strip constructed in crop field prevent accelerated erosion.
- Agronomic practices- cropping systems-mulching, alley cropping, contour cropping, timely planting, continuous cropping with well-managed crop residue, zero or minimum tillage and with legume-based and other crop rotations, legume plow down (green manure), cover crops, forage increase soil organic matters and soil microbial biomass.
- Fertility management- Soil test based recommendation, balanced use of fertilizers, organic matter application, cropping systems, green manuring,
- Water management- Minimizing water loss, sprinkler irrigation, drip irrigation, mulching to reduce soil moisture loss and maintain temperature,
- Pest management- Following eco-friendly and bio-rational practices including IPM, INM, ISPM etc. for crop specific important pests of commercial crop cultivation. INM system is the maintaining or adjusting plant nutrient supply to achieve a given level of crop production by optimizing the benefits from all possible sources of plant nutrients for sustainable crop production. Application of recommended dose of N-P-K @ 200-44-82 kg ha-1 plus either FYM at 5 Mg ha-1 or Vermi-compost at 3 Mg ha-1 was the best technology for harvesting higher yield of cauliflower with its quality produce and maintaining ecological health (Batabyal et al., 2016).
- Organic farming- It relies upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic waste, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests.
- Among different climatic factors, rainfall and temperature are the most dominating ones influencing nutrient leaching from soil. Use of slow release fertilizer is an important approach to reduce nutrient leaching. Further, reclamation of alkali soil using recommended dose of gypsum and acidic soil using lime.

- Farmers' field experimentation is important to determine the type and amount of fertilizers to suit particular soil type and crop. Improved timing and/or splitting of fertilizer N increased N recovery efficiency from 0.17 kg kg-1 in FFP plots to 0.27 kg kg-1 in Site Specific Nutrient Management plots with 63% greater agronomic N use efficiency compared to Farmer Field Practice (Khurana et al., 2008).
- The effects of trace elements on *Brassica napus* studied shows that trace element- 2 and 4 mMK2SiO used in salinity, 300 mMNaCl increased leaf area, leaf fresh weight, seed yield, and photosynthesis; also increased APX and NR activities and chl content. Similarly, 15 and 30g L-1 as Na2SeO3 used in drought, limited irrigation at early stem elongation increased plant height, pod and seed development and yield (Hasanuzzaman et al., 2020).
- Nanotechnology is showing promise and may help improve the nutrient efficiency. Nanofertilizers release the nutrients in a controlled manner in response to reaction to different signals such as heat, moisture, etc. For example, Titanium dioxide (TiO2) increased the light absorption and chlorophyll content in the plant, while zinc oxide nanoparticles had a twin role of being an essential nutrient and a cofactor for nutrient-mobilizing enzymes. With these the tomato plants were better able to absorb light and minerals producing nearly 82% (by weight) more fruit than untreated plants, and the fruit had higher antioxidant (lycopene) content.

Hence, it is necessary to know the real field and crop situation by frequently visiting crop fields, sampling and monitoring plants, identifying deficiency symptoms, plant growth and vigor, crop yield and quality, and recommended best eco-friendly practices for higher crop productivity with long-term sustaining of soil productivity.

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