Asian Journal of Multidimensional Research
ISSN: 2278-4853 Vol. 12, Issue 11, November 2023 SJIF 2022 = 8.179
A peer reviewed journal

MAPPING CHEMICAL PROPERTIES OF SOIL AT VILLAGE LEVEL: A CASE STUDY OF RINCHENPONG, SIKKIM

Abira Dutta Roy*; Shyamal Santra**

*Assistant Professor,
Department of Geography,
Bankura Zilla Saradamani Mahila Mahavidyapith,
Bankura, UZBEKISTAN
Email id: abira6520@bzsmcollege.org

*Assistant Professor,
Department of Geography,
Bankura Zilla Saradamani Mahila Mahavidyapith,
Bankura, UZBEKISTAN

DOI: 10.5958/2278-4853.2023.00143.X

ABSTRACT

Digital Soil Mapping at farmland scale or even at village scale is rare. With the initiative of government of India to implement soil health card at farm scale it becomes imperative to map soil properties at village level and suggest sustainable management practices. Rinchenpong village, in West Sikkim. was surveyed and randomly 20 soil samples were collected for their chemical analysis to estimate pH, Electrical Conductivity (EC), Soil Organic Carbon (SOC), Nitrogen (N), Phosphate (P), Potash (K) and micronutrients like Sulfur (S), Manganese (Mn), Copper (Cu), Zinc (Zn) and Iron (Fe) using state-of -the art laboratory facilities and norms. The values of different soil parameters were then interpolated using ordinary kriging technique and mapped in ArcGIS 10.4.1.The data were validated with the Soil Series of Sikkim data which is a National Bureau of Soil Survey and Land use planning (NBSSLUP) publication. The various chemical parameters show good correlation, except for the micronutrient concentrations in soil, but match perfectly with the test results of Soil Health Card scheme.

KEYWORDS: *Digital soil mapping, soil health card, Rinchenpong, Eastern Himalayas.*

INTRODUCTION

The Indian economy is heavily dependent on agriculture. Almost 20% of the Gross Domestic Product comes from this sector and 60% of the population rely on it as a source of livelihood (National Statistical Office (NSO), Ministry of Statistics and Programme Implementation). However, agriculture in India is conditioned by the poor fertility of the soil, which depends upon the level of nutrients. The physical, chemical and biological properties of the soil are useful to evaluate its fertility, to design cultivation plan and predict the crop productivity. Under the ongoing scenario of environmental degradation and global climate change leading to food insecurity, the digital soil mapping (DSM) becomes imperative in order to accurately quantify spatial soil information and understand the temporal changes and identify the causes behind soil degradation (Dharumarajan et al., 2019). Poor soil fertility is the primary bio-physical constraint that results in poor yields (Sanhez, 2010). In the past digital soil mapping has seldom been utilised to guide soil nutrient management in small holder farm settings. Dash et al., 2022 has done an extensive review of (DSM) comprising of papers from 2000 onwards. They found only two articles to have prepared digital soil maps at the national extent. Dash et al., 2022 also mentioned that very few local and regional extent DSM have been carried out and over 50% of the states and Union Territories have no DSM studies. Listed in Table 1 are some of the studies on DSM in India.

TABLE 1 LITERATURES ON DIGITAL SOIL MAPPING IN INDIA

Citations	Region	Properties
Luca-Belle et al., 2022	South Western India	SOC
Reddy et al, 2021	India	pH, Soil Organic Carbon (SOC), Clay and Sand content
Dharumarajan et al., 2020	Parts of Koppal and Gadag districts of Northern Karnataka Plateau	pH, OC, CEC, clay, sand, silt, field capacity and permanent wilting point
Kalambukattu et al, 2018	Hilly watershed located in the Mandi district of Himachal Pradesh	SOC, nitrogen (N) and phosphorus (P)
Kumar et al., 2018	Watershed in Uttar Pradesh	SOC
Dharumarajan et al., 2017	Village in Telegana district	SOC, pH and EC
Santra et al., 2017	Western India	Sand content
Sreenivas et al, 2016	India	Organic and Inorganic carbon
Dhillon and Dhillon, 2014	North Western India	Selenium
Sreenivas et al., 2014	Andhra Pradesh and Karnataka	SOC
Santra et al., 2011	Watershed in Orissa	Soil particle size distribution, pH, water retention behaviour, saturated hydraulic conductivity

It has been evident from the literatures reviewed in Table 1 that very little research endeavours have gone into digitally mapping soil not only at national level but also at regional and micro levels, especially villages where agricultural activities are predominant. Moreover, soil mapping has also been inadequate for Himalayan regions as well. But Himalayan regions too contribute greatly to the Indian agricultural sector. Partap, 2011 states that approximately 76 per cent of the gross cropped area of the entire Himalayan region is under staple food grain crops. Wheat, rice and maize are the dominant food crops in the Himalayan region, especially in the Kashmir Valley, Kangra Valley through terrace cultivation. In eastern Himalaya, rice is the staple food crop occupying about 81 per cent of the food-cropland. Nichols, 2015 writes that these areas are facing deteriorating land productivity and declining yield. A study by Shukla et al., 2018 reveals the causes behind the deteriorating agricultural yield in the Western Himalayas especially, Uttarakhand. They identified male out migration, marginal fragmented land holdings, extreme climatic events and anthropogenic disruptions leading to soil infertility as the main culprits.

Mukherjee et al., 2018 writes about how the agricultural productivity is facing challenges in the Central Himalayas.
Similarly, Singh et al., 2021; Babu et al., 2020; Das et al., 2017; have elaborately discussed the declining crop productivity in the eastern Himalayas, especially Sikkim (Mishra et al, 2021).Under such circumstances of soil mapping initiatives together with training farmers to practice climate resilient agriculture becomes the need of the hour. It can help small land holder i.e., marginal farmers to identify soil nutrient status and implement site specific soil management schemes. This paper attempts to take up a case study of a Gram Panchayat in West Sikkim District, in order to showcase the importance of DSM at village level.

STUDY AREA

The study area of this paper is Rinchenpong mouza, a typical remote Gram Panchayat in the Eastern Himalayas. It is located in the Soreng sub division of West Sikkim district and is 25 km from Gyalsing, the district headquarter. Figure 1 shows the location map of Rinchenpong. The latitudinal extension of Rinchenpongis from 27º14'00"N to 27º15'00" N. The longitudinal extension is 88º16'00" E and 88º16'30"E encompassing an area of 541394.23 m^2. The contour map derived from SRTM DEM (Shuttle Radar Topographic Mission, Digital Elevation Model) as shown in Figure 2 (d) depicts that the highest elevation is 1770 m towards the south of the village and the lowest is 1547.78 m towards the north of the study area. The average slope of the area ranges from 21-25 degrees as can be seen in Figure 2 (b). The steepest slope in the area ranges from 51-55 degrees and are found in the

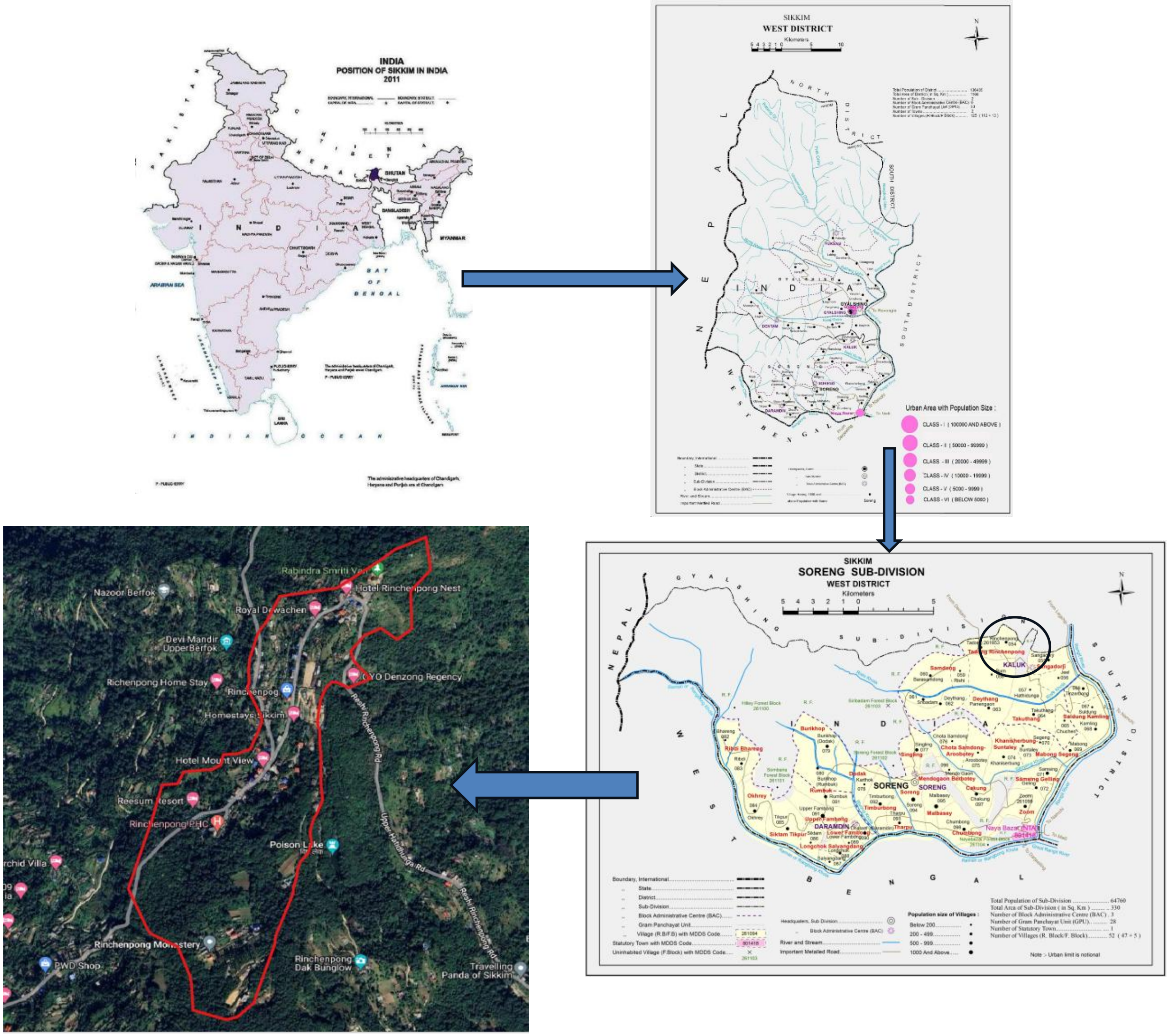


Figure1 Location of study area, Rinchenpong Village

northern boundary of the mouza. The aspect map is shown in Figure 2 (a). Most of the hillslopes face towards North West and Western direction. The recorded history of Rinchenpong dates back to 1860, when the British army had attacked Sikkim. It is mentioned in historic literatures

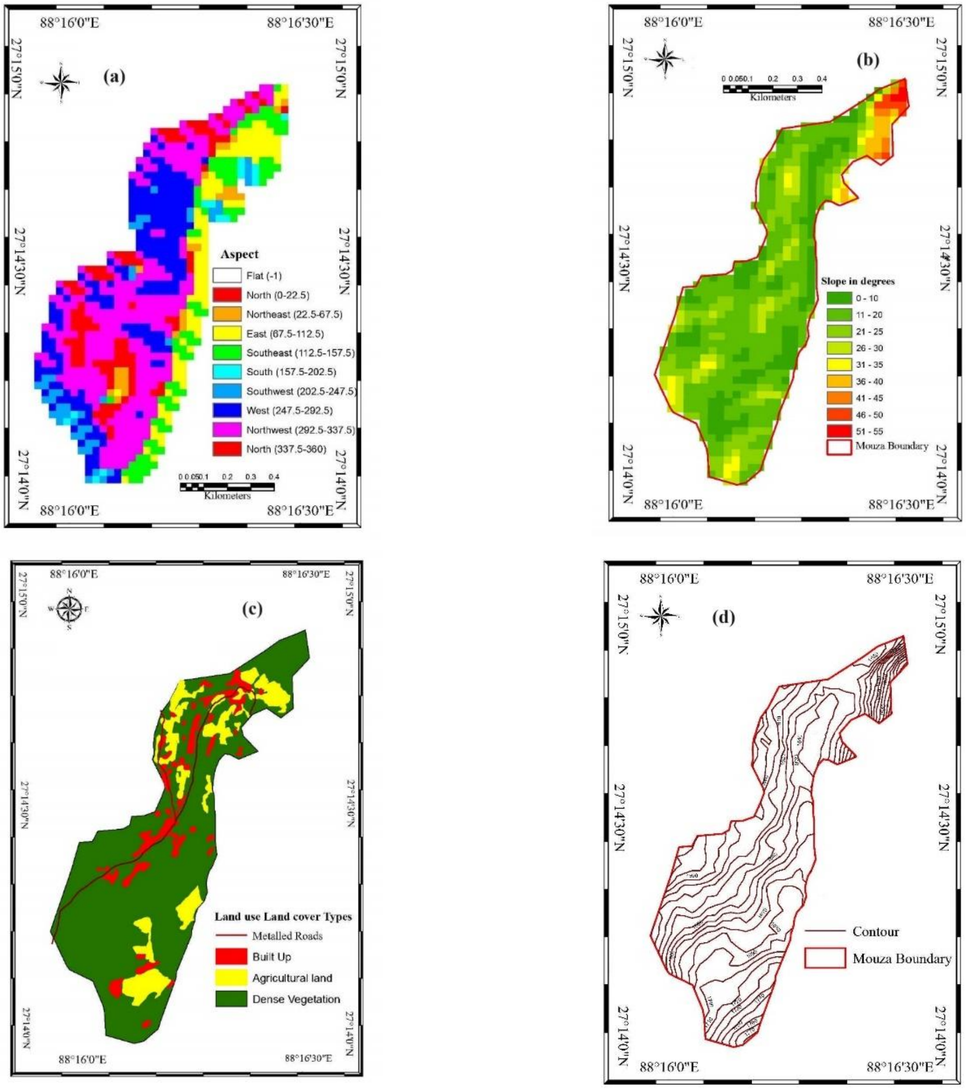


Figure 2 (a) Aspect map, (b) Slope map, (c) Land use land cover map, (d) contours of Rinchenpong

that when the army reached Rinchenpong, the Lepchas poisoned the water of a pond, which was the only source of drinking water then. As a result, many army men died, forcing them to retreat. The lake still exists in the name of "Poison Pokhri" and is of major tourist attraction since it had attained a prominence in the tourism scenario in this decade (Chakraborty, 2012). The majestic view of the Kanchenjunga in the pristine landscape is another reason for its growing tourism business. The settlement is well connected with Jorethang, Siliguri by roadways. The nearest railway station is New Jalpaiguri and the nearest airport is Bagdogra. The nearest IMD (India Meteorological Department) Station, Manga-Geyzingwhich showed that the daily maximum temperature reaches 27.1ºC during July and the daily minimum temperature declined to 6.6ºC in January. The rainfall data showed the Monsoon onset takes place in May and withdraws towards September. The highest rainfall amounted to 549.7 mm in June and the lowest in December is 18.5 mm. The number of rainy days in the area often reaches to 26.6 days in July.

According to Census, 2011 the total population of the village is 1458 persons of which 737 are male and 721 are female. There are 298 households.

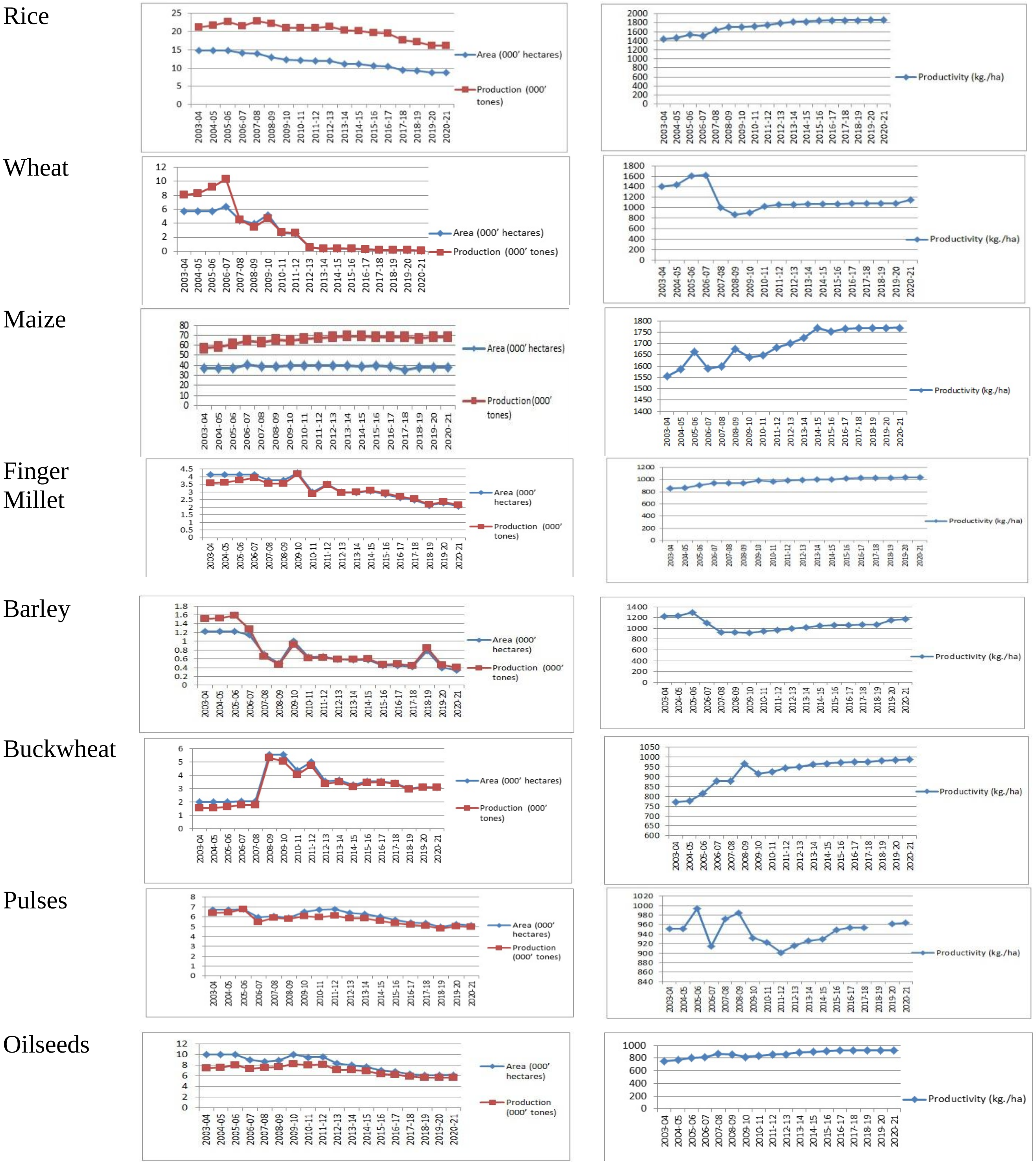


Figure 3 Area under major crops, their production and productivity in Sikkim

(Source: https://sikenvis.nic.in/Database/Agriculture_777.aspx)

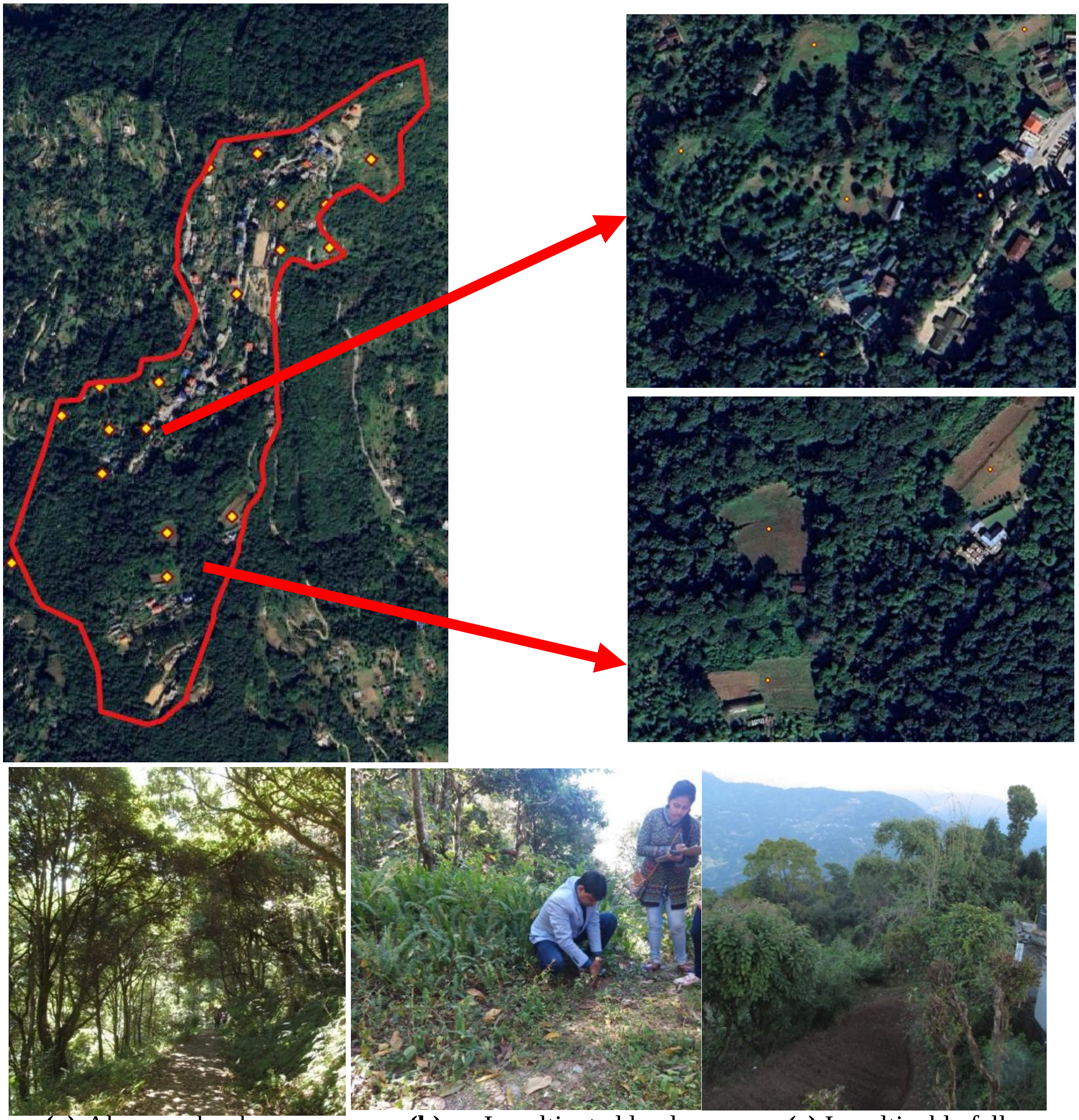
A primary questionnaire-based survey was carried out among 50 households randomly in order to assess the livelihood dependency scenario. Under the circumstances of recently growing economy based on tourism it has been found from primary survey that still 51% villagers were farmers, 11% were working in the educational sector, 5 % as carpenter, 24% were shop owners and only 9% were involved in tourism related

business. But the livelihood of the people which is based on agriculture earn meagre amount of Rs. 2000-5000 per month from it and hence have a very low standards of living. Figure 3 shows the trends in the production, area under cultivation and yield of major crops cultivated in Sikkim from 2003-2021. Production per hectare is important as it directly reflects the efficiency of the farming practices on a per-unit-area basis. It helps them understand how effectively the farmers are using their land resources. Whereas total production is more crucial when assessing overall regional agricultural output, trade, or economic impact. It provides a broader view of the volume of produce available for consumption, export, or industrial use. From the graphs it can be observed that over the last decade there has been a steady decline in the area under cultivation of most crops as well in the amount of production though yield has been stagnant for most of the crops. In order to increase yieldit's important to manage the available land resource in the optimum way possible, without increasing area under cultivation in a forested and fragile ecosystem like that of Sikkim. Soil testing and suggestion for sustainable management practice at field levels becomes crucial in this juncture.

MATERIAL AND METHODS

A gridded soil sample technique which is mostly followed has not been implemented in this case study. According to Schoeneberger et al., 2012 in locations with varied slope, landform, drainage conditions and erosional rate soil sampling can be done on the basis of required targets. In Rinchenpong soil samples have been collected from agricultural plots based on slope, vicinity of forests, in orchards, fallow especially based on management practices as shown in Figure 4. According to USDA's Soil sampling Guidelines Sampling depth for most soils is characteristically the tillage depth in 6-inch (15 centimetres) intervals. The top six inches or 15 centimetres of soil has the most root activity and fertilizer applications are generally delimited to this depth. These surface soil samples (0 to 6 inches/ 15centimetres) are typically used for conventional tests of organic matter, phosphorus, potassium, pH, and salt levels. Deep-rooted crops such as wheat and barley require deeper samples if nitrogen fertilizer doses are anticipated. It's also essential to discard surface litter. Subsoil samples from the 6- to 24-inch/60 centimetres depth are desirable to evaluate available nitrogen and in some cases sulphur. Nitrate- nitrogen and sulphate-sulphur are mobile in the soil and will move below the six-inch/15 centimetres tillage layer. If leaching has not lodged these nutrients below the rooting depth, they will be accessible for plant uptake. Both surface and subsurface soil samples are needed to test for available nutrients in the root zone. Thus, soil sampling 0-30centimetres were done in Rinchenpong mouza. Soil cores collected for each sampling point were stored in zipped plastic pouches with proper labelling of the latitude longitude, elevation and land use land cover details. Moist soil samples were air dried at room temperature and was brought to the Agricultural Ministry, Government of West Bengal, Soil Testing Laboratory at Nutanchati, Bankura. The soil samples were tested for pH, EC (Electrical Conductivity), SOC (Soil Organic Carbon), NPK

(Nitrogen, Phosphate and Potash) and Micronutrients. Many sampling techniques, testing procedures for different parameters and mapping techniques have been employed.



(a) Along orchards **(b)** In cultivated land **(c)** In cultivable fallow

Figure 4 Soil sampling points and field photographs in Rinchenpong in 2022

For carrying out the pH test the following steps were followed. To make a 1:2 soil water suspension, 20 g of airdried, 0.2 mm sieved soil sample is placed in a 100 ml beaker, and 40 ml of distilled water is added. For thirty minutes, the suspension is shaken at regular intervals. To give it time to warm up, the pH metre must be turned on at least fifteen minutes in advance. The temperature compensation knob is used to adjust the pH metre to room temperature. The electrode is then submerged in several buffer solutions with pH values of 4.0, 7.0, and 9.2 to calibrate the device. By dipping the electrodes into the soil suspension, the pH of the mixture is measured and recorded. However, the sample suspension is agitated with a glass rod just prior to submerging the electrode into the solution. In order to allow the pH meter's reading to stabilise, the electrode is submerged in the solution for at least 30 seconds. The electrodes need to be cleaned with regular filter paper and distilled water after every determination. A 0.01 (M) CaCl solution should be used to evaluate the pH of soils with a high salt concentration (Peverill et al., 1999).

In order to test the Electrical conductivity, weighed into a 100 ml glass beaker was 50 g of air-dry soil (less than 2 mm). To make a 1:5 soil: water suspension, 50 ml of deionized water was added to it using a graduated cylinder or 50-mL volumetric flask. After thoroughly mixing the suspension with a glass rod, it was let to stand for half an hour. For an hour, the suspension was swirled at regular intervals. Following an hour, the suspension was filtered via a Buchner funnel in a dry beaker using Whatman No. 42 filter paper. Using the KC1 reference solution, the conductivity metre was calibrated in accordance with the manufacturer's instructions to get the cell constant. After submerging the conductivity cell in the soil suspension, the measurement was recorded. At the same temperature, the electrical conductivity of the 0.01M KC1 and soil suspensions was observed (Peverill et al., 1999).

$$〖EC〗 \_2.5\ (dS/m) = (S\ X\ 1.413)/K,$$

K= Measured EC of KCl solution, S= Measured EC of Suspension

For measuring SOC, the in a 500 ml conical flask, 1 g of the 0.2 mm sieved soil sample was obtained. Using a pipette, 10 ml of 1(N) K2Cr707 was added to it. After that, 20 ml of concentrated H 2S04 (including Ag7S04) was added and well combined. To give the reaction time to finish, the flask was placed on an asbestos pad for thirty minutes.200 millilitres of distilled water were used to dilute the reaction mixture. It was mixed with 10 millilitres of 85% orthophosphoric acid and 1 millilitre of diphenylamine indicator. There will be a blue-violet colour.0.5 N ferrous ammonium sulphate solution was added to the solution until the colour changed from blue violet to green. In tandem with the sample, a blank was created using the same reagents as the sample but without any soil sample. This is known as the Walkley Black method. Equation 2 was used to calculate the percentage of SOC (Peverill et al., 1999).

$$SOC\ \% = (10\ X\ (B - T) X\ 0.003\ X\ 100)/(B\ X\ W),$$

B = ml of ferrous ammonium sulphate (FAS) solution required for blank titration.
T = ml of ferrous ammonium sulphate (FAS) solution required sample titration.
W = weight of soil sample in g.

The amount of Available Nitrogen present in the soil was calculated by first using akjeldahl flask is filled with a 5 g sample of soil.Ten millilitres or so of distilled water are used to wet the soil. It is mixed with 25 millilitres of 0.32% KMn04 solution and 25 millilitres of 2.5% NaOH solution. The Kjeldahl flask is filled with a few glass beads.A 250 ml conical flak filled with 20 ml of 2% boric acid is put beneath the Kjeldahl flask's reception tube. The boric acid solution is dipped into the receiver tube. Following the addition of alkali, the distillation equipment is attached, and the contents are steadily distilled in a Kjeldahl flask. Until the distillation process is finished and around 100 ml of the distillate is collected, the ammonia gas is distilled from the distillation flask.Ammonia absorption causes the pinkish colour to become green. The distillate, which is green in hue, is titrated against 0.02 N H2S04 till it becomes pink. A blank and a soil sample are carried out simultaneously (Peverill et al., 1999).

The available Nitrogen will be calculated using equation 3

$$(Available\ nitrogen =)\frac{(S-B) X\ Normality\ of\ acid\ X\ Atomic\ weight\ of\ N\ X\ Wt.of\ one\ ha\ soil}{Weight\ of\ soil\ sample\ X\ 1000},$$

Where.
S = Sample titration reading
B = Blank titration reading

For assessing the phosphate concentration in the soil about 50 ml of water was added to a 250 mL volumetric flask. Next, slowly 5 ml of concentrated sulfuric acid was poured after adding 0.75 g of ammonium sulphate and allowing it to dissolve. The mixture heated up. After letting it cool, distilled water was used to dilute it to the mark on the flask. Following this 200 mL of your sulfuric acid/ammonium sulphate combination and 10 g of dry soil was put into a plastic flask. The flask was periodically shaken for 30 minutes. The soil sample was placed aside after filtering it through fine filter paper. It might be a little brown in hue, but it would turnclear. In order to prepare standard solutions of phosphates. First, 0.220 g of solid KH2PO 4 weighed precisely was poured into a 500 ml volumetric flask to create a 300-ppm solutionand diluting it out to the appropriate amount. 10ml of the standard phosphate was pipetted into volumetric flasks measuring 200, 250, 500, and 1 l, and filled to the brim. Phosphate solutions of 15, 12, 6, and 3 ppm solution resulted from this. A 4.5 ppm solution was obtained by pipetting 15 ml of the standard solution into a 1 l volumetric flask. 5g of ammonium molybdate in 100ml of water was dissolved. This was transferred to a 500 ml volumetric flask. 160 mL of concentrated sulfuric acid was very gradually added to this. The flask was allowed to cool down for 15 minutes. After adding all of the acid, the mixture was diluted with 500 ml of water, adding it gradually while stirring in appropriate amount. In a 150 ml conical flask, 10 mL of the sample, 20 ml of water, 2 ml of the molybdate solution, and a spatula full of crystals of ascorbic acid was mixed. This developed a strong blue/green hue as it steadily heated to boiling, after which it was cooler. The steps listed below serve as a helpful guide on what to do. When dealing with colorimetry, a colorimetric tube was filled with water (referred to as a blank) and inserted it into the colorimeter. An absorbance reading was taken with the absorbance set at 650 nm (reddish light). This water sample was used to set zero in the colorimeter. A reading was noted after adding the lowest concentration solution (3 ppm from above) to the sample tube. Once the absorbance was recorded, the tube was cleaned and to measure the next most concentrated standard was continued, and so on, until all the standards have been measured. All the samples were inserted into the tube of the colorimeter and the absorbance reading was recorded (Peverill et al., 1999).

To estimate the amount of potassium in the soil sample, in a 50 ml volumetric flask5, 10, 15, 20, and 40 ppm K solutions were prepared by diluting the stock solution (1000 ppm K) with 1 N NH40AC solution.The flame photometer's gas and air pressures were prepared, and a suitable filter for K. was installed. With the blank (ppm), the flame photometer reading was set to zero, and with the 40 ppm, it was set to 100.Plotting the flame photometer readings along the Y-axis and the various concentrations (ppm) along the X-axis resulted in the standard curve. 0.4 mg/kg of K, or a factor of 1, will result from this flame photometer value. For calculating the potassium level in a soil sample 1 a 25 ml conical flask containing 5 g of 0.2 mm sieved soil sample was taken. After adding 25 millilitres of neutral normal ammonium acetate (pH = 7), the mixture was agitated for a duration of 25 minutes. Whatman No. l filter paper was used to filter the contents, and the filtrate was collected. The extract's potassium concentration flame photometrically requires the instrument to be configured and calibrated.The potassium content in the unidentified sample is ascertained by fitting the standard curve obtained from the stock K solution(Peverill et al., 1999).

For assessment of present of Sulphur in soil sample10g of air-dried soil sample was weighed and placed in a 50cm3 flask or extraction vessel. Pipette of 25cm3 of the monocalcium phosphate extraction reagent was poured into the container. For thirty minutes, the mixture was shaken. To the shaken liquid, 0.15 g, or ¼ tea spoon, of powdered charcoal was added, and stirred for an additional three minutes. After filtering the mixture, an aliquot of 10 cm3 of the filtrate was transferred to a different flask. To the aliquot above, 1 cm3 of the seed solution was poured, and then the flask was given a good shake.After setting the flask on a magnetic stirrer and adding 0.3 g of barium chloride crystals, swirling was done for approximately 60 seconds. A turbid solution was obtained. Using a calibrated UV-VIS spectrophotometer (zero absorbance with blank), an aliquot was transferred to a spectrophotometric tube or cuvette and the absorbance at 420 nm was measured. The observation table was noted. Six 100 cm^3 volumetric flasks with the following labels: 0 (blank), 10, 20, 30, 40, and 50 mg dm^{-3}, were labelled.0, 1, 2, 3, 4, and 5 cm3 of the standard stock solution were added, respectively, to the flasks with the above labels. Then, using EDTA solution, the volumes was adjusted. The solutions, referred to as the standard series, each had a S concentration of 0, 10, 20, 30, 40, and 50 mg dm-3.One by one, 10 cm3 of each of these solutions were taken, used to create the turbidity (just like with the soil extract).The absorbance of these solutions were measured and recorded in a table after setting the spectrophotometer to zero absorbance using a blank. The blank, the standards, and the sample all were processed at once (Peverill et al., 1999).

A generally accepted extractive technique for determining total free iron is the citrate bicarbonate dithionite (CBD) approach (Mehra and Jackson, 1960).0.5 g of soil that has been dried and sieved into a 100 ml polypropylene centrifuge tube was added.5 ml of sodium carbonate (1 M) and 40 ml of sodium citrate (0.3 M) was poured in it. The mixture was heated for 30 minutes at 80°C in a water bath. For ten minutes, while constantly stirring to the heated solution, 0.5 g of sodium dithionite was added. To improve flocculation, 10 ml of sodium saturated sodium chloride and 10 ml of acetone was added. The mixture was centrifuged at 3500 rpm for 10 minutes once it was cooled to room temperature, and the suspension was then syphoned off into a 200 ml volumetric flask. To ensure that all of the free iron has been removed, the solid residue was cleaned with distilled water. Next, the suspension was transferred to the previously used volumetric flask and filtered using a Teflon filter with a pore size of 0.2 μm, resulting in a total suspension volume of 150 ml. To determine the amount of iron in the filtered suspension, an atomic absorption spectrophotometer was used. For each sample, duplicate measurements were taken.

An µAUTOLAB analyzer (ECO CHIMIE, Netherlands) was used to do the voltammetric measurements for assessment of manganese in soil. The reference electrode was a KCl saturated calomel electrode (SCE) made by Radiometer (Denmark), the working electrode was a hanging mercury drop electrode (HMDE) with a surface area of 3 mm2 made by Laboratorni Pristroje (Czech Republic), and the counter electrode was Pt wire. A 250 cm3 bottle was filled with 10g of soil. After adding 100 cm3 of 1mol·dm–3 HCl, the soil was agitated on a mechanical shaker for one hour. Next, the extract was filtered. A 25cm3 standard flask was filled with 1 to 3cm3 of the extract. A buffer solution containing 0.2 mol·dm–3 ammonia/ammonium chloride was used to dilute the residue. A measuring vessel was filled with 20cm3 of solution after the pH was adjusted to 8.5.Manganese was deposited on the electrode surface for 15 to 30 seconds (depending on the predicted manganese concentration) at -1.70V in a stirred solution following the deaeration of the solution with pure nitrogen. The potential was changed to -1.15V five seconds after the stirrer, and the reformed manganese (II) ions were measured using differential pulse cathodic voltammetry, within the potential range of -1.15 to -1.70.It was done three times in this cycle. Triple standard addition was used to determine the concentrations of Mn (II).

In order to determine the amount of copper present in soil as micro nutrient boiling perchloric acid was used to carry out the mineralization process. Twenty centimetres of concentrated perchloric acid were introduced to a Kjeldahl flask containing two-gram soil samples, each of which had been precisely weighed to within 0.001 grammes. They were then heated for eight to nine hours under a reflux condenser in a sand bath. Following mineralization, the mixture was filtered and then redistilled water was added to 50cm3 measuring flasks until the mark was reached. The concentration of copper in the samples was measured. In order to determine the microgram quantities of copper (II), spectrophotometric analysis requires extracting the produced copper (II) diethyldithiocarbamate using CCI4 or CHClj, then measuring the absorbance of the solution at wavelength 436 nm. The determination is hampered by metal ions that combine with cupral to generate coloured complexes (such as Fe (III), Bi(III), Mn (II), Ni(Il), and Co(II)).By adding tartrate or citrate to an EDTA solution at pH 8–9, the interfering ions were hidden. To find out how much copper was in the soil, 10 cm3 of the solution left over after the samples were mineralized was put into a separatory funnel. All of the reagents were added one after the other, except for the copper standard solution, in a manner akin to that of plotting the calibration line. Chloroform was used to extract the solution, and the complex's absorbance at the organic phase was evaluated in comparison to a reagent blank (Jankiewiczet al., 1999). The calibration line was used to determine the copper Cx concentration [in mg/50 cm3].The following formula was used to compute the amount of copper (II) x in the soil:

$$x = C_X \frac{V_1 * 1000}{V_2 * m},$$

Where: C_x - concentration of copper read from the calibration line [mg/50 cm3];
V_1 - total volume of solution after mineralization [cm3];
V_2 - volume of the solution after mineralization taken for analysis [cm3]; m - weighed sample of soil [g].

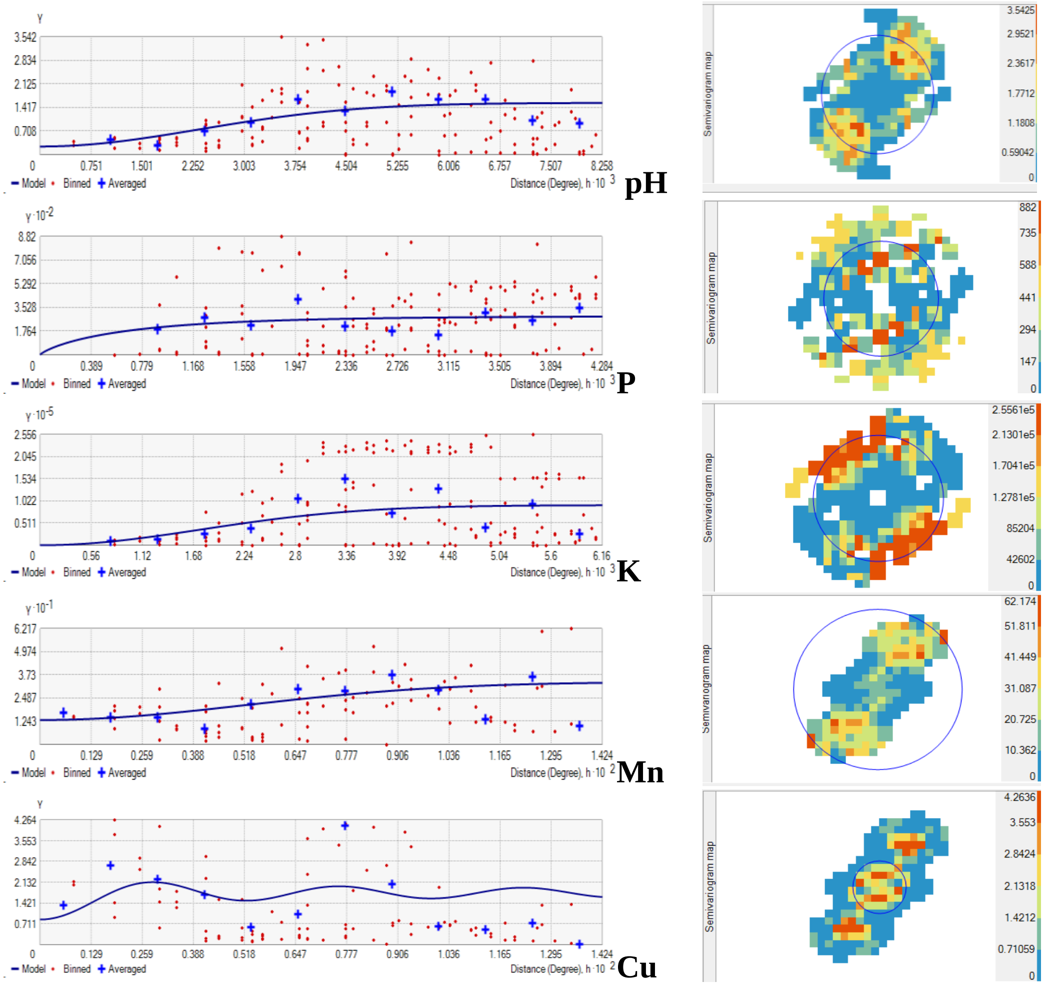
Extensive literature review on the techniques and process followed for digital soil mapping has been carried out by Arrouays et al., 2021; Nikiforova et al., 2020, Zhang et al., 2017.Targeted sampling and Kriging method of interpolation of soil data were found to be the most used technique in mapping soil properties (Liu et al., 2021Chabala et al., 2017; Heuvelink et al., 2006).The results of the chemical analysis are given in Table2. According to the OK kriging approach (Cressie, 1990), the mathematical expectation of the regional variable Z(x) is an unknown constant. Data having a trend can be processed using the OK approach. An un-interpolated position x0's value of variable Z is approximated using the i samples that surround it. The following is the formula for the process:

$$Z_{(x_0)} = \sum_{(i=1)}^{n} \lambda_i Z(x)_i$$

Where the contribution of each *Z (xi)* variable to *Z(x0)* is shown by the weighting coefficient *λi*, which is linked to *Z(xi)*. Next, using the semivariogram *[γ(h)]*, one may estimate *λi:*

$$\gamma(h) = 1/(2N(h)) \sum_{(i-1)}^{N} [Z(x_i) - Z(x_i + h)]^2$$

Where h is the separation distance, N (h) is the number of sample point pairs separated by h, and *Z(xi)* and *Z(xi +h)* are the observed values of variable *Z* at locations xi and xi +h. The semivariogram was computed in this work, and the variogram was then fitted using stable, spherical, Gaussian, and exponential models as shown in Figure 5.



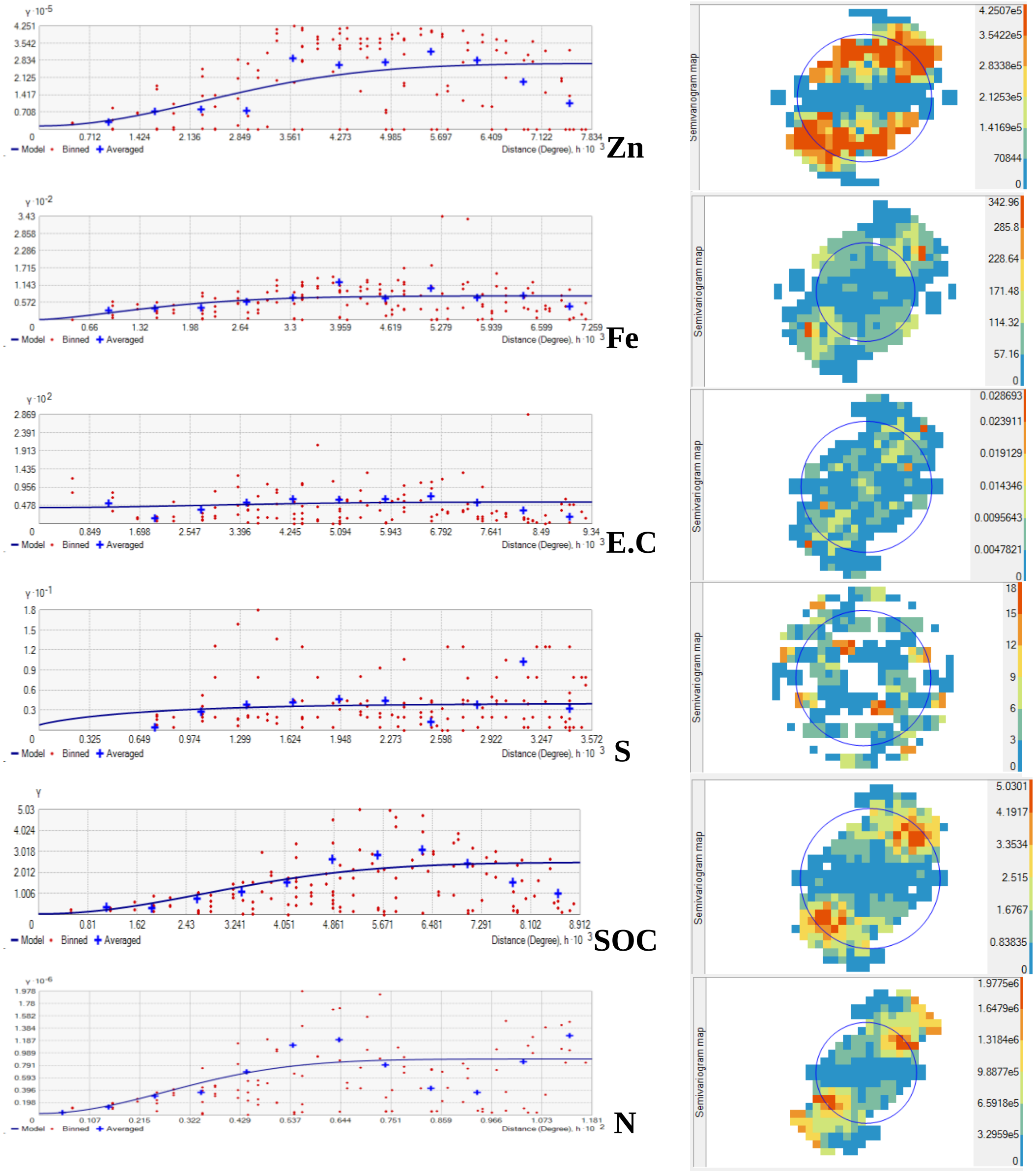


Figure 5variogramsemivariogram of the chemical properties of the soil samples computed for Ordinary Kriging

The Ordinary kriging showed better predictability, lesser RMSE and better fit than the Inverse Distance weighted method and hence was used for spatial mapping

RESULTS AND DISCUSSION

The soil samples were tested and the results are summarised as shown in Table 2. Kriging interpolation was used to map the spatial variation in the various soil characteristics.

pH

pH level in the Rinchenpongmouza varied from 4 to 7, which signifies that the soil samples are mostly acidic in nature. The northern and southern portions have less than 5.5 Ph value whereas the pH is highest at the sampling point no.1, which is situated near the dense vegetation cover along the way to the orchards. The pH value reduces outwards from the

TABLE 2 SOIL TEST RESULTS FOR THE SAMPLED POINTS

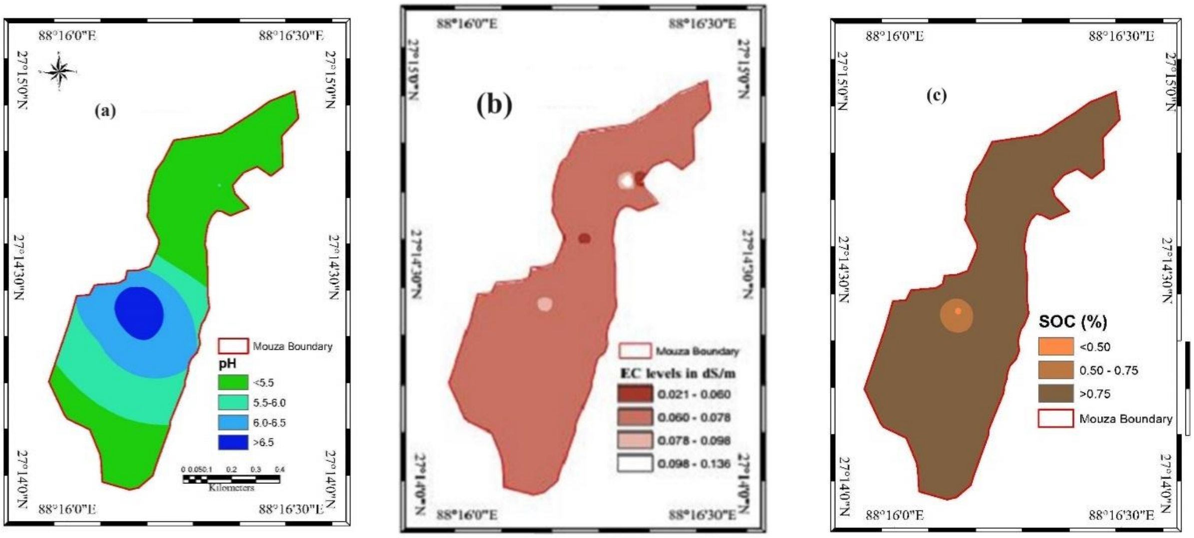
Sl_ no_	Latitude	Longitude	Elev (m)	pH	Phosphate (P)	Potash (K)	Manganese (Mn)	Copper (Cu)	Zinc (Zn)	Iron (Fe)	Electrical Conductivity (EC)	Sulphur (S)	Soil Organic Carbon (SOC)	Nitrogen (N)
1	27.240	88.269	1507	7.10	59	142	3.78	2.06	932	26.16	0.10	10	0.44	246
2	27.239	88.268	1500	6.10	21	151	4.54	7.32	12	28.96	0.07	8	1.22	732
3	27.237	88.266	1490	4.10	31	835	7.14	2.44	2	39.84	0.05	12	2.14	1284
4	27.236	88.265	1481	5.00	37	456	11.70	1.58	2	33.50	0.02	9	0.62	372
5	27.238	88.264	1452	5.10	31	244	4.92	3.00	12	40.48	0.04	10	1.58	948
6	27.243	88.271	1524	4.80	42	105	4.68	3.20	6	41.46	0.04	11	2.71	1626
7	27.245	88.273	1633	5.10	51	243	3.40	2.84	6	33.58	0.02	13	3.01	1806
8	27.245	88.272	1655	5.70	60	106	15.50	2.74	13	44.98	0.14	9	4.20	2520
9	27.244	88.272	1685	4.20	20	444	2.90	1.14	3	51.06	0.07	12	4.50	2700
10	27.246	88.274	1608	4.60	17	176	16.20	1.32	2	37.86	0.06	14	2.86	1716
11	27.246	88.271	1632	4.30	19	164	15.50	1.06	3	34.60	0.03	15	3.01	1563
12	27.246	88.270	1615	4.50	22	175	13.20	1.17	3	33.60	0.05	13	2.67	1666
13	27.244	88.273	1606	5.30	40	406	10.30	2.11	11	27.52	0.08	11	3.50	2620
14	27.241	88.269	1627	6.50	62	141	3.57	2.31	915	25.51	0.20	8	0.33	257
15	27.241	88.268	1598	7.00	60	139	3.69	1.68	865	24.87	0.10	11	0.28	287
16	27.240	88.267	1615	6.10	63	146	2.80	1.61	815	25.67	0.14	13	0.98	656
19	27.2	88.26	162	7.4	57	127	3.25	1.9	91	26.0	0.30	9	0.45	230

	40	8	1	0				9	1	4				
20	27.238	88.269	1695	5.00	32	801	7.16	2.56	2	40.69	0.06	11	2.37	1256
21	27.238	88.271	1709	4.70	29	820	7.32	2.21	1	41.08	0.10	13	2.00	1300
22	27.237	88.269	1714	6.20	33	798	7.00	2.32	2	38.72	0.15	11	2.15	1278

sampling point 1. Acidic soils are predominantly found here because rainwater leaches away basic ions of sodium, calcium, potassium and magnesium Bolan et al., 2005. Moreover, decomposed leaves and root respiration generates weak humic acid and nitric acids. As compared to the report of NBSSLUP, the pH value of the soil samples of our study are found to be similar. Figure 6 (a) shows the spatial distribution of pH across the mouza.

EC (Electrical Conductivity)

The soil electrical conductivity is measure of the amount of salts present in the soil. Values of EC below 1 are considered as a benchmark and values beyond 1 and ranging till 2 are considered to be critical in soils. In soils with low pH values, it is natural to have less than 1, EC values. The EC level in the soils of Rinchenpong mouza ranges from 0.078 to 0.098. Figure 6 (b) shows the distribution of EC which is mostly homogeneous across the study area.



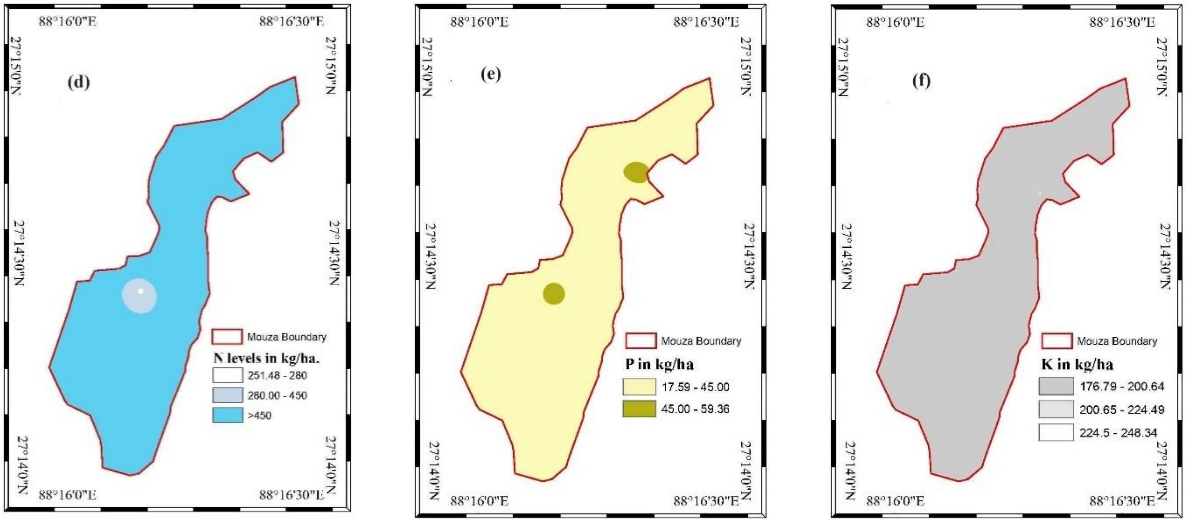


Figure 6 Interpolation (a) pH levels, (b) EC, (c) SOC, (d) N, (e) P, (f) K level in the soil samples of Rinchenpong

SOC (Soil Organic Carbon)

Organic matter constitutes just 2-10% of the soil mass but has a huge impact on the physical, chemical and biological functions of the soil. Above 58% of this organic matter exist as carbon. The Rinchenpong mouza contains more than 0.75 % of SOC which means it has high organic carbon present in the soil. The dense vegetation cover is the cause behind high carbon content in the soil. Figure 6 (c) shows the distribution of SOC in the area.

NPK (Nitrogen, Phosphate and Potash)

Nitrogen is a key component in many of the processes needed to carry out growth in plants. Nitrogen is required for chlorophyll which helps in photosynthesis and helps in development of amino acids which is the basis of proteins (Bassi et al., 2018). Nitrogen saturation causes soil acidification too (Bhattacharya, 2019). Phosphorous gives structural strength enhances crop quality, production, blooming and growth of roots. Potassium helps in betterment of quality, shape, colour and taste of any crop (Liu and Chen, 2014). It has been observed that Nitrogen levels have been exceptionally high in the study area showing a concentration of > 450kg/ ha. Though the villagers reported less or no use of chemical fertilizers but decomposed manuring could also result in such high concentration due to nitrogen fixation. Very low levels of phosphate have been found in the soils of Rinchenpong. The phosphate in the soil has ranged from 17.59 to 45.00 kg/ ha except in few locations having 59.36 kg/ ha. Even potassium content in the soil has been very low ranging from 176.79-200.64kg/ ha.

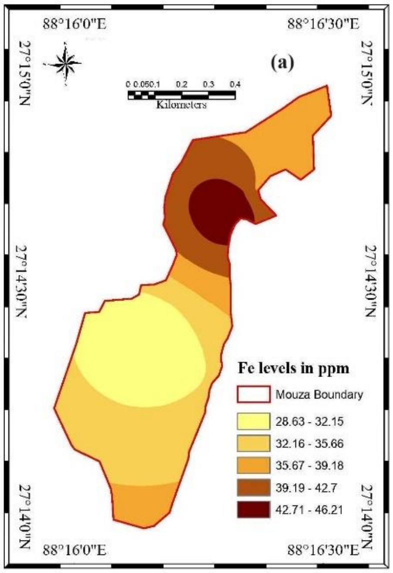
Micronutrients:

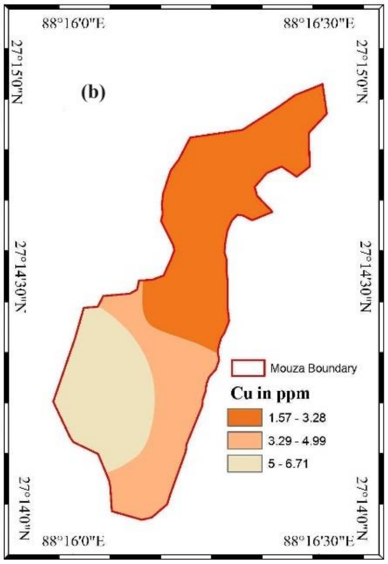
The micronutrients that were analysed during the soil test were sulphur, manganese, copper, zinc and iron. The normal concentration in soils is reported to be within 10-40 ppm for copper, 30-500 ppm for iron, 300-1000 ppm for manganese, 10-300 ppm for zinc (Pendias and Mukherjee, 2007; Prasad, 2008; Blum., et al, 2012, Ozturk et al., 2017). The laboratory test reports especially high ppm of micro nutrients. The table 3 shows the functions of different micro nutrients in plants (Neenu and Ramesh, 2020).

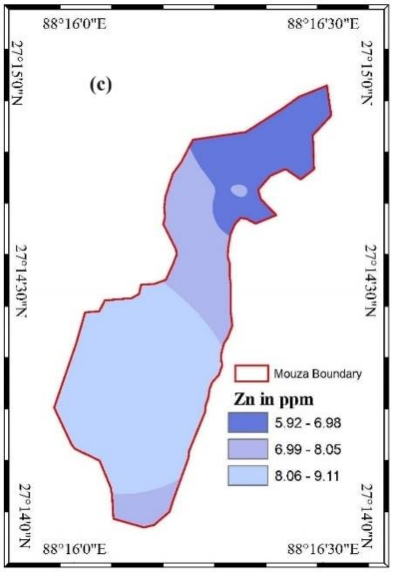
TABLE 3 ROLE OF MICRO NUTRIENTS IN PLANT GROWTH

Element	Function in plant
Cu	Components of enzymes, involved with photosynthesis
Fe	Components of enzymes, involved with photosynthesis, Essential for chlorophyll synthesis
Mn	Chloroplast production, co factor in many plant reactions, activates enzymes
Zn	Component of many enzymes, essential for plant hormone balance and auxim activity
S	Sulphur is the building block of protein and is essential for chlorophyll formation

The concentration of copper (Cu) is maximum in the centre and towards the north of Rinchenpong (1.57-3.28 ppm). Its content in the soil is moderately high towards the east of the mouza. The maximum concentration of 6.71 ppm of Cu is found on the west and south western part of the study area. The sampling points of 7, 8, and 9 have the highest concentration of Iron (Fe) in its soil. The Fe in the soil gradually decreases towards the west of the study area. But the areas around sampling point 1 and 2 have Fe levels lower than the desired values. Manganese (Mn) concentration of 8.2 to 9.2 ppm was found in the soil samples belonging to the north of Rinchenpong and lesser in amount in the soils of central and southern Rinchenpong. The top soil of the entire mouza is severely deprived of required amount of Mn. Low Mn values are common in organic soils. A similar pattern of distribution







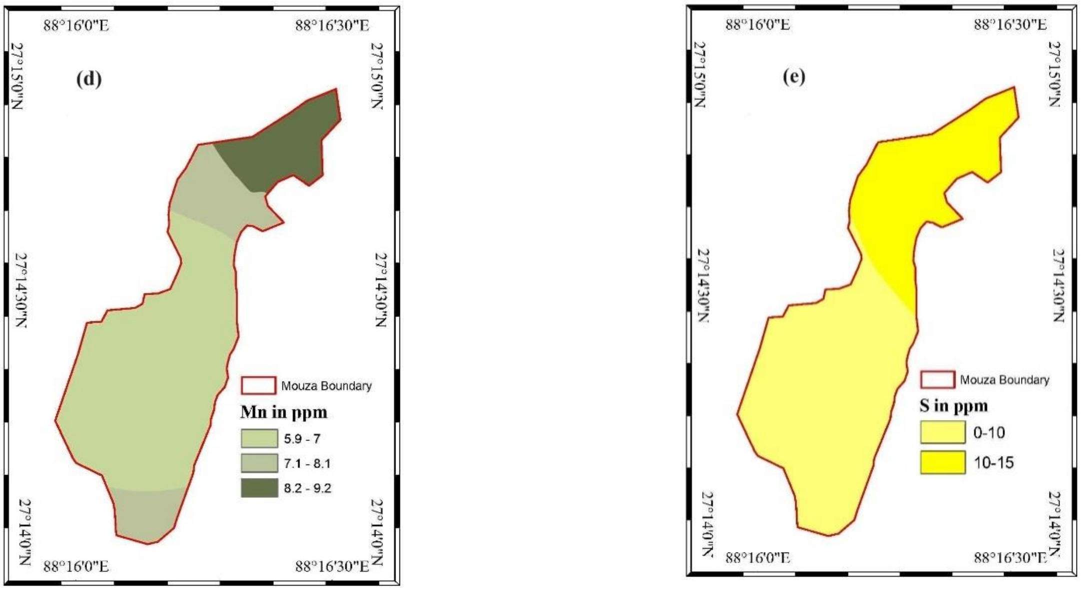


Figure 7 (a) Fe levels, (b) Cu, (c) Zn, (d) Mn and (e) S levels in soils sampled from Rinchenpong mouza.

of zinc is found in the soils. Sampling points 3,4, 6 and 9 have Zn lesser than the desired amount. 10-15 ppm of sulphur is found in the soils of northern Rinchenpong and 0-10 ppm in central as well as southern Rinchenpong.

The hill of West Sikkim mainly consists of Gneissose and schistose rocks, producing generally poor and shallow clayey soils (Gangyopadhyay et al., 2021). The soils are mainly coarse, with large concentrations of iron oxide which makes the soil colour reddish brown. The soil ranges from neutral to acidic and lacks organic as well as mineral nutrients except under thick vegetation cover. According to theSoil Series of Sikkim, NBSSLUP Publication105, technical bulletin, the soil found in the Rinchenpong Mouza area belongs to the Chongrang series. It is a coarse loamy, mixed, Thermic Entic Hapludolls. The soil is excessively drained and moderately permeable. The depth of a horizon varied from 25-50cm. The colour of the soil is 10 YR asper the Munsell soil chart. The textural classification is silty loam. The depth of C horizon is around 100cm with colour 10YR. Some physical and chemical properties of the soil horizons as per Soil Series of Sikkim, NBSSLUP Publication105, and technical bulletin have been tabulated in Table 4.

TABLE 4 SOIL CHARACTERISTIC OF RINCHENPONG GRAM PANCHAYAT

Horizon	Depth (cm)	Particle size diameter (mm)			% of the whole soil	pH	Organic Carbon %	Exchangeable bases					CEC	Base Saturati
		Sand 2-0.5	Silt .05-.002	Clay <0.002	Coarse fragments >2mm			Ca	Mg	Na	K	Sum		
Ap	0-28	26.4	52.9	20.7	10	4.4	2.5	3.5	2.5	0.4	.4	6.3	12.8	53
Ac	28-47	43.6	36.7	19.7	15	4.5	0.85	3.1	2.3	0.4	.3	5.8	11.5	53

C11	47-70	50.0	33.3	16.7	25	5.8	0.42	2.9	1.8	0.4	.3	5.4	8.7	62
C12	70-100	55.6	32.7	11.7	35	5.9	0.42	2.2	0.9	0.3	.4	3.8	5.9	64

(Source: NBSSLUP)

The values show similarity with the test results obtained from the soil sample tests. Higher number of soil samples provide more accuracy and spatial variability being mapped gives an added advantage for decision making in land resource management.

CONCLUSION

The Ministry of Agriculture and Farmers Welfare, Government of India had introduced the Soil Health Card (SHC) scheme in the year 2015. The card contains test results of 12 soil parameters, N, P, K (Macro-nutrients); S (Secondary- nutrient); Zn, Fe, Cu, Mn, Bo (Micro - nutrients); and pH, EC, OC (Physical parameters), on the basis of which the fertilizer recommendations and soil conservation measures are suggested in the cards. The initiative has been an excellent one where the farmers would be able to assess the health of the soil once in every three years. Of 64,9,481 villages (2011 Census) in India, 20,18,522 soil samples of soil has been collected as given in https://www.soilhealth.dac.gov.in/ under the SHC scheme by the year 2019-2020 and 19,64, 783 soil samples have been tested. In Sikkim 2936 samples has been collected and tested. In https://soilhealth.dac.gov.in/PublicReports/nutrientstatussamplesurveywise it has been shown the around 40 farmers in Rinchenpongvillagehave enlisted themselves to attain the benefits of SHC scheme.From the https://www.soilhealth.dac.gov.in/NewHomePage/StateWiseNPKChart website it can also be observed that in the Rinchenpong village 44% of the soil samples have low Nitrogen (N), and 56% have medium N concentration. 52% of the tested soil has medium Phosphorous (P) content, 40.8% has high P and 7.1% has very high P values. Similarly, 74 % of the soil has medium Potassium (K), 21% has high K and 5% of the soils tested have very low K values. The Graphs from the website are shown in Figure 8.

State : Sikkim
District: West District
Sub-District: Soreng
Village: Rinchenpong

Figure 8 Soil Test results of the samples from Rinchenpong Village as per SHC scheme

The pH values of the soil samples as seen from https://www.soilhealth.dac.gov.in/NewHomePage/StateWiseNPKChart prove the soils of Rinchenpong are acidic in nature. 51% of the soils tested were moderately acidic, 12% highly acidic, 23% slightly acidic, 9 % of the soil is neutral and 5% of the soil is moderately alkaline. In case of presence of micro nutrients except for Sulphur most soil samples have shown sufficiency in the soil. Grid wise soil analysis has also been conducted for 113 sites and has been uploaded in https://soilhealth.dac.gov.in/PublicReports/GridFormNSVW which also matches to a great extent with the test results of this study. But low in literacy and technically not sound enough the farmers of Rinchenpong do not have access to these data sets and hence the research works do not prove to be effective in managing the problem at the grass root level or reaching the target audience. Trivedi and Dutta, 2020writes most of the farmers have an issue that the soil is not from their fields. So, apart from grid sampling, point sampling procedure should be followed to minimize the inter-field heterogeneity leading to farmer-specific recommendations.Trivedi and Dutta, 2020 has also enlisted several loopholes in the SHC schemes such as lack of infrastructure, man-power in soil testing which has resulted in humungous gap between the soils sampled, soil tested, cards printed and distributed. Moreover, large numbers of marginal farmers are not aware about the SHC scheme. In orderto reduce the time gap and fasten the deliberation of test results, interactive village soil maps like the one in this study and even at cadastral level enabled with WebGIS or MobileGIS would be the most fruitful. The Digital India drive, narrowing digital divide post covid pandemic and with smartphone access in most households' digital soil maps will prove to be a game changer. Training of farmers in sampling the soil and using the map is essential. Added with the maps, the recommendations of soil, water and fertilizer management will enable the fast as well as sustainable soil conservation and agricultural practices.

Acknowledgements

The authors are grateful to the students of department of Geography, Bankura Zilla Saradamani Mahila Mahvidyapith for helping in collecting the soil samples and the scientists at the Soil Testing Laboratory, Nutanchati, Bankura for enabling the scientific testing of the different soil parameters.

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