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Cropping System Impact on Soil Chemical Properties of Northern Punjab, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study examined effect of cropping systems (rice-wheat, maize-wheat, sugarcane, mango, litchi, eucalyptus, poplar, and barren land) on selected soil chemical properties in the northern Punjab. Soil samples were collected from different cropping systems at 0-15, 15-30, 30-60, 60-90, and 90-120 cm depths and analyzed for pH, electrical conductivity (EC), soil organic carbon (SOC), available potassium, available phosphorus, and DTPA extractable micronutrients (zinc, iron, manganese, and copper). The study showed that soil chemical properties were significantly influenced due to cropping systems. Higher values of pH, EC, available phosphorus, and potassium were observed in rice-wheat and maize-wheat systems, while higher SOC and DTPA extractable micronutrients were found in poplar and eucalyptus systems. All soil properties showed higher values at the surface layer (0-15 cm) and decreased with depth, except for pH, which increased with depth. The study highlights the importance of cropping system choice in maintaining soil health and fertility.

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Keywords: Cropping system; micronutrients; soil depth; soil chemical properties.

1. INTRODUCTION

Successful agriculture requires sustainable use of soil resource. A success in soil management to maintain the soil quality depends on an understanding of how the soil responds to agricultural practices over time. In agricultural systems, soil and crop management decisions affects soil quality, soil nutrient dynamics and soil chemical properties. These management decisions include crop rotation, residue management, and the intensity and frequency of tillage [1]. Cropping system is another approach which influences the soil properties and the cycling and availability of nutrients. The change in cropping system results in variation of soil properties like pH, soil organic carbon (SOC), cation exchange capacity (CEC), soil structure, macronutrients and micronutrients [2] which leads to variation in the soil fertility and productivity of soil. The availability of important macro and micronutrients in the soil, as defined by Tisdale et al. [3] is referred to as soil fertility. Distribution and availability of macronutrients to a certain extent are also influenced directly or indirectly by change in crop cultivation, biomass production and soil organic matter (SOM) content [4]. Soil micronutrients availability also depends on soil pH, SOM content and various physical, chemical and biological conditions of the rhizosphere. The variation in soil chemical properties and the nutrient availability is affected to a great extent by the change in cropping systems [5], Wasihun et al., 2015). Moreover, crops do not only take nutrients from surface layer but also draw a part of their nutrient requirement from subsurface layer of the soil. Hence, the knowledge of vertical distribution of nutrients is very important in recommending management practices [6]. Because soil is a vital component of the earth's biosphere and plays a role in maintaining local, regional, and global environmental quality in addition to producing food and fibre, there has been a recent interest in assessing the quality of our soil resource. Sustainability of agriculture requires the careful management of soil resources to maintain soil quality and productivity. Cropping systems influence soil properties, nutrient cycling, and availability, impacting soil fertility and crop yields. This study evaluates the impact of different cropping systems on soil chemical properties which provides insights into soil fertility dynamics and effective management practices.

2. MATERIALS AND METHODS

2.1 Study Site

The investigation was carried out in Gurdaspur district of Punjab. The region is located in the northernmost part of Punjab state, between latitude 31° 08' and 32° 31' N and longitude 74° 30' and 76° 20' E, at an elevation of about 265 m above mean sea level. Soil samples were collected from various sites representing different cropping systems. The soil texture in the samples varied from sandy loam to loam.

2.2 Climate

The region is characterized by high precipitation and high humidity with extremely hot and dry summers. The study area experiences a sub-humid and sub-tropical climate with three distinct seasons; Summer (April to June), Monsoon (July to September), Hot and moist, Winter (November to March). The region receives higher rainfall than central Punjab, with an average annual rainfall of around 1100 mm, two-thirds of which occurs during the monsoon season. Relative humidity remains above 80% throughout the summer season.

2.3 Cropping Systems and Soil Sampling Design

Rice-wheat, maize-wheat, sugarcane, mango, litchi, poplar, eucalyptus, and barren land were cropping systems used for the study. Soils of rice-wheat, maize-wheat, sugarcane, mango, and litchi cropping systems were continuously cultivated for 10 years and more, while the soils under the poplar and eucalyptus systems were 7 years older or more. The barren land was uncultivated and lacked plantation during the sampling period. The cropping systems were replicated at eight locations and soil were sampled at 0-15, 15-30, 30-60, 60-90, and 90-120 cm depths. Sampling coordinates were recorded using a Global Positioning System (GPS). Soil samples were collected using a steel auger and air-dried under shade, then ground to pass through a 2 mm sieve.

2.4 Soil Analysis

Soil pH: The potentiometric method was used to determine soil pH in a 1:2 soil-water suspension. Soil pH was measured using a glass electrode pH meter after equilibrating the soil with distilled water for half an hour [7].

Electrical Conductivity: Soil electrical conductivity was measured in a 1:2 soil-water suspension kept for 24 hours. The soluble salts were measured after obtaining a clear supernatant solution and expressed in deci siemens per meter (dS m^{-1}) [7].

Organic Carbon: Organic carbon (OC) in soil was determined by the rapid titration method (Walkley and Black, 1934). In a 250 ml conical flask, 2 g of air-dried soil sample was mixed with 10 ml of 1 N potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml of concentrated sulfuric acid (H_2SO_4). Sodium fluoride (0.5 g) and distilled water (100 ml) were added, along with a diphenylamine indicator. The mixture was titrated against 0.5 N ferrous ammonium sulfate solution until the violet color changed to bright green. A blank sample without soil was also run for comparison.

Available Phosphorus: It was determined using 0.5 N sodium bicarbonate ($NaHCO_3$) adjusted to pH 8.5 [8]. The filtrate was treated with 5 N sulfuric acid, ascorbic acid solution, and distilled water, then measured using a colorimeter at 760 nm. The phosphorus content was calculated based on color intensity.

2.5 Available Potassium

Available potassium was determined using neutral ammonium acetate (pH 7) as an extractant [9]. The filtrate was aspirated into a flame photometer, and the reading was used to calculate available potassium in kg ha^{-1}.

2.6 DTPA-Extractable Micronutrients

DTPA-extractable Zn, Fe, Mn, and Cu were determined using the method by Lindsay and Norvell (1978). Soil samples were shaken with DTPA solution for 2 hours, then filtered and measured using an atomic absorption spectrophotometer. The micronutrient content was expressed in mg kg^{-1}.

2.7 Statistical Analysis

The physicochemical properties of soil were analysed using a factorial randomized block design with two-way analysis of variance (ANOVA). Significant differences among soil samples were assessed using the least significant difference (LSD) test at a significance level of $p \leq 0.05$. The correlations between soil properties and micronutrient fractions and their interrelationships were evaluated using SPSS version 23.

3. RESULTS AND DISCUSSION

3.1 Soil PH

The soil pH among different land use systems increased with an increase in soil depth from 7.2 to 7.6, which might be due to decrease in OC [10]. The interaction of different land use systems and soil depth was observed to be non-significant. The soil pH varied significantly among different cropping systems (Fig. 1) ranged from 7.2 to 7.8 with the highest pH values in the agriculture land use system, however, the soil pH in other land use systems i.e. horticulture, forestry and barren land were found statistically at par with each other. Soil pH remained neutral across all land uses, with slightly higher values in agricultural systems. Soil pH increased with depth, indicating a potential leaching or buffering effect at deeper layers.

3.2 Soil Electrical Conductivity (EC)

Among the different land use systems mean value of soil EC varied from 0.10 to 0.16 dS m^{-1} with significantly highest EC values in the agriculture system however, the soil EC in horticulture and forestry systems were found statistically at par and the soil EC in the barren land was significantly lower than the other respective systems. The decrease in soil EC value with the increase in soil depth under all land uses was observed and the higher EC values were recorded in the cropland, lower in forestry, grassland and uncultivated soil [11,12,13]. Soil EC among different land use systems decreased from 0.16 to 0.11 dS m^{-1}depth-wise and the reason for higher soil EC in the surface layer was due to higher nutrient ions, and with the decrease in nutrient ions with depth, the EC decreased [14]. The different land use systems and soil depth interaction was found to be non-significant. The soil EC among rice-wheat, maize-wheat and sugarcane sub systems varied from 0.14 to 0.16 dS m^{-1}. In the horticulture system, soil EC ranged between 0.12 to 0.13 dS m^{-1} among mango and litchi-based sub systems. Similarly, in the forestry system, soil EC among poplar and eucalyptus sub systems ranged between 0.12 to 0.13 dS m^{-1}. The higher soil EC in the agriculture system might be due to the continuous addition of salts through fertilizers. Agriculture systems exhibited the highest EC values whereas Horticulture and forestry systems had lower EC values.EC decreased with depth, indicating reduced soluble salt concentrations as soil depth increases.

3.3 Soil Organic Carbon (OC)

OC levels were highest in poplar, eucalyptus, litchi, and mango-based cropping systems (Fig. 1), followed by sugarcanemaize-wheat, rice-wheat, and barren land systems. The highest

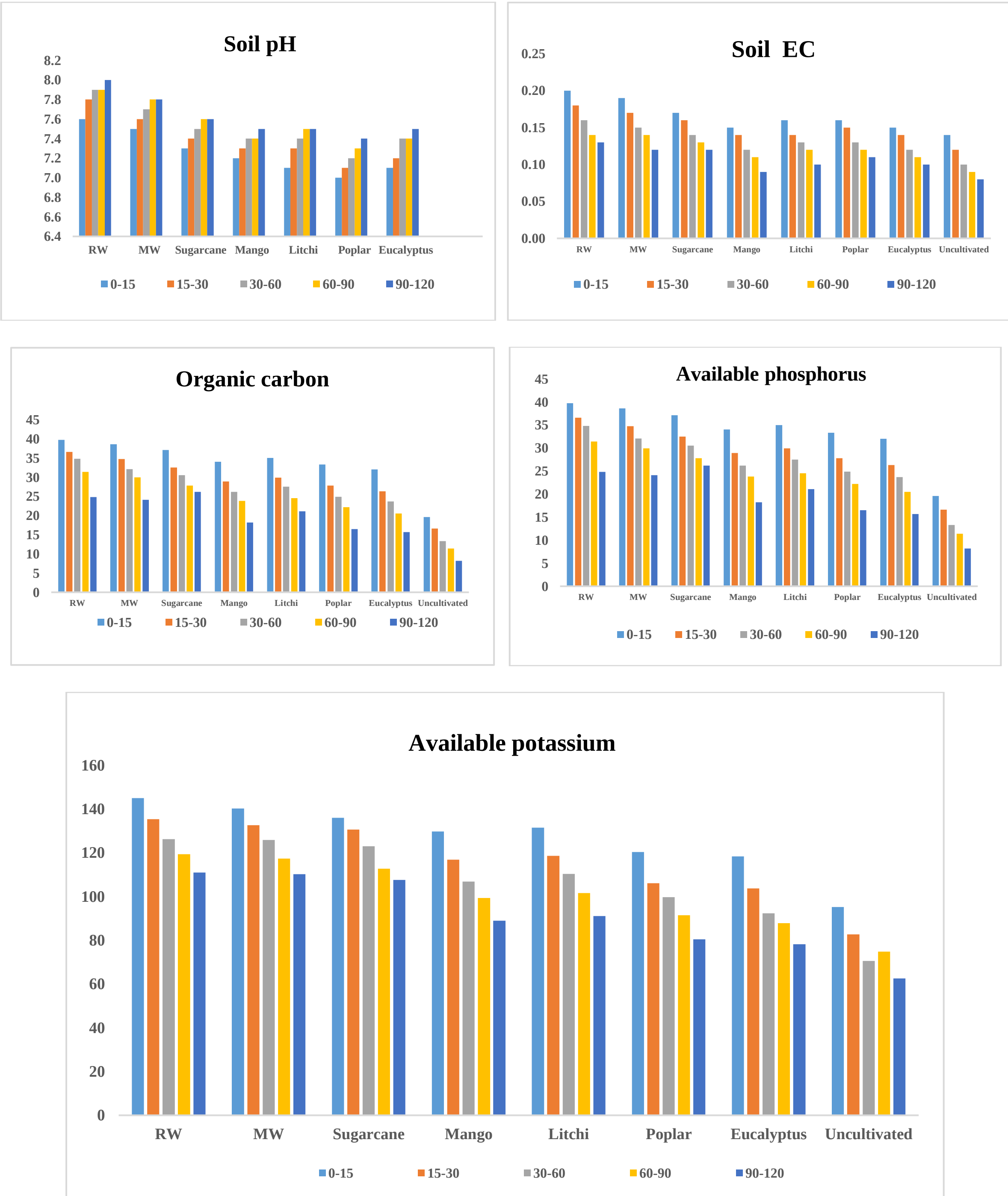

Fig. 1. Effect of cropping systems and soil depths on soil chemical properties

Table 1. DTPA-extractable micronutrients as influenced by cropping Systems and soil depth

Cropping Systems	DTPA Zn	DTPA Fe	DTPA Mn	DTPA Cu
		(mg kg^{-1})		
Rice-Wheat	0.63	12.2	3.60	0.97
Maize-Wheat	0.60	12.0	3.46	1.01
Sugarcane	0.58	13.8	3.73	1.03
Mango	1.79	15.2	6.26	1.15
Litchi	1.90	16.1	6.52	1.18
Poplar	2.07	18.0	7.66	1.27
Eucalyptus	1.99	17.2	7.37	1.24
Barren Land	0.31	8.42	1.90	0.66
LSD (p=0.05)	0.16	1.10	0.63	0.13
Soil depth (cm)				
0-15	1.56	18.1	6.20	1.20
15-30	1.32	16.3	5.27	0.13
30-60	1.20	14.2	4.97	1.06
60-90	1.12	12.2	4.69	1.01
90-120	0.99	9.76	4.17	0.93
LSD (p=0.05)	0.12	0.87	0.50	0.11

OC values were found in surface soils, with content decreasing with depth. The increased OC in poplar, eucalyptus, litchi, and mango-based systems can be linked to the addition of organic matter from leaf litter and dead roots. In contrast, lower OC levels in rice-wheat and maize-wheat systems may result from the lower return of organic matter to the soil and a higher oxidation rate due to continuous cultivation [15]. Sugarcane had the highest OC content among agriculture systems, indicating better organic matter retention. It decreased significantly with depth, meaning most organic material is concentrated in surface layers.

3.4 Soil Available Phosphorus and Potassium

Available phosphorus and potassium were higher in rice-wheat and maize-wheat cropping systems (Fig. 1) and lower in sugarcane, litchi, mango, poplar, and eucalyptus-based systems, with barren land having the lowest values. The content of these nutrients decreased with soil depth. Higher phosphorus levels in rice-wheat and maize-wheat systems attributed to the greater application of phosphatic fertilizers compared to other systems [11,12]. The higher organic matter in surface soils contributes to the decrease in available phosphorus with increasing depth [16,13]. Phosphorus availability also decreased with depth indicating nutrient accumulation in surface layers.

3.5 DTPA Extractable Micronutrients (Zn, Fe, Mn, and Cu)

DTPA extractable micronutrients were significantly higher in poplar, eucalyptus, litchi, and mango-based cropping systems (Table 1), and lower in rice-wheat, maize-wheat, and sugarcane-based systems. The higher levels of micronutrients in poplar, eucalyptus, litchi, and mango-based systems was attributed to the higher organic matter content from decomposed tree leaves and root biomass [17-20]. In contrast, lower micronutrient levels in rice-wheat, maize-wheat, and sugarcane-based systems were due to nutrient depletion from continuous crop cultivation [21,19]. The decrease in DTPA extractable micronutrients with soil depth is linked to the reduction in OC content with depth [22,20]. Micronutrient availability decreased with depth, highlighting their surface accumulation [23].

4. CONCLUSION

The study underscores the importance of understanding how different cropping systems influence soil chemical properties. The findings highlight the need for sustainable soil management practices to mitigate the adverse effects of intensive agricultural practices on soil fertility management. The forestry systems, particularly poplar and eucalyptus showed better soil fertility status in terms of organic carbon content and micronutrient availability. However, among agricultural systems, in rice-wheat cropping system, nutrient availability and organic carbon content was good. For long-term sustainability and improved soil organic matter, integrating agroforestry (combining trees and crops) might be beneficial due to high nutrient content.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that Large Language Model ChatGPT, Grammarly have been used for editing of the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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