Impact Of Agricultural Practices On Soil Health: A Case Study From Shivalik Foothills Of Uttarakhand India

Anudita Chamoli[1], Shruti Saxena[*] and Meenakshi Bharti[2]
[1]Research scholar, Shri Guru Ram Rai University, Dehradun Uttarakhand, India.
*Assistant Professor, Shri Guru Ram Rai University, Dehradun Uttarakhand, India.
[2]Scientist, Department of Zoology and Environmental Sciences,
Punjabi University, Patiala Punjab, India.
***-Corresponding author Email: : shrutigwl@gmail.com**

Abstract

In order to assess the effects of pesticide use as an agricultural practice on soil health, soil samples were collected from three different eco-environments (forest, agriculture, and urban), and the comparative nutritional status was examined. A survey was also conducted with 65 farmers from 8 villages in Dehradun (Uttarakhand) to assess the effects of pesticide use on farmers' health as well as to assess farmers' knowledge and practices surrounding pesticide use. Pre-tested questionnaires were used to gather data on the aforementioned criteria, which were then, analyzed using the right statistical software. 93% of respondents used pesticide, 44.6% were aware of its effects on health and the environment, 64% disposed of leftover pesticide in the field, and 18% reported having complaints about various health conditions. Significant correlation was found between health problems and disposal methods. Regarding pH and conductivity, the nutritional condition of soil from three ecosystems varied greatly. Forest and agricultural soil samples had considerably different levels of organic carbon, potash, and iron. The amounts of copper in soil samples from agricultural and urban areas varied significantly.

Keywords: Soil health, farmer health, pesticide, environment, awareness

DOI: 10.48047/ecb/2023.12.7.294

1. Introduction

Humans have started to change their surroundings and depend on soil since the beginning of agriculture (about 11,000 years ago). There are many instances of civilizations collapsing because their soil resources were mismanaged throughout the history of human agriculture (Diamond 2005). The modern societies are also dealing with a serious decline in soil resources, due to increase in World population which has further led to high demand of food (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2018). In light of the ecosystem services that both the agricultural and natural ecosystems provide, it is crucial to assess the soil quality (Bunemann et al. 2018) as soil health determines "the soil's ability to support crop development without getting deteriorated or otherwise harming the environment" (Acton and Gregorich 1995).

In Uttarakhand, a sizable portion of the topography is steep with mainly rain-fed subsistence farming. Its undulating topography, diverse climate, sparse arable land, high proportion of small and marginal holdings, challenging working conditions, high input costs, low yields on food grain crops, sparse settlement, soil erosion, and land degradation, as well as inadequate infrastructure, such as poor transportation options in remote areas, pose significant obstacles to the development of agriculture. With 21% of cultivable land, two third of Uttarakhand people are involved in farming business and majority of farm families are semi – literate or illiterate. Agricultural land in hills can lose as little as 2 tonnes of soil per year by surface erosion to as much as 105 tonnes per year (Acharya et al. 2007).

Since the 1990s, a wide range of tools for measuring and assessing soil quality have become available (Acton and Gregorich 1995; Wang et al. 1997; Macdonald et al. 1998; Andrews and Carroll 2001; Andrews et al., 2004; Karlen et al. 2001; Wienhold et al. 2004, 2009; Guimaraes et al. 2011; Ball et al. 2017). As part of quality evaluation and system adaptation, soil quality must be taken into account (Stavi et al. 2016; Mader et al. 2002; Seufert and Ramankutty 2017). Our impact on natural resources has beyond its bounds due to growing populations, economic growth, and international trade (Weidmenn et al. 2015; Willemen et al. 2020).

Farmers are crucial stakeholders who must be included in programmes for soil conservation because information on their agricultural practices and observations of the soil and plants have been very helpful in developing programmes for soil quality assessment (Romig et al. 1996; Mueller et al. 2013; Abdollahi et al. 2015). One agricultural practice that negatively affects the environment and human health is the use of pesticides (Soerjani 1990; Tsimbiri et al. 2015; Damalas and Koutroubas 2016; De Joode et al. 2016; Barraza et al. 2020; Joko et al. 2020).

The goal of the current study was to gather data with respect to soil health as a result of agricultural practices, to compare the soil's nutritional quality to that of other habitats in villages of Dehradun, to assess agricultural practices and awareness of the risks associated with pesticide use among Indian farmers and its influence on their health and the environment

2. Materials and methods

2.1 Study sites and data collection

The Himalayan foothills of the Shivalik range are where Dehradun, the state capital of Uttarakhand, is located (30018'59.3856" N, 780 01'55.8768" E). With four distinct seasons—winter (December to February), summer (March to May), monsoon or south-west season (June to September), and post-monsoon season (October to November), it has an extreme form of continental climate. The average temperature is roughly 35°–36°C, with summertime highs of up to 41°C and wintertime lows of 1°–2°C.

The crop season of Uttarakhand can be divided into rabi, kharif and zayad based on sowing and harvesting season with major crops wheat, rice, sugarcane, mustard, pulses and vegetables. People in Uttarakhand rely heavily on agriculture for their livelihood, but as time has gone on, population expansion has out placed agricultural production, increasing the inputs of chemical fertilizers and pesticides in their field.

Based on pesticide usage in relation to the types of crops grown, the study was conducted in eight villages (Devipur, Ummedpur, Palio, Jhiberhedi, Bhoodpur, Malhan, Simlas Grant, and Sherpur) of the Dehradun district. Using a minimum of 3 to 4 acres as a screening threshold, farmers were chosen for the survey based on the land they were cultivating. Using a standardized and previously tested questionnaire, 65 farmers were all individually questioned; pesticide list was made to check the usage of banned pesticide and soil health of the agricultural land was accessed.

2.2 Survey questionnaire and data analysis

To gather data on the pattern of pesticide consumption for which pre-coded alternatives were used, a survey questionnaire for farmers was created. With a focus on gathering data on farmers' practices regarding the use of pesticides and their awareness of its effects on health and the environment, basic socioeconomic status data, were gathered. From individual farms, specific data was gathered on names of pesticides used, health issues associated with pesticide use, disposal methods for any leftover pesticide, and pesticide container reuse. It featured awareness questions with two understandable responses, complete awareness and no awareness, each with a score of 1 and 0. Each responder was asked for their opinion, point of view, or advice in order to gauge their level of normative knowledge. Finally, using an appropriate statistical technique (SPSS), the data gathered through surveys was coded, keyed, and analyzed.

2.3 Soil sampling and processing

To compare soil health in disturbed and undisturbed areas, three separate areas were picked i.e. agricultural land, forest and urban area. A total of 27 soil samples were taken from 9 different locations from agricultural, urban, and forest areas during a period of 3 months from October – December 2021, at a depth of 1 to 2 cm, in accordance with the Soil Authority of India's procedure for agricultural soil evaluation and fertilizer recommendation. The soil samples were gathered, labelled, and put in wooden trays. All soil samples were air dried naturally at room temperature (temperature not exceeding 35°C and relative humidity between 30 and 60%) in the laboratory, and organic material, stones, plants, pebbles, debris, and plant roots were removed before sieving. Following that, the materials were run through a sieve with a mesh size of 150mm. Each 500 g dried sample was then packaged for additional analysis

2.5 Analysis of nutritional status of the soil samples

By evaluating the primary nutrients, secondary nutrients, and micronutrients in the soil, the nutritional status of the soil was examined. The soil samples' pH and electrical conductivity were also assessed. The main macronutrients were potash, phosphorus, and organic carbon. Sulphur was a secondary macronutrient, whereas zinc, iron, boron, manganese, and copper were micronutrients. Electrical conductivity was measured using a conductivity meter, while pH was determined using a pH meter. The amount of organic carbon was determined using the titration method (Walkley and Black 1934), phosphorus using the Watanabe and Olsen (1965), available potassium using the flame photometric method (Toth and Prince 1949), sulphur using the barium sulphate precipitation method, and micronutrients using DTPA extraction and atomic absorption spectroscopy (Lindsay and Norvell 1978).

3. Data analysis

All soil-related data were represented as mean S.E.M. By utilizing GraphPad Prism 5 and Bonferroni Post tests, statistical comparisons were done between the soil samples and the agricultural, forest, and urban habitat. Every comparison used the 0.005 level as the threshold for lowest statistical significance.

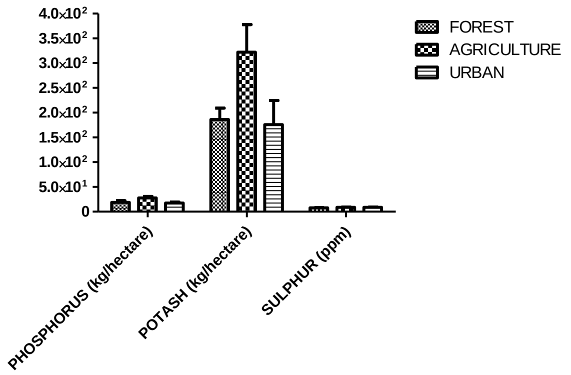
4. Results

4.1. Soil Health

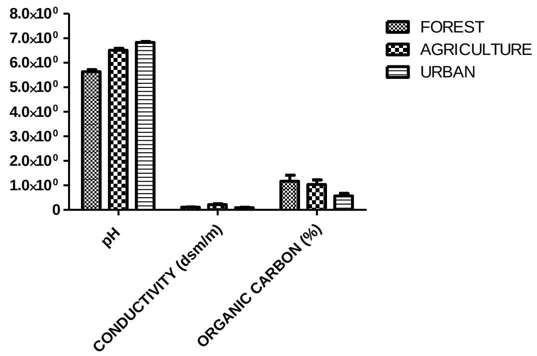
By evaluating the primary nutrients, secondary nutrients, and micronutrients in the soil, the nutritional status of the soil was examined. The soil samples' pH and electrical conductivity were also assessed. The main macronutrients were potash, phosphorus, and organic carbon. Sulphur was a secondary macronutrient, whereas zinc, iron, boron, manganese, and copper were micronutrients. Electrical conductivity was measured using a conductivity meter, while pH was determined using a pH meter. The amount of organic carbon was determined using the titration method (Walkley and Black 1934), phosphorus using the Watanabe and Olsen, 1965, available potassium using the flame photometric method (Toth and Prince 1949), sulphur using the barium sulphate precipitation method, and micronutrients using DTPA extraction and atomic absorption spectroscopy (Lindsay and Norvell 1978). The Table 1 presents the reference Range and Observed Values of Nutrients and figure 1 present a comparative analysis of the soil from all the three habitats.

Table 1. Reference Range and Observed Values of Nutrients

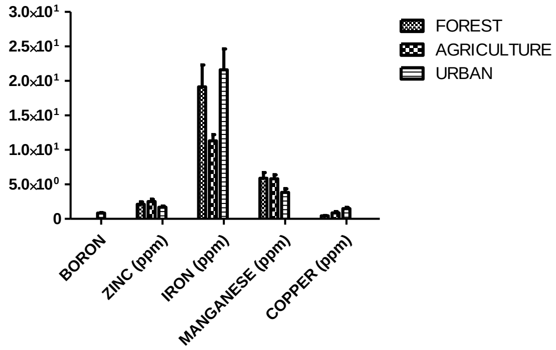
S. No	Macro/ micronutrients	Reference range	Mean values in forest soil samples	Mean values in agriculture soil samples	Mean values in urban soil samples
1	pH	6.5 – 8.5	6.83	6.52	5.6
2	Conductivity	1 – 3	0.22	0.11	0.09
3	Organic carbon (%)	0.5 – 0.75	2.16	1.04	0.57
4	Available phosphorous (kg/hectare)	28 - 56	18.92	27.87	17.42
5	Available potash (kg/hectare)	140 - 280	296.76	186.27	93.52
6	Sulphur (ppm)	10 - 20	7.86	8.92	8.85
7	Boron (ppm)	1 - 2	0.84	0.83	0.84
8	Zinc (ppm)		2.12	2.50	1.69
9	Manganese (ppm)	5 - 10	5.88	5.81	3.84
10	Copper (ppm)	0.2 – 0.4	0.44	0.76	1.48
11	Iron (ppm)	5 - 10	12.72	13.55	21.78



(a)



(b)

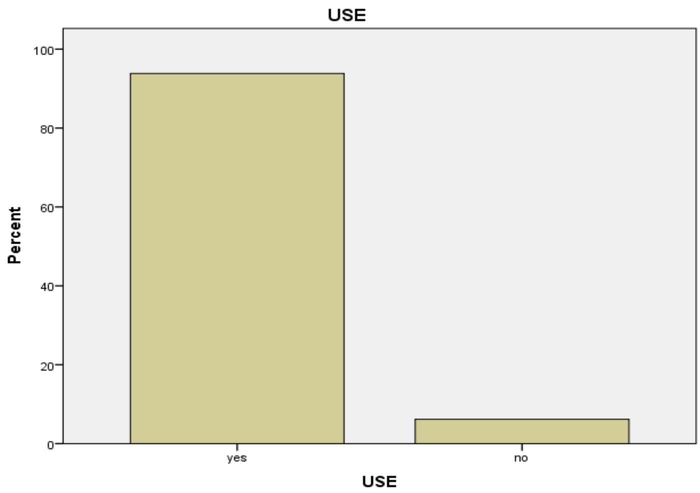


(c)

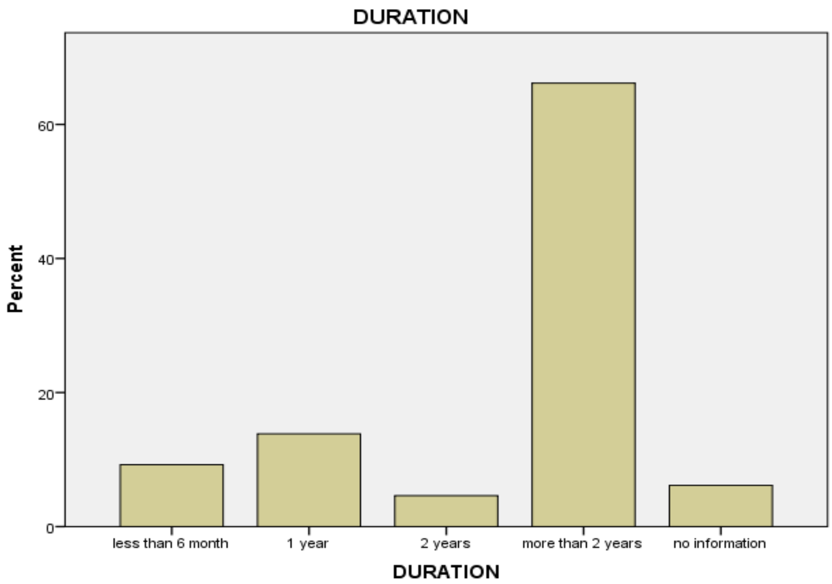
Fig. 1 Comparative analysis of soil from all the three eco habitats for a) p^H, conductivity and organic carbon content b) phosphorus, potash and sulphur content c) boron, zinc, iron, manganese and copper content

4.2. Farmers' agricultural practices and application of pesticide

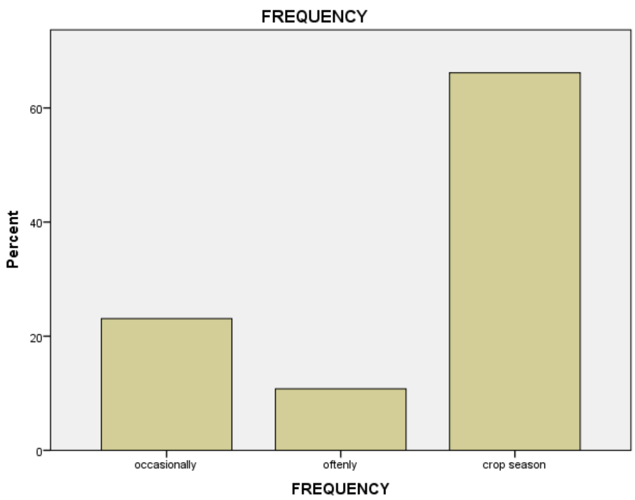
According to the results of the current study, 93% of the respondents used pesticides as shown in Fig 2a, with the majority of them having done so for longer than two years as shown in Fig 2b. Only 10.8% of farmers used pesticides after noticing a pest infestation as shown in fig 2c, while 66% of farmers used pesticides during the crop season. It was found that the majorities of the respondents were using their own doses and schedules to prevent financial loss, such as applying pesticides prior to pest invasion as a preventative strategy. In support of this, earlier research revealed that 80% of the Indian farmers polled relied on erroneous information regarding plant protection (Shetty et al. 2010). These farmer stereotypes are prevalent in the agricultural practices of other Asian nations, such as Palestine, where only 56.1% of pesticides were used at the required dose (Yassin et al. 2002).



(a)



(b)



(c)

Fig. 2 Bar diagrams depicting a) proportions of farmers using the pesticide b) duration for which pesticide has been used c) frequency of use of pesticide

4.3. List of pesticide used in the area of study

India has many growing season due to prevalence of high temperature through a long period. Different crop seasons are based on sowing and harvesting season of crops. Kharif are sown at the beginning of south west monsoon and harvested at the end of south – west monsoon, rabi need relatively cool period during the period of growth but warm climate during the germination of their seed and maturation, beside rabi and kharif crops zaid are being raised throughout the year due to artificial irrigation. The table 2 presents the list of common pesticides used by surveyed farmers for major crops.

Table 2. List of common pesticides used by surveyed farmers for major crops.

Crop Season	Major Crops grown	Pesticide used by the farmers	Pesticides banned
Rabi (October – April)	**Wheat**	**1 Propiconazole 25%EC 2 Carbaryl 3 Thiamethoxam 1% + Chlorantraniliprole 0.5%**	
Kharif (May – October)	**Rice Sugarcane**	**1 Aluminium Phosphide 2 Chlorantraniliprol 0.4% G.R. 3 Chlorantraniliprol 18.5%SC 4 Methyl Parathion 50% EC 5 Carbaryl 6 Naphthyl methylcarbamate**	**1.Aluminium Phosphide 2. Methyl Parathion**
Zaid (February – May, August– January)	**Vegetables**	**1 Monocrotophus36%SL**	**Banned for vegetables**

4.4. Impact of pesticide

Health concerns associated with the handling and use of pesticides are greater in developing countries because farmers often do not have adequate personal protective equipment (PPE) and are often unable to read labels that are usually the only source of safety instructions. 18% of the respondents had complains of various health issues during the use of pesticide as shown in fig 3, such as headache, vomiting, dizziness and breathing problems. Significant correlation was found between method of disposal and health problems, indicating accumulation of pesticide residue in soil and increase in the magnitude of crop contamination with pesticide residue. Inappropriate pesticide container disposal is a growing problem because of frequent pressure to reuse plastic containers (UN 2021). The lack of awareness of proper pesticide use proved to be the key reason behind the common diseases among farmers in the Tu Ky district of Vietnam, it was found that after spraying, 93% of the farmers washed the used pesticide bottles in nearby canal, while more than 6% did not wash the bottle at all (Huyen et al. 2020).

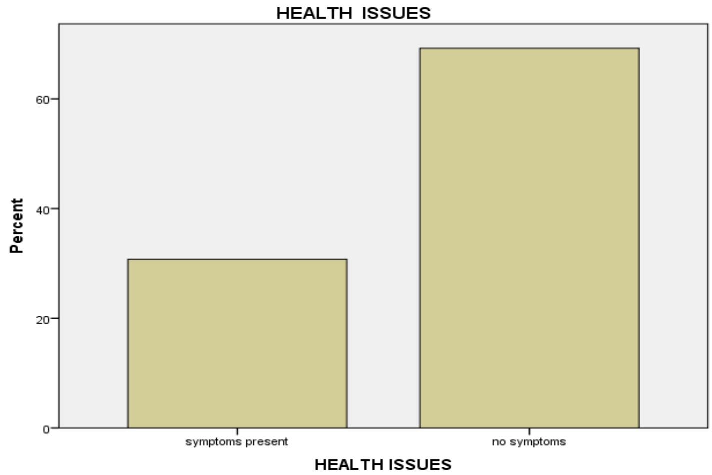
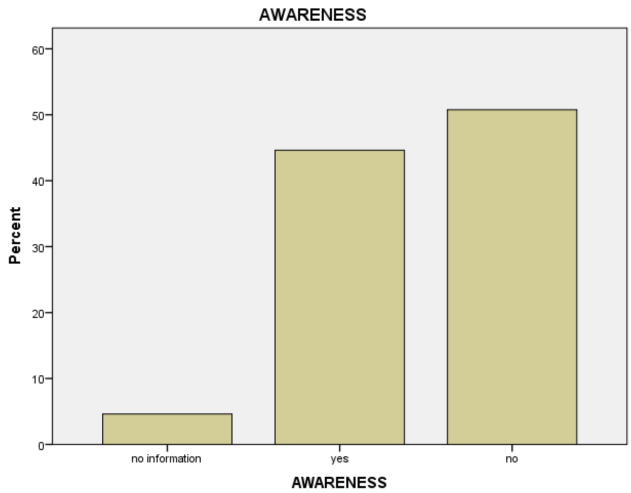


Fig. 3 Bar diagrams for % of farmers having health related issues while using the pesticide or after using the pesticide

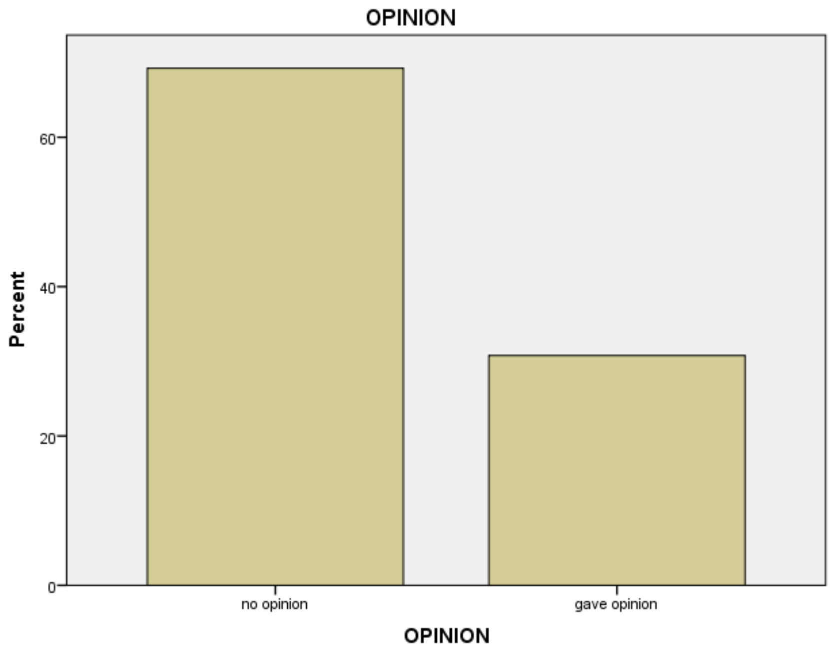
4.5. Farmers' awareness on impact of pesticide on health and environment

Majority of the literate respondents in this study expressed strong perception on the negative impact of pesticide on soil, air, water and other beneficial organisms in the environment, resulting in awareness among 44.6 % of the respondents as given in fig 4a. Significant correlations were found between awareness and hygienic practices. 20% of the respondents gave their opinion on use of pesticide as given in fig 4b, with most of them having knowledge of other alternate methods of pest control methods such as organic farming and use of biocontrol agents.

In a similar study by Yassin et al. (2002), 97.8% farmers of developing regions like Palestine had knowledge about the adverse effects of pesticides on human and ecosystem health and hence were against the use of pesticide in pest management. However, they justified the use of pesticide by the absence of other successful alternatives for pest management (Yassin et al. 2002).



(a)



(b)

Fig. 4 Bar diagrams for a) proportion of surveyed farmers who were aware about impact of usage of pesticide b) % of farmers who gave their opinion on usage and impact of pesticide.

5. Discussion

In the present study soil pH and conductivity of forest soil samples differed significantly from the agricultural and urban soil samples and significant differences were found in organic carbon, potash and iron content between the forest and agricultural soil samples. Agricultural and urban soil samples differed significantly in terms of copper content. The trend observed indicates the impact of the usage of pesticide as an agricultural activity to affect soil health. Soil health determines the fitness of the soil to support crop growth without becoming degraded that would harm the environment (Acton and Gregorich 1995). Soil health has also been illustrated via the analogy to the health of an organism or a community (Larson et al. 1991).

The methods that farmers use to control pests are a reflection of how they view the issues, which is further influenced by their degree of education and awareness. Since it broadens farmers' perspectives and introduces them to a variety of possibilities and features related to agriculture and related fields, education, in particular, has a significant impact on socioeconomic position. Farmers who were surveyed had an average age of above 40 and 70% of farmers were literate. It was observed that literate farmers were more aware about the ill effects of using pesticide on environment and human health. Looking at this for comparison, the literate farmers reduced pesticide use by around 50% while maintaining rice yields in Indonesia's national IPM initiative (Indraningsih et al. 2005).

In order to develop efficient soil conservation strategies, it is vital to understand the elements that influence farmers' views, knowledge, and practices. Geographical factors such as climate, topography, soil and biotic factors influence agricultural practices and production. It is estimated in Uttarakhand that a general pattern of major cereals removed 310 kg of nutrients from soil annually on a hectare basis. Since on an average, only 29 kg of plant nutrients per hectare is added to the soil through fertilizers, net loss of plant nutrients from the inherent fertility reserve in the soil is alarming and could be a reason for use of pesticide in spite of being aware of its negative impact upon soil and farmers' health.

The study unequivocally identifies the use of pesticides as one of the anthropological activities that affect the health of the soil. This study's overarching goal is to educate farmers and other land managers on the impacts of soil management on soil functionality and the promotion of soil quality as a crucial component of improving the environment in general.

Acknowledgements

Authors are thankful to S.G.R.R. University, Dehradun (Uttarakhand), Punjabi university, Patiala (Punjab) and Uttarakhand Forest Department for their support to conduct present research work. Special thanks to Dr. Nitesh Painuly (consultant psychiatrist, NHS, UK) and Dr. Anand Singh (Lab Incharge, Soil Testing Laboratory, Department of Agriculture, Uttarakhand) for their indispensible guidance. Many thanks are due to the people who helped to carry out the survey including the agricultural labourers and farmers who participated in the survey.

References

1. Abdollahi L, Hansen EM, Rickson RJ, Munkhlom LJ (2015) Overall assessment of soil quality on humid sandy loams: effects of location, rotation and tillage. Soil and Tillage Research 145: 29-36.
2. Acharya GP, Mcdonald MA, Tripathi BP, Gardner M, Mawdesley KJ (2007) Nutrient losses from rain fed bench terraced cultivation system in high rainfall areas of the mid hills of Nepal. Land degradation and development 18(5): 486 – 499.
3. Acton DF, Gregorich LJ (1995) The health of our soils: toward sustainable agriculture in Canada. Centre for Land and Biological Resource Research, Research Branch, Agriculture and Agri – food Canada, Ottawa: 38.
4. Andrews SS, Carroll CR (2001) Designing a soil quality assessment tool for sustainable agroecosystem management. Ecological Applications 11: 1573 – 1585.
5. Andrews SS, Karlen DL, Mitchell JP (2002) A comparison of soil quality indexing methods for vegetable production system in Northern California. Agriculture, Ecosystem and Environment 90: 25-45.
6. Ball BC, Gulmaraes RML, Cloy JM, Hargreaves PR, Shepherd TG, McKenzie BM (2017) Visual soil evaluation: a summary of some applications and potential developments for agriculture. Soil and Tillage Research 173: 114-124.
7. Barraza D, Jansen, Wesseling C, de Joode BVW (2020) Pesticide risk perceptions among bystanders of aerial spraying on bananas in Costa Rica. Environmental research 189: 109877.
8. Bezdicek, D.F., Stewart, B.A (Eds.), Defining Soil Quality for a sustainable Environment. SSSA, Madison, WI: 3-21.
9. Bonvoisin T, Utyasheva L, Knipe D, Gunnell D, Eddleston M (2020) Suicide by pesticide poisoning in India: a review of pesticide regulations and their impact on suicide trends. BMC public health 20(1): 1-16.
10. Bouchez T, Blieux AL, Dequiedt S, Domaizon, Dufresne A, Ferreira S, Ranjard L (2016) Molecular microbiology methods for environmental diagnosis. Environmental Chemistry Letters 14: 423-441.

11. Bunemann EK, Bongiorno G, Bai Z, Creamer RE, De Deyn, G, De Goede R, Brussaard L (2018) Soil quality–A critical review. Soil Biology and Biochemistry 120: 105-125.
12. Crowder DW, Jabbour R (2014) Relationships between biodiversity and biological control in agroecosystems: current status and future challenges. Biological control 75: 8-17.
13. *Damalas CA, Koutroubas SD (2016) Farmers' exposure to pesticides: toxicity types and ways of prevention. Toxics 4(1): 1.*
14. Das BS, Wani SP, Benbi DK, Muddu S, Bhattacharyya T, Mandal B, Reddy NN (2022) Soil health and its relationship with food security and human health to meet the sustainable development goals in India. Soil Security 100071.
15. de Joode BVW, Mora AM, Lindh CH, Hernández-Bonilla D, Córdoba L, Wesseling C, Mergler D (2016) Pesticide exposure and neurodevelopment in children aged 6–9 years from Talamanca, Costa Rica. cortex 85: 137-150.
16. Doran JW, Parkin TB (1994) Defining and assessing soil quality. In: Doran, J.W., Coleman, D.C.,
17. Doran JW, Parkin TB (1996) Quantitative indicators of soil quality: a medium data set. In: Doran, J.W., Jones, A.J. (Eds.), Methods for Assessing Soil Quality. Soil Science Society of America: 25—37.
18. Escalada MM (1985) Baseline survey of rice farmers' knowledge, attitudes and practices of integrated pest control (Western Leyte): Final report of the project Inter Country Programme on Integrated Pest Control (Rice), funded by the United Nations Food and Agriculture *Organization (FAO). Rome, Italy.*
19. Guimaraes RML, Ball BC, Tormena CA (2011) Improvements in the visual evaluation of soil structure. Soil Use & Management 27: 395-403.
20. Huyen VN, Van Song N, Thuy NT, Hoan LK (2020) Effects of pesticides on farmers' health in Tu Ky district, Hai Duong province, Vietnam. Sustainable Futures 2: 100026.
21. Indraningsih I, Sani Y, Widiastuti R (2005) Evaluation of farmer's appreciation in reducing pesticide by organic farming practice.
22. Joko T, Dewanti NA, Dangiran HL (2020) Pesticide poisoning and the use of personal protective equipment (PPE) in Indonesian farmers. Journal of environmental and public health 5379619: 1-7.
23. Karlen DL, Andrews SS, Doran JW (2001) Soil quality: current concepts and applications. Advances in Agronomy 74 (74): 1-40.
24. Lal R (2000) Controlling greenhouse gases and feeding the globe through soil management. The ohio state university, Columbus, ohio.
25. Larsen AE, Gaines SD, Deschênes O (2017) Agricultural pesticide use and adverse birth outcomes in the San Joaquin Valley of California Nature communications 8(1): 302.
26. Larson SJ, Capel PD, Goolsby DA, Zaugg SD, Sandstrom, MW (1995) Relations between pesticide use and riverine flux in the Mississippi River basin. Chemosphere 31(5): 3305-3321.
27. Lindsay WL, Norvell W (1978) Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil science society of America journal 42(3): 421-428.
28. Litsinger JA, Price EC, Herrera R T (1980) Small farmer pest control practices for rainfed rice, corn, and grain legumes in three Philippine provinces. *Philippine entomologist 4*(2): 65-68.

29. Macdonald KB, Wang F, Fraser WR, Lelky GW (1998) Broad scale assessment of agricultural soil quality in Canada using existing land resource database and gis. Research Branch Technical Bulletin.
30. Mader P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U (2002) Soil fertility and biodiversity in organic farming. Science 296: 1694-1697.
31. Mueller L, Shepherd G, Schindler U, Ball BC, Munkholm IJ, Hennings V, Smolentseva E, Rukhovic O, Lukin S, Hu S (2013) Evaluation of soil structure in the framework of an overall soil quality rating. Soil and Tillage Research 127: 74-84.
32. Romig DE, Garlynd MJ, Harris RF (1996) Farmer based assessment of soil quality: a soil health scorecard. In: Doran, J.W., Jones, A.J. (Eds.), Method of Assessing Soil Quality. Soil Science Society of America: 39-60.
33. Seufert V, Ramankutty N (2017) Many shades of gray- The context-dependent performance of organic agriculture. Science Advances 3: 14.
34. Shetty PK, Murugan M, Hiremath MB, Sreeja K G (2010) Farmers' education and perception on pesticide use and crop economies in Indian agriculture. Journal of Experimental Sciences 1(1): 3-8.
35. Sivakumar SD, Subramanian SR, Suresh S, Gopalan M (1997) Pest management practices of rice farmers in Tamil Nadu, India. Pest Management of Rice Farmers in Asia, IRRI, Los Banos: 75-85.
36. Soerjani M (1990) Trend of pesticide use in Indonesia and Asian countries with negative impact to the environment. *Crop Protection Toward the Sustainable Agriculture and Environmental Save. Agricon*: 719-745.
37. Stavi I, Bel G, Zaady E (2016) Soil function and ecosystem services in conventional, conservation and integrated agricultural systems. A review. Agronomy for Sustainable Development 36: 32.
38. Toth, SJ, Prince AL (1949) Estimation of cation-exchange capacity and exchangeable Ca, K, and Na contents of soils by flame photometer techniques. Soil Science 67(6): 439-446.
39. Tsimbiri PF, Moturi WN, Sawe J, Henley P, Bend JR (2015) Health impact of pesticides on residents and horticultural workers in the Lake Naivasha Region, Kenya. Occupational Diseases and Environmental Medicine 3(02): 24.
40. Walkley A, Black CA (1934) An experimentation of the delayreff method for determining organic matter of the chronic and titration method. Journal of Agricultural Sciences 37(1): 29-38.
41. Wan C, Gregorich LJ, Rees HW, Walker BD, Holmstrom DA, Kenney EA, Woodrow EF (1995) Benchmark sites for monitoring agricultural soil quality. The health of our soils: toward sustainable agriculture in Canada: 31-40.
42. Wang C, Walker BD, Rees HW (1997) Establishing a benchmark system for monitoring soil quality in Canada. In Developments in soil science 25: 323-337.
43. Watanabe FS, Olsen SR (1965) Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. Soil Science Society of America Journal 29(6): 677-678.
44. Wienhold BJ, Andrews SS, Karlen, DL (2004) Soil quality: a review of the science and experiences in the USA. Environmental Geochemistry and Health 26: 89-95.
45. Wienhold BJ, Karlen DL, Andrews SS, Stott DE (2009) Protocol for indicator scoring in the soil management assessment framework (SMAF). Renewable Agriculture and Food Systems 24: 260-266.
46. World Health Organization (WHO) (2019), Suicide, Newsroom, Facts sheet.

47. Yassin MM, Mourad TA, Safi JM (2002) Knowledge, attitude, practice, and toxicity symptoms associated with pesticide use among farm workers in the Gaza Strip. Occupational and environmental medicine 59(6): 387-393.