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Impact of modern agricultural practices on soil quality of agricultural lands around Ranga Reddy district of Telangana

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Abstract
The experiment was conducted during Rabi season 2020-2021 at Laboratory conditions of Green Fields Institute of Agriculture Research & Training, Mangalpally, to study the “Impact of Modern Agricultural Practices on Soil Quality of Agricultural Lands around Rangareddy District of Telangana”. As soil is the major source and important component for the production of crop in the field of agriculture. The leading productions by the field crops are due to the physical, chemical property which directly influences the soil productivity and crop productivity. The nature of the soil mainly depends upon the different parameters such as pH, Conductivity, Salinity, Alkalinity, Bulk density, hydrated density, Moisture content etc. The heavy usage of inorganic chemicals, fertilizers, pesticides and herbicides in a part of crop production and crop protection, directly showing impact on physico-chemical parameters of soil. Taking this factor into consideration the present investigation carried by collecting various soil samples from agricultural fields located in and around rangareddy district of telangana state, to understand the soil chemistry at different sampling zones. The collected soil samples were analyzed for various physical and chemical parameters according to standard methods available from literature. The obtained results were compared with soil quality parameters given by WHO for agriculture and concluded that most of the sampling points shown significant changes in their physical and chemical compositions. The obtained results also concluding that the soil quality was degraded because of heavy loads of chemicals and fertilizers.

Keywords: Soil quality, pesticides, herbicides, chemical fertilizers, soil quality of agricultural lands and ground soil quality

Introductions
The evolution of modern agricultural practices has revolutionized global food production, resulting in remarkable increases in crop yields and efficiency [1]. However, this intensification has raised concerns regarding its impact on soil quality, a pivotal factor for sustainable agriculture. With the world's population steadily rising, understanding the consequences of modern agriculture on soil health is crucial for ensuring long-term food security [2]. Modern agricultural methods have transformed traditional farming, characterized by diverse cropping systems and minimal external inputs, into intensive monoculture systems heavily reliant on agrochemicals, machinery, and irrigation [3]. While these advancements have boosted productivity, they have also sparked debates about their effects on soil health and the broader ecosystem. Scientific evidence indicates that the extensive use of chemical fertilizers, pesticides, and herbicides can alter soil structure and nutrient dynamics, potentially leading to soil degradation [4]. Furthermore, the overreliance on synthetic inputs may disrupt the delicate balance of microbial communities in the soil, affecting vital processes like nutrient cycling and organic matter decomposition [5]. Excessive irrigation in certain regions can exacerbate soil salinization, further compromising soil quality.

Through soil sampling, laboratory analyses, and field experiments, researchers have evaluated changes in soil properties, microbial diversity, and overall soil health under different farming systems [3]. Advancements in molecular biology and genomic technologies have provided deeper insights into the microbial communities inhabiting the soil and their responses to agricultural practices. This synthesis of current scientific literature aims to explore the multifaceted dimensions of soil health impacted by modern agricultural

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practices. By integrating empirical studies and scientific evidence, we aim to contribute to the ongoing discourse on sustainable agriculture and advocate for practices that mitigate adverse effects on soil ecosystems. This comprehensive understanding will inform future efforts to strike a balance between agricultural productivity and environmental stewardship.

Materials and Methods

Study Area

Agriculture in Telangana

In recent years, Telangana's agricultural sector has garnered significant attention, particularly following the tragic suicides of numerous cotton farmers during the 1997-98 agricultural season [6]. Prevailing perceptions suggest that Telangana's agriculture has historically lagged behind and remained stagnant, compounded by a perceived inadequacy of irrigation resources due to neglect by the Andhra Pradesh government [7]. This paper delves into two fundamental aspects of agricultural development in Telangana. Firstly, it analyzes growth rates at the district level from 1970 to 2001, dissecting the contributions of cropping patterns, yield, and cultivated area to agricultural growth. Additionally, it examines the instability of agricultural output in Telangana, challenging prevailing notions about the region's agricultural performance. The study also scrutinizes irrigation data, revealing substantial increases in groundwater irrigation despite governmental neglect of canal irrigation development. The proliferation of groundwater irrigation has facilitated significant agricultural growth in Telangana districts, albeit at a cost.

The reliance on groundwater irrigation necessitates substantial private capital, posing challenges for small-scale farmers who often resort to borrowing to sustain competitiveness. This dependence on borrowing and the depletion of groundwater levels raise concerns about the long-term sustainability of irrigation practices, particularly in districts heavily reliant on well irrigation [8]. The districts experiencing the highest agricultural and irrigation growth rates also witness alarming rates of farmer suicides, highlighting the complex interplay between agricultural development, irrigation practices, and socioeconomic pressures. Despite potential criticisms of official data sources regarding methodological rigor and accuracy, they remain the primary data reservoirs for assessing agricultural trends at the district level. While discrepancies between official data sources and census data may exist, the data from statistical abstracts provide a reasonable basis for analysis, covering the majority of Telangana's agricultural landscape.

Ranga Reddy District

Over the past half-decade, the Indo-French Centre for Groundwater Research, based at the National Geophysical Research Institute (NGRI) in Hyderabad, has conducted extensive research in the Maheshwaram granite aquifer, situated in the Ranga Reddy District of Andhra Pradesh. The focus of this research has been to gain insights into the structure and functionality of hard-rock aquifers [9-12]. Methodologies have been developed to accurately evaluate groundwater balance [13-15], facilitate borewell siting [16, 17], map various aquifer layers [18], and enhance groundwater modeling techniques [19-21]. Advanced techniques such as geostatistics have also been employed to regionalize aquifer parameters and optimize monitoring networks [22, 23].

The Maheshwaram watershed, spanning 53 square kilometers and located 35 kilometers south of Hyderabad, serves as the pilot site for this research endeavor. It is chosen for its representative characteristics of South Indian rural catchments, including geological composition dominated by hard-rock formations, aquifer overexploitation, prevalent cropping patterns, and socioeconomic context. The region boasts a relatively flat terrain, with elevations ranging from 590 to 670 meters above sea level, and is devoid of perennial streams. The area experiences a semi-arid climate influenced by the seasonal monsoon, which occurs from June to October, known as the rainy or kharif season. Annual precipitation averages around 750 millimeters, with more than 90% of rainfall occurring during the monsoon period. The mean annual temperature hovers around 26 °C, peaking at 45 °C during the summer months of March to May. Geologically, the watershed primarily comprises Archean granites, typical of the region's geological makeup. This uniform geological composition provides a conducive setting for studying groundwater dynamics and aquifer behavior in hard-rock terrains.

Sampling

Fifty representative soil profiles were studied at fifty selected study sites across Ranga Reddy district (Figure-1). Of these, 13 soil profiles were located in

Zone-1: Sirpura, Patloor, Tekulapalle, Lingampalle, Peelaram, Boppanaram, Jangaon, Nagaram, Kerelly, Rampur, Allapur.S, Gundal and Mokila.

Zone–2: which are Nuthankal, Narayanpur, Jeedimetla, Ammuguda, Bogaram, Rajapur, Serilingampally, Boduppal, Gandipet, Nagole, Chandanagar, Balapur and Koheda

Zone-3: Malkangiri, Allapur, Girijapur, Chintalapalle, Kankal, Chityal, Naskal, Khammam Nacharam, Kothapally, Ramnagar, Kondapur and Reddipalle.

Zone-4: Rudraram, Rayannaguda, Madanpalle, Bongloor, Pocharam, Gangaram, Japala, Loyapalle, Bachupally, Madhepur, Gungal and Thakkellapalle.

Physico-Chemical analysis of soil quality

Determination of pH

The pH value of a solution serves as an indicator of the concentration of hydrogen ions present within the solution. Originating from the work of Sørensen in 1909, the pH concept quantifies this concentration by representing the logarithm of the reciprocal of hydrogen ion concentration, measured in moles per liter at a specific temperature. Spanning a scale from 0 (indicating high acidity) to 14 (indicating high alkalinity), with a midpoint of 7 representing neutrality at 25 °C, the pH scale plays a pivotal role in various chemical calculations and assessments. Utilized in the determination of carbonate, bicarbonate, CO_2 levels, corrosion susceptibility, and solution stability, among other applications, the pH scale aids in understanding the chemical behavior of solutions. While alkalinity or acidity signifies the overall resistance to pH fluctuations or buffering capacity, pH specifically denotes the activity of hydrogen ions within the solution.

Measurement of pH can be conducted through two primary methods: calorimetrically or electrometrically [24]. These methodologies provide crucial insights into the chemical properties of solutions, contributing to a deeper understanding of their behavior and reactivity.

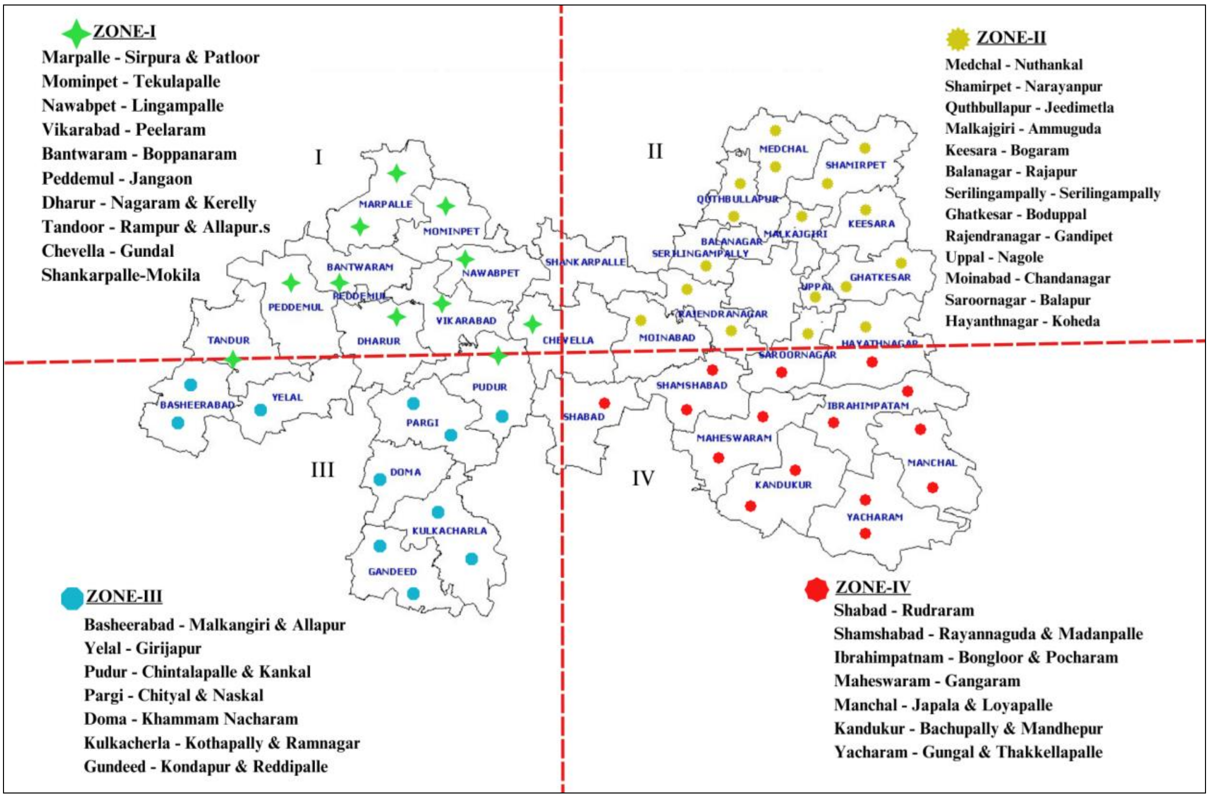

Fig 1: Sampling zones from agricultural lands of Rangareddy district, Telangana, India.

Determination of alkalinity of soil

The alkalinity of water is a measure of its capacity to neutralize acids. It is primarily due to salts of weak acids, although weak or strong bases may also contribute. Alkalinity is usually imparted by bicarbonate, carbonate, and hydroxide. It is measured volumetrically by titration with 0.02 N sulfuric acid and is reported in terms of CaCO3 equivalent [25].

Phenolphthalein Alkalinity = $\frac{V1XNX50X1000}{Volumeofsample}$

Total Alkalinity = $\frac{V2XNX50X1000}{Volumeofsample}$

Determination of Acidity of soil

Acidity of water refers to its ability to neutralize a strong base to a specific pH. The acidity of water is primarily due to the presence of strong mineral acids, weak acids such as carbonic and acetic, and hydrolyzing salts such as ferric and aluminium sulphates. The amount of base required to neutralize a given sample to a specific pH is used to measure the acidity of water [26].

Methyl Orange Acidity/Mineral Acidity = $\frac{V1X1000XNX50}{Volumeofsample}$

Phenolphthalein/Total Acidity = $\frac{V2XNX50X1000}{Volumeofsample}$

Estimation of Zinc

Adding an indicator to a solution containing Mg^2+ forms a red-colored magnesium indicator complex. When the disodium salt of EDTA is introduced, it reacts with the magnesium, forming a magnesium EDTA complex. This reaction releases the previously bound indicator, resulting in a blue color at pH 10. Moreover, EDTA has the capability to displace the indicator from the zinc indicator complex, leading to a noticeable color change that signals the endpoint of the reaction [27].

Estimation of Iron (Fe^{+2} ion)

The Fe^2+ ion undergoes oxidation to Fe^{3+} by $KMnO_4$ in the presence of dilute H_2SO_4. The endpoint is indicated by a faint pink color of permanganate. Additionally, sodium oxalate ion transforms into CO_2 and water in this chemical process [27].

Moisture Content

Moisture content (MC) was determined through the gravimetric method. Soil samples were initially weighed in ceramic crucibles to obtain their fresh weight. Subsequently, the samples were subjected to oven drying at a constant temperature of 105 °C for approximately 24 hours until reaching a constant weight, and the resulting dry weight was recorded [28].

Electrical conductivity

Electrical conductivity serves as a crucial indicator of soil quality, assessing the presence of ions in the soil solution. This property is instrumental in swiftly and affordably evaluating soil health. The measurement of electrical conductivity reflects the concentration of ions, with higher levels indicating increased ion concentration. Therefore, it provides a rapid and straightforward means of gauging the overall condition of the soil [29].

Bulk density

Bulk Density was assessed utilizing the core method outlined by Yerima and Van Ranst (2005). This involved placing samples within the core rings of predetermined weight [30].

Packed density

Packed density, also known as packing fraction, refers to the proportion of space occupied by the elements comprising a given packing within a defined area. In the context of packing problems, the primary goal typically involves achieving the highest attainable density in the packing arrangement [31].

Hydrated density

A hydrate is a substance that incorporates water or its fundamental elements. The chemical configuration of the water can vary significantly among different categories of hydrates, some of which were named prior to a comprehensive understanding of their chemical structure.

Results

The physicochemical analysis of soil quality parameters was conducted on soil samples collected from Rangareddy District, Zone-1. The results (Table-1) revealed significant variations across the parameters measured, indicating diverse soil characteristics within the study area. Bulk Density (BD) values ranged from 1.02 g/cm³ to 1.42 g/cm³, reflecting the compactness and porosity of the soil, with lower values suggesting higher porosity and better water retention capacity. Packed Density (PD) values ranged from 1.06 g/cm³ to 1.60 g/cm³, indicating the soil's ability to pack tightly, potentially affecting root penetration and water infiltration. Hydrate Density (HD) ranged from 0.41 g/cm³ to 1.00 g/cm³, reflecting the soil's capacity to retain moisture, crucial for plant growth. Oil Retention Capacity (ORC) varied from 1.18 to 1.74, indicating the soil's ability to retain oils and organic compounds, which contributes to soil fertility. Moisture Content (MC) ranged from 0.19% to 5.93%, reflecting the water content in the soil, with higher moisture content potentially leading to waterlogging and nutrient leaching. Moisture Correction Factor (MCF) values ranged from 1.001 to 1.05, indicating adjustments made to correct moisture-related variations in other parameters. Emulsifying Activity (EA) ranged from 0.284 to 0.337, reflecting the soil's ability to emulsify oils and water, essential for soil structure and nutrient availability. pH values ranged from 8.55 to 9.47, indicating the soil's acidity or alkalinity, with extreme pH levels potentially affecting nutrient availability. Electrical Conductivity (EC) ranged from 38.7 µS/cm to 45.4 µS/cm, reflecting soil salinity levels, which can impact plant growth and fertility. Carbonates (CO_3) and Bicarbonates (HCO_3) ranged from 13.7 mg/kg to 82.5 mg/kg, indicating the presence of carbonate minerals and bicarbonate ions in the soil, influencing soil pH buffering and alkalinity. Alkalinity values varied, reflecting the soil's capacity to neutralize acids, which influences pH stability and nutrient availability. Zinc (Zn) and Iron (Fe) concentrations varied across the sampled sites, indicating variations in soil nutrient availability, essential for plant growth and metabolism. Overall, the diverse range of values observed underscores the heterogeneity of soil properties within Rangareddy District, Zone-1, highlighting the importance of understanding these variations for effective soil management and agricultural practices aimed at optimizing crop productivity and sustainability in the region.

The physicochemical analysis of soil quality parameters was conducted on soil samples collected from Rangareddy District, Zone-2, revealing diverse characteristics across the parameters measured (Table-2). BD values ranged from 0.92 g/cm³ to 1.28 g/cm³, indicating variations in soil compaction and porosity, with implications for water retention and root growth. PD values ranged from 1.04 g/cm³ to 1.25 g/cm³, reflecting the soil's ability to pack tightly, influencing soil structure and water infiltration rates. HD ranged from 0.25 g/cm³ to 1.00 g/cm³, indicating variations in soil moisture retention capacity, crucial for plant growth and nutrient availability. ORC varied from 1.43 to 1.91, suggesting differences in the soil's ability to retain organic compounds, which can affect soil fertility. MC ranged from 1.04% to 1.62%, reflecting variations in soil water content, with implications for plant water uptake and nutrient availability. MCF values showed considerable variation, indicating the need for adjustments to account for moisture-related variations in other parameters. EA ranged from 1.005 to 1.26, reflecting the soil's ability to emulsify water and organic compounds, influencing soil structure and nutrient availability. pH values ranged from 7.42 to 8.59, indicating soil acidity or alkalinity levels, with implications for nutrient availability and microbial activity. EC ranged from 40.6 µS/cm to 82 µS/cm, reflecting variations in soil salinity levels, which can impact plant growth and soil fertility. Carbonates and Bicarbonates concentrations varied across the sampled sites, influencing soil pH buffering and alkalinity. Alkalinity values varied, reflecting the soil's capacity to neutralize acids, which affects soil pH stability and nutrient availability. Zn and Fe concentrations varied, indicating differences in soil nutrient availability, essential for plant growth and metabolism. Overall, the diverse range of values observed underscores the heterogeneity of soil properties within Rangareddy District, Zone-2, highlighting the importance of understanding these variations for effective soil management and agricultural practices aimed at optimizing crop productivity and sustainability in the region**.**

The analysis of soil quality parameters in soil samples from Rangareddy District, Zone-3, reveals notable variations across key metrics (Table-3). BD ranges from 0.96 g/cm³ to 1.25 g/cm³, indicating variability in soil compaction and porosity, influencing water retention and root development. PD exhibits diversity from 0.9 g/cm³ to 1.42 g/cm³, reflecting differences in soil structure under pressure, affecting water infiltration and aeration. HD varies from 0.4 g/cm³ to 1.12 g/cm³, indicating differences in moisture retention capacity critical for plant growth. ORC, shows a broad range from 0.93 to 6.05, suggesting variations in the soil's ability to retain organic compounds, impacting fertility. MC, ranges from 1.14% to 1.7%, affecting water availability for plants and microbial activity. MCF varies widely, necessitating adjustments for moisture-related variations in other parameters. EA, ranges from 1.008 to 1.15, affecting nutrient availability and soil structure. pH values vary from 7.64 to 7.84, influencing nutrient availability and microbial activity. EC ranges from 79.2 µS/cm to 83.1 µS/cm, reflecting soil salinity levels impacting plant growth. CO_3 and HCO_3 concentrations vary, affecting soil pH buffering capacity and alkalinity. Alkalinity values exhibit variability, influencing soil pH stability and nutrient availability. Zn and Fe concentrations vary, affecting soil nutrient status and plant metabolic functions. These findings emphasize the heterogeneous nature of soil properties within Zone-3 of Rangareddy District, underscoring the necessity for tailored soil management strategies to support sustainable agriculture and ecosystem health in the region.

The analysis of soil quality parameters in soil samples from Zone-4 of Rangareddy District presents a comprehensive overview of key metrics crucial for understanding soil health and fertility (Table-4). BD spans from 0.83 g/cm^3 to 1.25 g/cm^3, reflecting variations in soil compaction and structure. PD demonstrates diversity ranging from 0.96 g/cm^3 to 1.25 g/cm^3, indicating differences in soil porosity and water retention capacity under pressure. HD varies from 0.45 g/cm^3 to 0.9 g/cm^3, shedding light on the soil's ability to retain moisture, vital for sustaining plant growth. ORC showcases a broad spectrum from 1.22 to 1.76, signifying the soil's capacity to retain organic compounds critical for fertility. MC, fluctuates between 1.53% and 4.48%, impacting soil water availability and microbial activity. MCF displays notable variability, necessitating adjustments to account for moisture-related effects on other parameters. EA, ranges from 1.002 to 1.07, influencing nutrient availability and soil structure. pH levels vary between 7.73 and 7.82, impacting nutrient solubility and microbial activity. EC spans from 75.4 µS/cm to 79.5 µS/cm, indicating soil salinity levels affecting plant growth. CO_3 and HCO_3 concentrations exhibit diversity, influencing soil alkalinity and buffering capacity. Alkalinity values vary, affecting soil pH stability and nutrient availability. Zn and Fe concentrations showcase variability, impacting soil nutrient status and plant metabolism. These findings underscore the heterogeneity of soil properties within Zone-4, emphasizing the need for tailored soil management strategies to support sustainable agricultural practices and ecosystem resilience in the region.

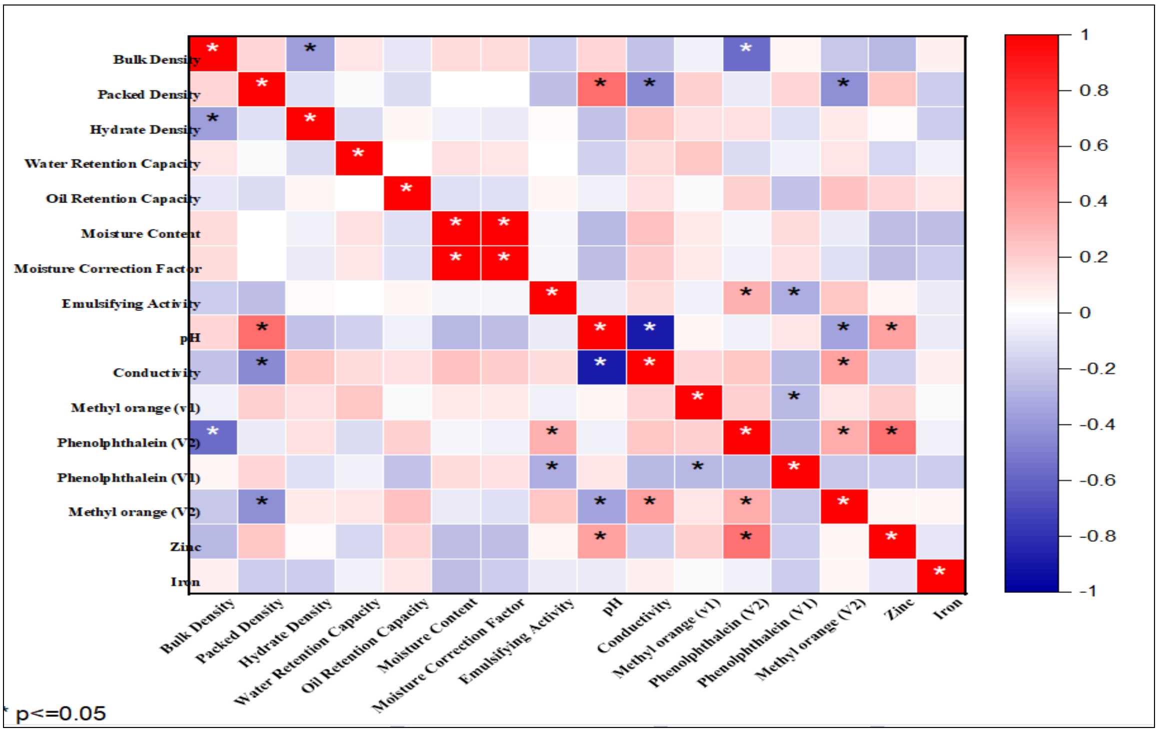

Fig 2: Correlation coefficient between the soil samples collected from different zones

Correlation between zone-1, zone-2, zone-3 and zone-4 soil samples

The characterization of soil properties across distinct zones reveals significant variations in key parameters essential for understanding soil health and composition. Bulk density, reflecting mass per unit volume, ranges from 1.02 to 1.42 g/cm^3 in Zone I, indicating denser soil, while Zone IV exhibits comparatively lower values, suggesting relatively loose soil. Packed density, indicative of soil compaction, shows similarities between Zones I and II, with notable distinctions in Zones III and IV, where Zone IV displays higher packed density [32]. Hydrate density, representing soil compactness when saturated, exhibits variability across all zones, with Zone III displaying the highest values [33]. Water retention capacity is notably higher in Zone III, indicating varied moisture holding capabilities compared to other zones [33]. Similarly, Zone III also exhibits the highest oil retention capacity, potentially linked to differences in soil composition or organic matter content [33]. Moisture content is lowest in Zone III, indicating drier soil conditions relative to other zones [33]. Emulsifying activity, illustrating soil's ability to form stable emulsions, is most pronounced in Zone III, suggesting potential variations in soil properties [33].

pH levels vary across zones, with alkaline conditions predominant in Zone I, shifting towards neutral conditions in Zones II and III [34]. Electrical conductivity, reflecting the water's capacity to conduct electrical current, exhibits variability across zones, with Zone III displaying the highest conductivity levels [35]. Alkalinity, highlighting water's buffering capacity, shows notable variability across zones, with Zone III demonstrating a resilient buffering capacity to pH changes [36]. Acidity levels also vary across zones, indicating potential fluctuations in water chemistry [36].

Variability in zinc and iron levels is evident across samples in each zone, underscoring the imperative for additional investigation [37]. The fluctuations in zinc and iron levels prompt the need for thorough analysis and ongoing monitoring efforts, aligning with previous studies on soil properties.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a statistical technique widely used in various fields, including soil science, to simplify complex datasets by reducing their dimensionality while retaining most of the variability present in the original data. In the context of soil quality parameters correlation and regression, PCA serves as a valuable tool for identifying underlying patterns and relationships among multiple soil quality variables. By transforming a large number of correlated variables into a smaller set of uncorrelated variables called principal components, PCA helps researchers gain insights into the structure of the data and identify the key factors influencing soil quality. The principal components derived from PCA are linear combinations of the original variables and are orthogonal to each other, meaning they are independent and capture different aspects of the variation in the data. This reduction in dimensionality not only simplifies the data but also facilitates its interpretation and visualization, making it easier for researchers to understand the relationships among soil quality parameters. Additionally, PCA aids in reducing redundancy in the data by identifying and eliminating redundant information, thereby improving the efficiency of subsequent analyses. Moreover, PCA can be used as a pre-processing step to enhance the performance of regression models by reducing the risk of overfitting and multicollinearity. By transforming the original variables into orthogonal principal components, PCA addresses multicollinearity issues and produces more robust and interpretable regression results. Overall, PCA plays a crucial role in advancing our understanding of soil quality and enhancing the accuracy and reliability of predictive models in soil science research.

Principal Component Analysis (PCA) is a statistical method used to reduce the dimensionality of a dataset while preserving most of its variability. In the context of soil quality parameters from Zone-1 of Rangareddy District, Telangana, PCA can be applied to identify underlying patterns and relationships among the various parameters. To perform PCA, the first step is to standardize the data to ensure that all variables have a mean of zero and a standard deviation of one. This step is crucial because PCA is sensitive to the scale of the variables. Once the data is standardized, the covariance matrix or the correlation matrix of the variables is calculated. The eigenvalues and eigenvectors of this matrix are then computed. The eigenvectors represent the principal components, which are new variables that are linear combinations of the original variables. These principal components are orthogonal to each other and capture different amounts of variance in the data. The eigenvalues represent the amount of variance explained by each principal component.

PCA typically generates as many principal components as there are original variables. However, for practical purposes, only the principal components that capture a significant amount of variance in the data are retained. This can be determined by examining the eigenvalues or by setting a threshold for the amount of variance to be retained. The principal components can be used to visualize the relationships among the soil quality parameters and to identify any underlying patterns or clusters in the data (Figure-3). Additionally, PCA can help identify which variables contribute the most to the variability in the dataset and can be used for dimensionality reduction in subsequent analyses. In the PCA analysis of the soil quality parameters from Zone-1 of Rangareddy District, Telangana, it was observed that variables S1, S2, S3, and S4 exhibited positive loadings towards the first principal component (PC1). This indicates that these parameters contribute significantly to the variability captured by PC1. Similarly, variables S4, S8, S9, S10, and S11 showed positive loadings towards the second principal component (PC2), suggesting that they contribute most to the variability captured by PC2 (Figure-4). Positive loadings indicate a positive correlation between the variables and the corresponding principal component. Therefore, in this analysis, parameters S1, S2, S3, and S4 are positively associated with each other and with PC1, while parameters S4, S8, S9, S10, and S11 are positively associated with each other and with PC2.

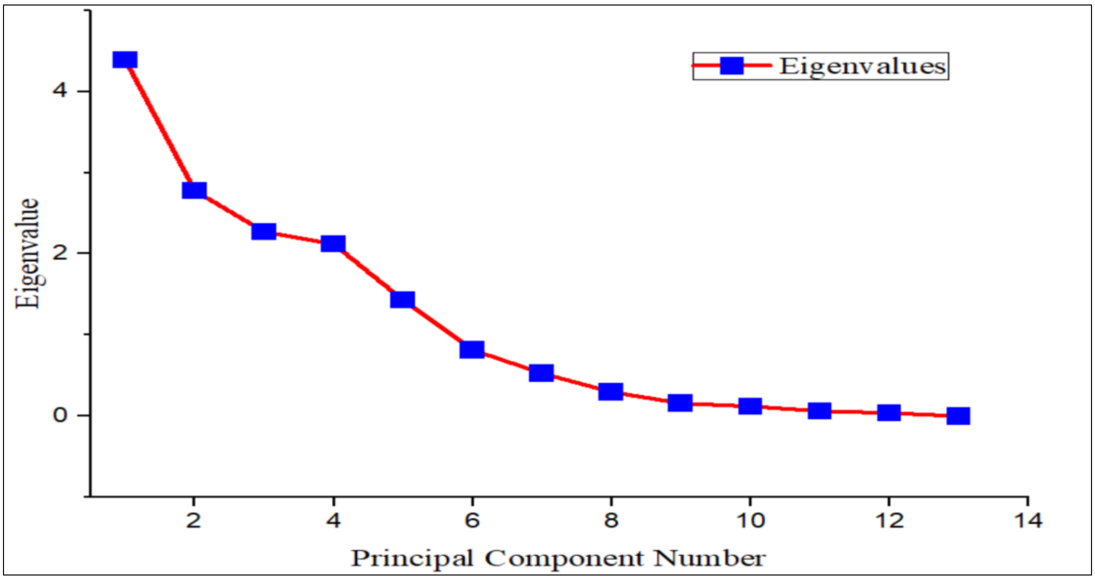

Fig 3: Scree plot for soil quality parameters of zone-1 samples collected from Rangareddy district of Telangana.

The analysis aimed to reduce the dimensionality of the dataset and identify the most influential variables contributing to the observed variability. The PCA revealed that the first principal component (PC1) captured the majority of the variance in the dataset. Variables such as Bulk Density, Packed Density, Moisture Content, EC (Electrical Conductivity), Carbonates, Bicarbonates, Alkalinity (p), Alkalinity (M), Zinc, and Iron exhibited strong positive loadings towards PC1. Additionally, samples S7, S8, S9, S10, S11, and S13 also showed positive loadings towards PC1, indicating their significant contribution to the overall variability observed in the soil samples from Zone-2. On the other hand, the second principal component (PC2) accounted for additional variability in the dataset. Variables such as Hydrate Density, Oil Retention Capacity, Moisture Correction Factor, and Emulsifying Activity displayed positive loadings towards PC2. Moreover, samples S2, S5, S8, and S13 exhibited positive loadings towards PC2, suggesting their unique contribution to the observed variability in the soil samples and their correlation with PC2 (Figure-5 and 6).

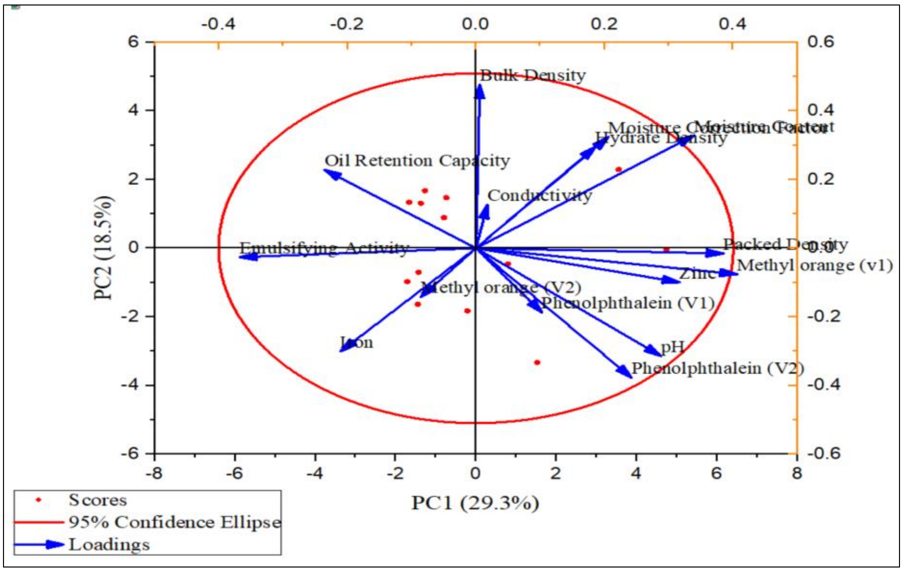

Fig 4: Biplot for soil quality parameters of zone-1 samples collected from Rangareddy district of Telangana.

In the Principal Component Analysis (PCA) of soil quality parameters from Zone-2 of Rangareddy District, Telangana, several significant findings emerged. In the Principal Component Analysis (PCA) conducted on soil quality parameters from Zone-3 of Rangareddy District, Telangana, several significant findings were unveiled. The analysis aimed to condense the dataset's dimensionality while discerning the primary sources of variability among the parameters. The PCA elucidated that the first principal component (PC1) elucidated a substantial proportion of the variance in the dataset. Parameters such as Hydrate Density, Oil Retention Capacity, Moisture Content, Moisture Correction Factor, pH, EC (Electrical Conductivity), Carbonates, Bicarbonates, Alkalinity (p), Alkalinity (M), Zinc, and Iron demonstrated robust positive loadings towards PC1. Furthermore, samples S6, S7, S9, S11, and S12 exhibited notable positive loadings towards PC1, indicating their significant contributions to the overall variability observed in the soil samples from Zone-3. Conversely, the second principal component (PC2) captured additional variability in the dataset. Parameters such as Bulk Density, Packed Density, Emulsifying Activity, and Zinc displayed positive loadings towards PC2. Additionally, samples S6, S7, S8, S10, S11, and S12 demonstrated positive loadings towards PC2, signifying their distinct contributions to the observed variability in the soil samples and their correlation with PC2 (Figure-7 and 8).

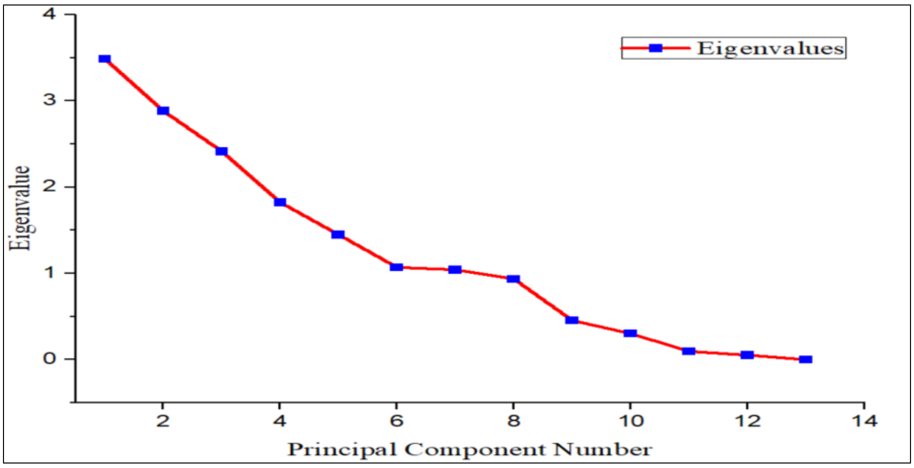

Fig 5: Scree plot for soil quality parameters of zone-2 samples collected from Rangareddy district of Telangana

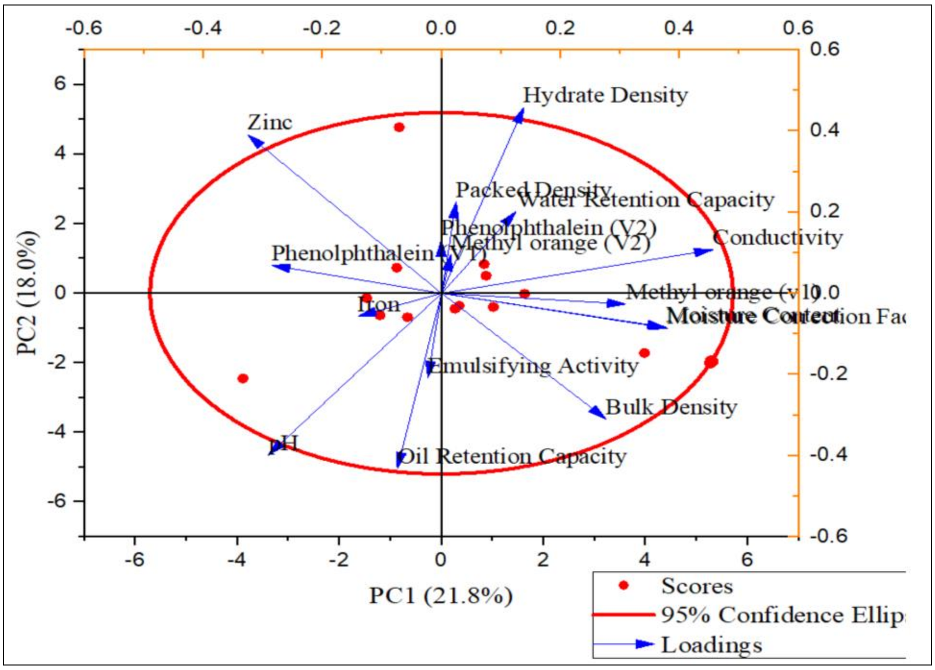

Fig 6: Biplot for soil quality parameters of zone-2 samples collected from Rangareddy district of Telangana

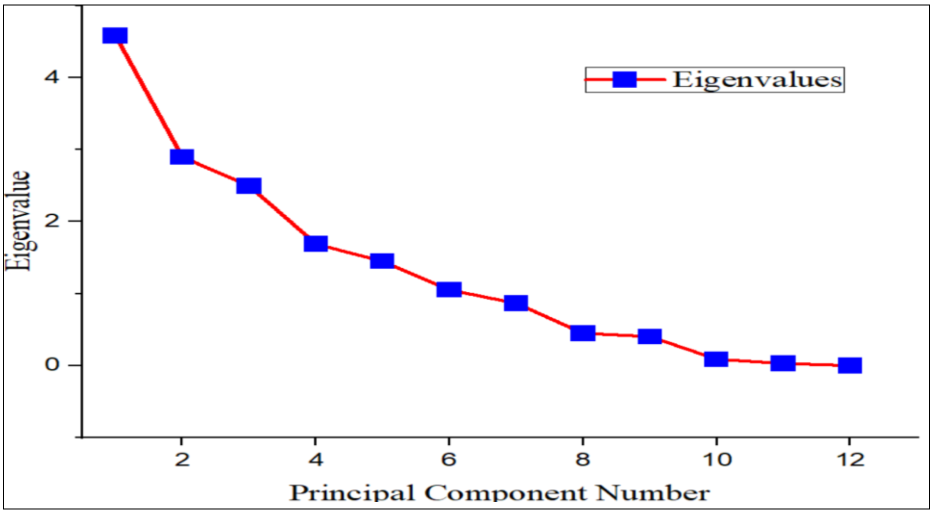

Fig 7: Scree plot for soil quality parameters of zone-3 samples collected from Rangareddy district of Telangana

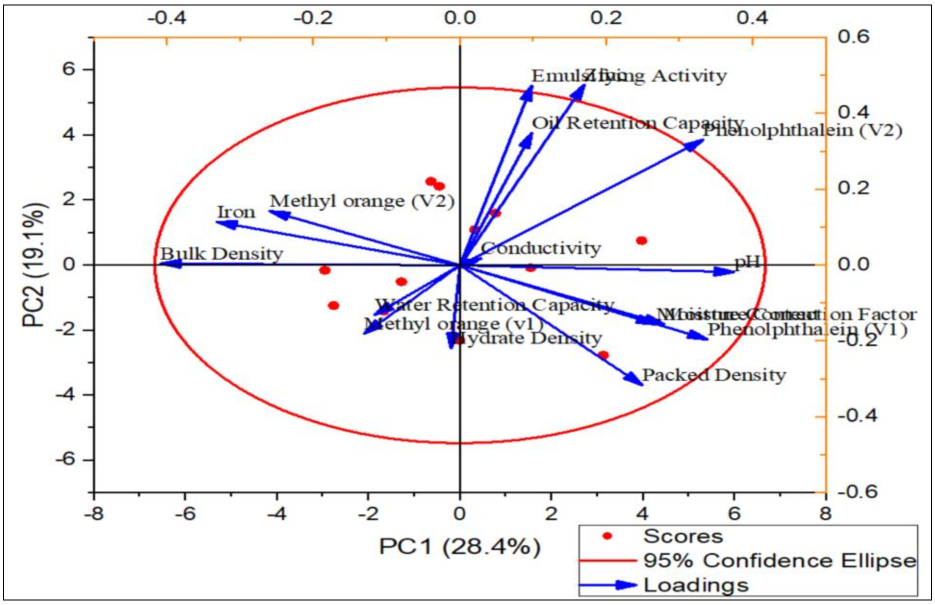

Fig 8: Biplot for soil quality parameters of zone-3 samples collected from Rangareddy district of Telangana.

In the Principal Component Analysis (PCA) conducted on soil quality parameters from Zone-4 of Rangareddy District, Telangana, significant insights were revealed regarding the underlying structure of the dataset. The analysis aimed to reduce dimensionality while identifying the primary sources of variability among the parameters. The PCA results indicated that the first principal component (PC1) explained a substantial portion of the variance in the dataset. Parameters such as Bulk Density, Packed Density, Hydrate Density, Oil Retention Capacity, Moisture Content, Moisture Correction Factor, Emulsifying Activity, pH, EC (Electrical Conductivity), Carbonates, Bicarbonates, Alkalinity (p), Alkalinity (M), Zinc, and Iron displayed strong positive loadings towards PC1. Additionally, soil samples excluding S10, S11, and S12 demonstrated significant positive loadings towards PC1, suggesting their notable contributions to the overall variability observed in the soil samples from Zone-4. On the other hand, the second principal component (PC2) captured additional variability in the dataset. Parameters such as Hydrate Density, Moisture Correction Factor, Emulsifying Activity, Carbonates, Bicarbonates, Alkalinity (p), Alkalinity (M), Zinc, and Iron exhibited positive loadings towards PC2. Furthermore, samples S3, S6, S7, and S11 displayed notable positive loadings towards PC2, indicating their distinct contributions to the observed variability and their correlation with PC2 (Figure-9 and 10).

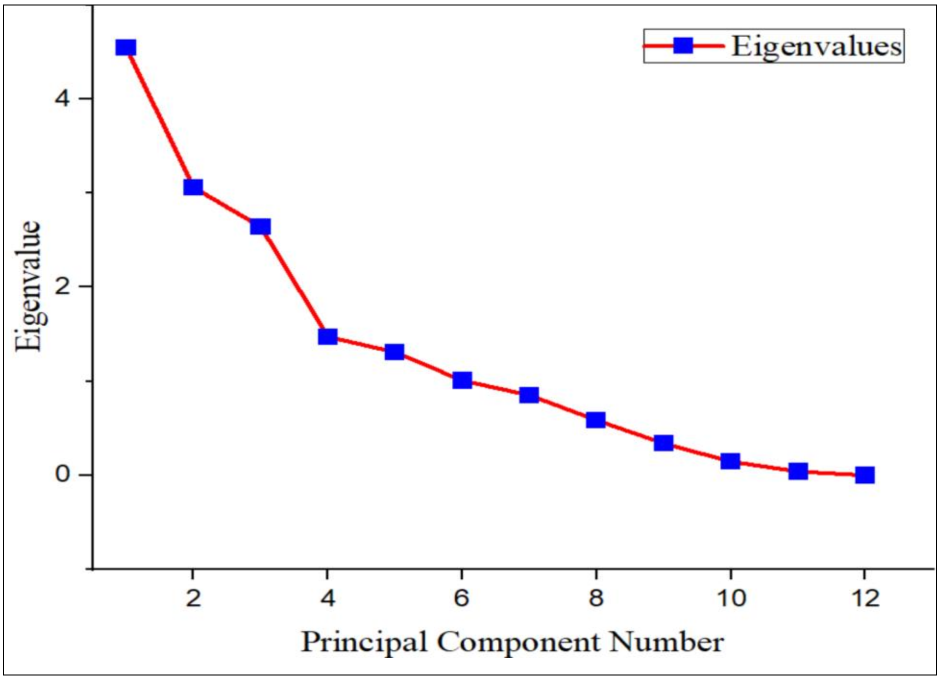

Fig 9: Scree plot for soil quality parameters of zone-4 samples collected from Rangareddy district of Telangana

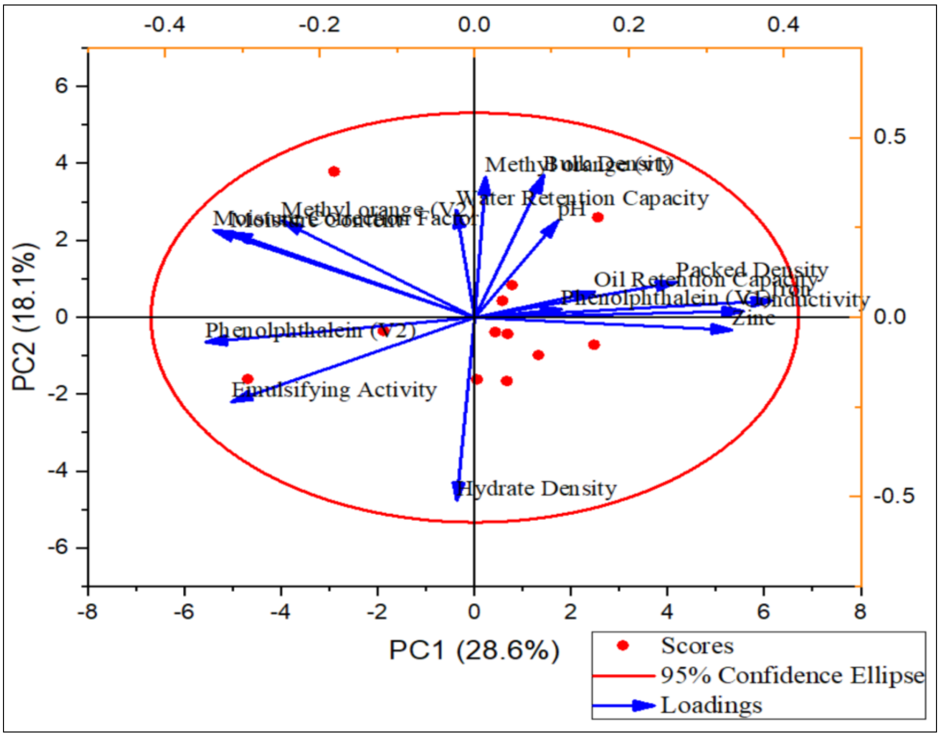

Fig 10: Biplot for soil quality parameters of zone-4 samples collected from Rangareddy district of Telangana.

Discussion

The impact of modern agricultural practices on soil quality in the agricultural lands around Ranga Reddy District of Telangana is a subject of significant interest and concern, as evidenced by a variety of studies and research findings. [38] delved into the adoption and diffusion of cash crops among smallholders in Guatemala, offering insights into how the introduction of cash crops, often associated with modern agricultural practices, affects soil composition and fertility. Similarly, [39] provided a comprehensive examination of recent advances in impact analysis methods for ex-post assessments of agricultural technology, which can be applied to evaluate the specific effects of modern agricultural technologies on soil quality and productivity in Ranga Reddy District [40], explored the evolution of farming systems in Sub-Saharan Africa due to agricultural mechanization, indicating potential influences on soil management practices and erosion rates in regions like Ranga Reddy District [41], emphasized the role of agricultural technology in poverty reduction, underscoring its direct and indirect effects on soil quality and rural livelihoods [42] examined the adoption of new technologies in Ethiopian agriculture, offering insights into factors influencing technology uptake and its implications for soil management practices [43]. Investigated the role of education in the adoption of chemical fertilizers in Ethiopia, highlighting socio-economic factors that may influence fertilizer use and its impact on soil quality in agricultural lands around Ranga Reddy District. Additionally, [44] explored constraints on a green revolution in Sub-Saharan Africa, providing valuable insights into factors hindering agricultural innovation and soil quality improvement efforts. In conclusion, the multifaceted nature of the impact of modern agricultural practices on soil quality in Ranga Reddy District necessitates a comprehensive understanding of technology adoption, mechanization, education, and socio-economic conditions to inform strategies for promoting sustainable soil management practices and ensuring long-term agricultural productivity and resilience**.** [38] shed light on the adoption of cash crops among smallholders, which often involves the introduction of modern agricultural technologies. Cash crop cultivation may lead to changes in soil pH due to alterations in nutrient uptake and soil microbial activity. Similarly, [40] discuss agricultural mechanization's evolution, which can affect soil salinity and EC levels through increased irrigation and fertilizer application.

The role of education in fertilizer adoption, as explored by [43] is crucial in understanding soil parameter dynamics. Improper fertilizer use can contribute to changes in soil pH, salinity, and carbonate levels, impacting soil health and fertility [44]. Highlight constraints on agricultural innovation in Sub-Saharan Africa, which may influence soil carbonate and bicarbonate levels due to suboptimal soil management practices. Factors such as pesticide and herbicide usage, discussed by various authors including [41] can also affect soil parameters. Pesticide runoff may alter soil pH and EC levels, while herbicide residues can impact carbonate and bicarbonate concentrations, thereby affecting soil quality and fertility.

Table 1: Physico-chemical parameters of soil samples collected from zone-1 of Rangareddy district, Telangana.

Parameter	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**
Bulk Density	1.1	1.2	1.16	1.28	1.04	1.06	1.02	1.25	1.31	1.42	1.28	1.19	1.25
Packed Density	1.56	1.6	1.47	1.42	1.08	1.06	1.11	1.19	1.28	1.31	1.25	1.11	1.19
Hydrate Density	0.45	0.6	0.46	1	0.54	0.63	0.5	0.5	0.5	0.5	0.6	0.8	0.41
Oil Retention Capacity	1.18	1.6	1.59	1.43	1.61	1.7	1.69	1.6	1.7	1.62	1.74	1.6	1.57
Moisture Content	1.41	4.16	1.57	5.93	0.6	0.33	0.6	2.45	0.19	3.3	1.41	3.09	1.21
MCF	1.01	1.04	1.01	1.05	1.006	1.02	1.001	1.03	1.01	1.01	1.05	1.005	1.01
Emulsifying Activity	0.326	0.284	0.301	0.289	0.33	0.326	0.29	0.329	0.318	0.322	0.337	0.314	0.32
pH	9.47	9.43	8.76	8.55	8.69	8.58	8.85	8.62	8.66	8.77	8.68	8.76	8.64
EC	40.6	45.4	43.8	38.7	38.8	40.8	43.8	44.9	44.1	44.7	40.1	44.3	42.4
Carbonates	32.5	41.25	28.7	35	22.5	22.5	23.7	17.5	26.2	25	23.75	13.7	25
Bicarbonates	82.5	61.2	57.5	75	75	67.5	66.2	20	13.7	37.5	30	36.2	35
Alkalinity(p)	23.75	25	20	22.5	18.75	17.5	30	22.5	12.5	12.5	13.75	32.5	32.5
Alkalinity(M)	23.75	18.7	26.2	30	25	37.5	28.7	21.2	12.5	17.5	15	33.7	81.25
Zinc	1.11163	3.87135	2.03087	1.5548	1.65008	1.71355	2.18925	1.2058	1.49142	1.07887	0.95195	1.17407	1.17407
Iron	7.8901	3.308	3.56328	0.7635	5.7012	7.381	5.3449	2.5452	4.0723	6.363	8.6536	2.5452	5.0904

Table 2: Physico-chemical parameters of soil samples collected from zone-2 of Rangareddy district, Telangana.

Parameter	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**
Bulk Density	1.08	0.92	1.11	1.28	1.19	1.25	1.25	1.28	1.21	1.28	1.25	1.25	1.25
Packed Density	1.04	1.21	1.28	1.25	1.11	1.04	1.06	1.25	1.04	1.16	1.02	1.11	1.19
Hydrate Density	0.38	1	0.25	0.5	0.63	0.5	0.54	0.75	0.8	0.46	0.64	0.72	0.63
Oil Retention Capacity	1.16	1.5	1.5	1.6	1.91	1.49	1.43	1.58	1.56	1.52	1.49	1.44	1.43
Moisture Content	1.6	1.04	1.57	1.57	1.62	1.405	1.61	1.47	1.59	1.53	1.59	1.28	1.27
MCF	1.38	5.48	0.59	1.41	1.01	0.59	11.6	12.28	2.72	26	9.74	4.21	0.6
Emulsifying Activity	1.01	1.05	1.005	1.01	1.01	1.005	1.11	1.12	1.02	1.26	1.09	1.04	1.006
pH	8.59	7.42	7.74	7.79	7.8	7.77	7.72	7.69	7.8	7.72	7.68	7.8	7.75
EC	40.6	66.3	65.3	66.4	65.8	65.5	65.6	66	82	80.4	66.2	79.4	80.4
Carbonates	22.5	26.2	18.7	20	15	18.7	16.2	20	32.5	33.7	26.2	37.5	22.5
Bicarbonates	38.7	43.7	31.2	37.5	43.7	26.2	38.7	31.2	31.2	41.2	50	30	42.5
Alkalinity (p)	30	28.7	23.7	40	30	25	32.5	31.25	25	18.75	28.75	23.75	16.25
Alkalinity(M)	32.5	31.2	26.2	25	31.2	23.7	37.5	28.7	27.5	26.2	30	33.7	41.2
Zinc	0.8567	1.17407	0.6977	0.88851	0.82503	0.7297	0.60292	0.88851	0.60292	0.4759	0.7933	0.56889	0.63465
Iron	6.872	6.872	6.617	6.10848	4.3268	5.34492	5.34492	2.2906	6.10848	6.10848	6.10848	5.34492	5.599

Table 3: Physico-chemical parameters of soil samples collected from zone-3 of Rangareddy district, Telangana.

Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Bulk Density	1	1.25	1.25	1.25	1.25	1.02	1.16	1.13	1	1.16	1.02	0.96
Packed Density	1.25	1.06	1.02	1.21	0.9	1.42	1.04	1.02	1.25	1.16	1.02	1.08
Hydrate Density	1.12	0.42	0.6	0.45	0.75	0.7	0.8	0.5	0.76	0.6	0.53	0.4
Oil Retention Capacity	1.33	1.39	1.46	6.05	1.03	0.93	1.15	0.93	1.43	1.54	1.48	1.37
Moisture Content	1.46	1.59	1.14	1.52	1.605	1.405	1.7	1.62	1.54	1.58	1.64	1.59
MCF	3.3	4.58	4.94	7.91	1.18	8.08	5.8	0.8	1.7	1.18	2.7	15.7
Emulsifying Activity	1.03	1.04	1.04	1.07	1.01	1.08	1.05	1.008	1.01	1.01	1.02	1.15
pH	7.82	7.65	7.64	7.64	7.66	7.84	7.78	7.74	7.81	7.77	7.7	7.8
EC	81.1	79.3	79.4	80.6	79.7	80.1	83.1	81.1	80.1	79.2	79.5	79.6
Carbonates	31.25	17.5	26.2	38.7	36.2	26.2	18.75	23.7	27.5	20	36.2	21.2
Bicarbonates	31.25	43.7	38.7	41.2	38.7	77.5	63.75	78.7	81.2	81.2	78.7	82.5
Alkalinity (p)	17.5	22.5	12.5	18.7	17.5	30	16.25	15	18.7	17.5	20	25
Alkalinity(M)	36.2	33.7	41.2	45	48.7	18.7	36.2	38.7	37	53	18.7	37.5
Zinc	0.8885	0.539	0.76157	0.76157	0.6977	0.82502	1.39607	1.87015	1.39607	2.3799	1.71355	1.71355
Iron	4.5813	6.10848	6.10848	4.8358	5.8539	4.3268	4.8358	6.87204	1.01808	7.12656	4.3268	1.476

Table 4: Physico-chemical parameters of soil samples collected from zone-4 of Rangareddy district, Telangana.

Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Bulk Density	1.19	0.92	1.25	0.83	1	1.19	1.25	1	1	1.02	1.11	1
Packed Density	1.04	0.96	1.25	1.11	1.13	1.06	1.08	1.25	0.96	1.02	0.98	1.02
Hydrate Density	0.75	1	0.45	0.9	0.64	0.5	0.53	0.72	0.9	0.75	0.45	0.8
Oil Retention Capacity	1.46	1.57	1.56	1.38	1.5	1.6	1.22	1.5	1.44	1.58	1.76	1.33
Moisture Content	1.62	4.48	4.46	1.58	1.53	1.6	1.58	1.57	1.63	1.57	1.59	1.7
MCF	5.9	0.4	2.9	1.7	2.6	0.8	2.72	1.18	0.2	2.3	7.06	6.54
Emulsifying Activity	1.05	1.004	1.02	1.01	1.02	1.008	1.02	1.01	1.002	1.02	1.07	1.06
pH	7.76	7.79	7.82	7.79	7.73	7.78	7.8	7.75	7.81	7.77	7.8	7.75
EC	77	79.5	79	77.5	78.3	77.5	77.8	77.2	77.6	76.8	76.5	75.4
Carbonates	21.2	26.2	28.7	25	30	26.2	28.7	30	32.5	27.5	41.2	21.2
Bicarbonates	75	77.5	63.7	73.7	63.7	75	73.7	58.7	72.5	76.2	77.5	81.25
Alkalinity (p)	18.7	13.7	16.2	21.25	12.5	16.25	15	21.25	18.75	12.5	18.7	15
Alkalinity (M)	33	48	60	55	45	47.5	57.5	32.5	46	62	65	58
Zinc	2.25299	1.5229	1.74525	1.49142	1.65008	1.80875	1.77665	1.77665	1.77665	1.39607	1.23756	1.2058
Iron	6.617	5.4467	7.126	4.8358	5.497	5.599	7.12656	6.617	7.8901	4.0723	4.3268	3.8178

Conclusion

The provided data encompasses soil quality parameters from various zones within Rangareddy District, Telangana. Analysis of these parameters offers insights into the characteristics and variations of soil quality across the region. Bulk Density and Packed Density show variation, indicating differences in soil compaction and pore space. Hydrate Density also varies, reflecting disparities in soil moisture content and water retention capacity. Oil Retention Capacity exhibits considerable variation, suggesting differences in soil organic matter content and nutrient retention capabilities. Moisture Content and Correction Factor display significant variability, indicating differences in water availability and soil moisture retention capacities. Emulsifying Activity levels vary, reflecting differences in soil organic matter and microbial activity. pH and Electrical Conductivity (EC) levels vary, indicating differences in soil acidity or alkalinity and salinity, respectively, which can impact nutrient availability and plant growth. Carbonates and Bicarbonates levels vary, indicating differences in soil alkalinity and carbonate buffering capacity. Alkalinity levels also vary, reflecting differences in soil chemical properties and potential impacts on plant growth. Additionally, Zinc and Iron levels vary across zones, suggesting differences in soil nutrient availability and potential deficiencies or toxicities. In conclusion, understanding these variations is crucial for informed land management practices, agricultural productivity enhancement, and environmental sustainability efforts within Rangareddy District. Further research and monitoring are essential to assess the long-term impacts of these soil quality variations and develop targeted strategies for soil conservation and improvement.

Declarations

- **Study Limitations:** The impact of modern agricultural practices on soil quality in the agricultural lands around Ranga Reddy District, Telangana, is a topic of critical importance due to its implications for agricultural productivity, environmental sustainability, and food security. However, conducting a comprehensive study in this area is subject to several limitations that could significantly affect the research outcome:
- **Data Availability:** Access to accurate and comprehensive data on soil quality parameters, historical land use practices, and agricultural inputs may be limited, making it challenging to establish baseline conditions and trends over time.
- **Spatial and Temporal Variability:** Soil quality can vary spatially and temporally due to factors such as topography, soil type, climate, and land management practices. Capturing this variability adequately requires extensive sampling efforts and long-term monitoring, which may not always be feasible.
- **Sampling Techniques:** The selection of sampling locations and techniques can influence the representativeness of the data. Random sampling may not capture localized impacts of agricultural practices,

while systematic sampling may introduce bias.

- **Confounding Factors:** Soil quality is influenced by a multitude of factors, including land use history, irrigation practices, fertilizer application, pesticide use, and crop rotation. Isolating the effects of modern agricultural practices from other confounding factors can be challenging.
- **Data Interpretation:** Interpreting soil quality data requires consideration of complex interactions between different parameters and their implications for soil health and ecosystem function. Simplistic interpretations may overlook important nuances and trends.
- **Scale of Analysis:** The scale at which the study is conducted (e.g., field-scale, watershed-scale, regional-scale) can affect the observed impacts of agricultural practices on soil quality. Different scales may reveal different patterns and processes.
- **Long-Term Effects:** Some impacts of modern agricultural practices on soil quality may only become apparent over the long term, making it difficult to assess their full extent within the scope of a single study.
- **Social and Economic Factors:** Socioeconomic factors such as farmer behavior, land tenure systems, market dynamics, and government policies can influence the adoption of modern agricultural practices and their impacts on soil quality.
- **Mitigation Measures:** Assessing the effectiveness of mitigation measures, such as conservation agriculture practices or precision farming technologies, requires careful consideration of their implementation and adoption rates.
- **Interdisciplinary Approach:** Fully understanding the impact of modern agricultural practices on soil quality requires an interdisciplinary approach that integrates agronomic, ecological, socioeconomic, and policy perspectives. Collaboration between scientists, policymakers, extension agents, and farmers is essential but can be challenging to coordinate.
- Despite these limitations, addressing the impact of modern agricultural practices on soil quality in Ranga Reddy District is crucial for informing sustainable land management strategies and promoting agricultural resilience in the face of environmental change.

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Competing Interests

Not Applicable

Reference

1. Lal R. Soil degradation as a reason for inadequate human nutrition. Food Security. 2015;7(5):866-875.
2. Pimentel D, Hepperly P, Hanson J, Douds D, Seidel R. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience. 2005;55(7):573-582.
3. Vanlauwe B, Descheemaeker K, Giller KE, Huising J. Divergent crop and soil effects on yield and nutrient use efficiency in a long-term cropping systems experiment. Agriculture, Ecosystems & Environment. 2014;188:250-261.
4. Six J, Conant RT, Paul EA, Paustian K. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant and Soil. 2002;241(2):155-176.
5. Cassman KG, Pingali PL. Intensification of irrigated rice systems: Learning from the past to meet future challenges. GeoJournal. 1995;35(3):299-305.
6. Shameem, Parthasarthy. Suicides of cotton farmers in Andhra Pradesh: An exploratory study. Economic and Political Weekly. 1998;33(13):720-726.
7. Visweswara Rao PL, Simhadri S. Telangana: Dimensions of underdevelopment. Centre for Telangana Studies, Hyderabad. 1997.
8. Revathi E. Farmers’ suicide: Missing issues. Economic and Political Weekly. 1998;33:1207.
9. Kekane SS, Chavan RP, Shinde DN, Patil CL, Sagar SS. A review on physico-chemical properties of soil. International Journal of Chemical Studies. 2015;3(4):29-32.
10. Assefa F, Elias E, Soromessa T, Ayele GT. Effect of changes in land-use management practices on soil physicochemical properties in Kabe Watershed, Ethiopia. 2020 Jan 10.
11. Wong MK, Selliah P, Ng TF, Hassan MHA, Van Ranst E, Inubushi K. Impact of agricultural land use on physicochemical properties of soils derived from sedimentary rocks in Malaysia. 2019 Apr 17.
12. Tellen VA, Yerima BPK. Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon. Environmental Systems Research. 2018;7:3.
13. Parthasarathy G, Shameem. Suicides of cotton farmers in Andhra Pradesh: An exploratory study. Economic and Political Weekly. 1998;33(13):720-726.
14. Simhadri S, Visweswara Rao PL. Telangana: Dimensions of underdevelopment. Centre for Telangana Studies, Hyderabad. 1997.
15. Revathi E. Farmers’ suicide: Missing issues. Economic and Political Weekly. 1998;33:1207.
16. Maréchal JC, Dewandel B, Subrahmanyam K, Torri R. Specific methods for the evaluation of hydraulic properties in fractured hard-rock aquifers. Current Science. 2003;85:511-556.
17. Maréchal JC, Dewandel B, Subrahmanyam K. Use of hydraulic tests at different scales to characterize fracture network properties in the weathered–fractured layer of a hard rock aquifer. Water Resources Research. 2004;W11508:1-17.
18. Maréchal JC, Wyns R, Lachassagne P, Subrahmanyam K. Vertical anisotropy of hydraulic conductivity in the fissured layer of hard rock aquifers due to geological

structure of weathering profiles. Journal of the Geological Society of India. 2004;63:545-550.

19. Dewandel B, Lachassagne P, Wyns R, Maréchal JC, Krishnamurthy NS. A generalized 3-D geological and hydrogeological conceptual model of granite aquifers controlled by single or multiphase weathering. Journal of Hydrology. 2006;330:260-284.
20. Maréchal JC, Galeazzi L, Dewandel B, Ahmed S. Importance of irrigation return flow on the groundwater budget of a rural basin in India. IAHS Red Book. 2003;278:62-67.
21. Maréchal JC, Dewandel B, Ahmed S, Galeazzi L, Zaidi FK. Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. Journal of Hydrology. 2006;329:281-293.
22. Dewandel B, Lachassagne P, Wyns R, Maréchal JC, Krishnamurthy NS. A generalized 3-D geological and hydrogeological conceptual model of granite aquifers controlled by single or multiphase weathering. Journal of Hydrology. 2006;330:260-284.
23. Kumar D, Krishnamurthy NS, Ahmed S, Jain SC, Dhar RL. Mise-à-la-masse technique in establishing the lateral extension of fractures in hard rocks. Journal of the Geological Society of India. 2003;61:185-194.
24. Fernández-Cirelli A, *et al*. Environmental effects of irrigation in arid and semi-arid regions. Chilean Journal of Agricultural Research. 2009;69(Suppl. 1).
25. Montanaro G, *et al*. Effects of soil-protecting agricultural practices on soil organic carbon and productivity in fruit tree orchards. Land Degradation & Development. 2009. doi: 10.1002/ldr.917.
26. Tadele M. Impacts of soil acidity on growth performance of faba bean (*Vicia faba* L.) and management options. Academic Research Journal of Agricultural Science and Research. 2020;8(4):423-431.
27. Salunkhe DK, Desai BB. Effects of agricultural practices, handling, processing, and storage on vegetables. In: Nutritional Evaluation of Food Processing. Dordrecht: Springer Netherlands; 1988. p. 23-71.
28. Shah AN, Tanveer M, Shahzad B, Yang G, Fahad S, Ali S, *et al*. Soil compaction effects on soil health and crop productivity: an overview. Environmental Science and Pollution Research. 2017;24:10056-10067.
29. Gandhi N, Sirisha D, Asthana S. Germination of seeds in soil samples of heavy traffic zones of Hyderabad, Telangana, India. Environmental Science-An Indian Journal. 2015;10(6):204-214.
30. Gürsoy S. Soil compaction due to increased machinery intensity in agricultural production: Its main causes, effects, and management. Technology in Agriculture. 2021;1-18.
31. Drewry JJ, Carrick S, Penny V, Houlbrooke DJ, Laurenson S, Mesman NL. Effects of irrigation on soil physical properties in predominantly pastoral farming systems: a review. New Zealand Journal of Agricultural Research. 2021;64(4):483-507.
32. Gürbüz M. Çevre Tarım İlişkileri. Ziraat Dünyası Dergisi, Türkiye Ziraatçılar Derneği Yayınları. 1992;(411).
33. Zollweg J, Makarewicz JC. Detecting effects of best management practices on rain events generating nonpoint source pollution in agricultural watersheds using a physically-based stratagem. Journal of Great Lakes Research. 2009;35(Suppl 1):37-42.
34. Esen E, Uslu O. Assessment of the effects of agricultural practices on non-point source pollution for a coastal watershed: A case study Nif Watershed, Turkey. Ocean & Coastal Management. 2008;51:601-11.
35. Stoate C, Ba'ldi A, Beja P, Boatman ND, Herzon I, van Doorn A, de Snoo GR, Rakosy L, Ramwell C. Ecological impacts of early 21st century agricultural change in Europe – A review. Journal of Environmental Management. 2009;91:22-46.
36. Wohlfahrt J, Colin F, Assaghir Z, Bockstaller C. Assessing the impact of the spatial arrangement of agricultural practices on pesticide runoff in small catchments: Combining hydrological modeling and supervised learning. Ecological Indicators. 2010;10:826-39.
37. Odoux CG, Aurousseau P, Cordier MO, Durand P, Garcia F, Masson V, Monviola JS, Tortrat F, Trepos R. A decision-oriented model to evaluate the effect of land use and agricultural management on herbicide contamination in stream water. Environmental Modelling & Software. 2009;24:1433-46.
38. Carletto C, Kirk A, Winters P. Non-traditional exports, traditional constraints: The adoption and diffusion of cash crops among smallholders in Guatemala. Life Science Journal. 2017;14(2):74. Available from: http://www.lifesciencesite.com
39. De Janvry A, Dustan A, Sadoulet E. Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: Options for the CGIAR. CGIAR Independent Science and Partnership Council; 2011.
40. Pingali P, Bigot Y, Binswanger HP. Agricultural mechanization and the evolution of farming systems in Sub-Saharan Africa. World Bank, John Hopkins University Press; 1987.
41. De Janvry A, Sadoulet E. World poverty and the role of agricultural technology: Direct and indirect effects. Journal of Development Studies. 2002;38(4):1-26.
42. Kebede Y, Gunjal K, Coffin G. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga District, Shoa Province. Agricultural Economics. 1990;4:27-43.
43. Asfaw A, Admassie A. The role of education on the adoption of chemical fertilizer under different socio-economic environments in Ethiopia. Agricultural Economics. 2004;30:215-28.
44. Kijima Y, Otsuka K, Sserunkuuma D. An inquiry into constraints on a green revolution in Sub-Saharan Africa: The case of NERICA rice in Uganda. World Development. 2011;39(1):77-86.