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Improving Soil Quality with Intercropping System: Corn (*Zea (Mays*) and Soybeans (*Glycine max*)

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Abstract

The conversion of rubber land to oil palm in the TBM phase has the potential to cause soil degradation due to low organic matter and nutrient availability. low organic matter and increasing risk of erosion on the plant. Not yet producing (TBM). Land conditions are open, without vegetation, which speeds up washing. Nutrients are essential, so a management strategy is needed that maintains soil quality while providing economic benefits to farmers. The intercropping system of corn and soybeans is an important strategy for improving soil quality while increasing economic benefits for oil palm farmers. Study This aim analyze influence system intercropping corn (*Zea mays*) And soya bean (*Glycine max*) to change characteristic physique and chemistry land on TBM phase oil palm land resulting from conversion from rubber, and comparing the quality of the soil with the land without intercropping. The study was conducted in the Village of Cape Rambutan, Regency of Kampar, with a purposive sampling design. Sample land taken before and after the implementation of intercropping, with a total of 48 samples analyzed in the laboratory. The parameters observed included soil physical properties (texture, bulk density, porosity, infiltration rate and water-holding capacity). Water level and characteristic soil chemistry (pH, organic carbon, total nitrogen, available phosphorus, CEC, exchangeable bases, and base saturation). Data were analyzed, and the results of the research showed that the application of the corn and soybean intercropping system improved the physical and chemical properties of the soil on oil palm land during the TBM phase, making it a more effective and sustainable land management method. Therefore, this system is recommended to farmers and plantation managers as an alternative to maintain soil quality while increasing the economic value of the land.

Keywords: Land Conservation, Land Management, Land Productivity, Physical-Chemical Properties of Soil, Soil Quality

1. Introduction

Land conversion from rubber to oil palm plantations is an increasing trend in Indonesia. The area of oil palm plantations increased from 2.40 million hectares in 2015 to 2.86 million hectares in 2020, then continued to increase to 3.40 million hectares in 2023, and most of this land came from the conversion of rubber plantations (Riau, 2025). From the results of research conducted in Riau regarding farmers' decisions to convert rubber plantations to oil palm plantations, both in terms of technical and economic aspects (income), age and land area, it is significant (Alfiandi & Jalil, 2024). Kampar Regency has experienced a significant transformation in plantation land use, with a trend of increasing land conversion from rubber to oil palm since 2015 due to higher economic returns (Rachma Wita & Asri, 2021). Oil palm plantations have lower organic carbon content than rubber plantations. Other studies have shown that soil carbon stocks at 0–30 cm can decrease by up to 28% compared to rubber plantations (Guillaume et al., 2016). This decrease in organic matter has the potential to reduce soil fertility and quality in the long term.

Bare land in oil palm plantations during the immature phase (TBM) increases the risk of erosion and decreases soil fertility. Young oil palm plantations tend to experience higher erosion and surface runoff than areas with good vegetation cover, demonstrating the importance of vegetation cover in reducing erosion. In addition, the loss of ground cover accelerates the leaching of essential

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nutrients such as nitrogen (N), phosphorus (P), and potassium (K), thereby reducing soil fertility in the long term. (Jaya et al., 2023) .

intercropping systems are one solution to maintain land productivity during periods when oil palm plants are not yet producing (Mthembu et al., 2018). The *intercropping* system has a positive impact on soil fertility and increases land productivity in corn and soybean crops. (Anis et al., 2024) . Plants such as corn (Zea mays) and soybeans (Glycine max) have significant ecological benefits, improving soil structure and increasing water infiltration, while soybeans, as a legume, can increase nitrogen fixation. through symbiosis with Rhizobium bacteria, they help maintain soil fertility by increasing nitrogen use efficiency. (Du et al., 2019) .

Several studies have shown that *Intercropping* Corn and soybean plants can provide economic and environmental benefits and increase soil fertility. compared *to no intercropping* (monoculture) (Cui et al., 2024) & (Harsono et al., 2020). In addition to increasing nitrogen availability, the corn-soybean intercropping system has also been shown to improve soil physical and chemical properties. Another study (Nasar et al., 2024) showed that corn-soybean intercropping increased soil organic matter content, N, P, and K availability, soil enzyme activity, nutrient uptake, and crop yield compared with monoculture systems. These conditions indicate that intercropping not only increases crop productivity but also serves as a soil conservation technology that can sustainably improve soil quality.

Systems research: *Intercropping* of corn and soybeans on immature oil palms evaluates the economic feasibility, land efficiency (LER and LOER), and profitability of corn–soybean farming on oil palm TBM. (Agustira et al., 2018) . The study has not evaluated changes in soil physical and chemical properties. The novelty of this study lies in the comprehensive evaluation of changes in soil quality, integrating physical and chemical soil parameters, resulting from the application of the corn-soybean intercropping system on oil palm land in the TBM phase after rubber land conversion. In contrast to previous studies that generally focus on the productivity and economic aspects *of intercropping*, this study emphasizes intercropping as a strategy for rehabilitating soil quality, as measured by changes in bulk density, total pore space, permeability, water-holding capacity, pH, organic C, CEC, and base saturation.

Thus, this study was conducted to analyze changes in soil quality resulting from the application of the corn and soybean intercropping system on oil palm land that was diverted or formerly used as a rubber plantation.

2. Material and Methods

This study was conducted in the Tanjung Rambutan Village area, Kampar District, Kampar Regency, Riau Province. The research location is at coordinates 0 ° 18'15.74” North Latitude. and 101°02'21.09” BT, with an altitude of 60 masl, with rainfall of ± 1500 - 3000 mm/year, average temperature 26 °C–28 °C, and air humidity 75%–85%. The research land used is a coconut plantation. palm oil on age 3 non-productive years (TBM). The study was conducted for 3 months, from June to October 2025.

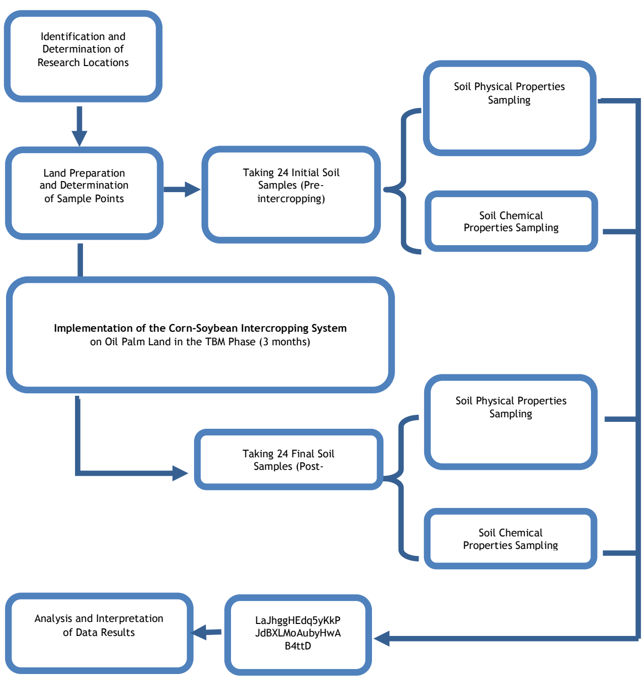

Figure 1. Research flow diagram

The tools and materials used in the field research included light agricultural equipment such as hoes, soil sample rings, soil scales, GPS, and laboratory measuring instruments for analyzing soil physical properties. The materials used included corn (*Zea mays*) and soybean (*Glycine max*) seeds for 1 hectare of land, as well as labels for plots and sample points. Corn and soybean seeds were planted in each oil palm row using a 1:2 planting pattern with a spacing of 20 cm between plants. The corn planting distance was 75x25 cm, and the soybean planting distance was 25x25 cm.

The number of sample points to be analyzed on 1 hectare of oil palm land to be planted with *intercropping plants* is 6 lines (living fences). Each line contains 4 sample points. The total sample points per stage are 24 soil samples during pre-intercropping and 24 during post-intercropping.

The total number of samples to be collected during the research is 4-8. This way was done by collecting primary and secondary data. The primary data collected were the soil's physical and chemical properties, obtained in the field and analyzed in the laboratory. The tools used in this study consisted of field and laboratory equipment. Laboratory equipment included a digital scale, oven, desiccator, soil sieve, permeameter, pH meter, shaker, spectrophotometer, and flame photometer. AAS, burette, measuring pipette, Erlenmeyer flask, beaker glass, and measuring flask.

Data was analyzed using Statistical analysis was carried out using SPSS to determine the differences in soil parameter values before and after intercropping.

3. Results and Discussion

3.1. Physical Properties of Soil

Soil physical property analysis was conducted to assess the effect of the intercropping system on changes in soil physical characteristics in oil palm land resulting from land conversion to rubber plantations. The results of this analysis are very important for assessing the physical quality of the soil and the effectiveness of nutrient absorption, root growth, and oil palm plant productivity in the intercropping system. To support this research, several physical characteristics of the soil were analyzed to identify changes that indicate an increase in the quality of oil palm soil in land conversion to rubber plantations based on corn and soybean *intercropping, namely*:

3.1.1. Soil Texture

The results of the soil texture analysis test at the pre-research stage showed that the average of all samples had a composition of 50.9% Sand, 35.7% Clay and 13.4% Dust, while the soil texture after planting corn and soybeans between oil palm plants in the TBM phase was 42.1% Sand, 24.50% Clay and 33.41% Dust. Changes in soil texture indicate that the corn and soybean *intercropping system* can improve soil structure, increase biological activity, and strengthen aggregate formation, thereby decreasing the sand and clay fractions relatively, while the dust fraction increases significantly (S. Zhang et al., 2021).

Table 1. Analysis values of physical properties of soil in the pre-intercropping and post-intercropping phases *of corn* and soybean plants on TBM oil palm land.

Physical Properties Parameters	**Average value**	
	Pre- *Intercrop*	**Post- *Intercrop***
Water content*	24.88% S	21.06% SS
Bulk Density (BD)**	1.37 g/cm 3 KS	0.63 g/cm 3 S
Particle Density (PD)	2.09 g/ cm3 CR	1.60 g/cm 3 R
TRP	34.37% CR	60.30% T
Permeability*	5.72 AC	7.35 C

Converted with Source: (*) Bierman (2007) in Riwandi and Handajaningsih (2011); (**) Tarigan, *et. al* (2015); Description: S: Healthy, SS: Very Healthy, KS: Not Healthy, CR: Quite Low, R: Low, T: High, AC: Somewhat Fast, C: Fast

3.1.2. Soil Water Content

The soil water content analysis values in Table 1 decreased post-intercropping, from 24.88% to 21.06%, after the corn and soybean intercropping system was implemented. This decrease in soil water content occurred due to increased water absorption by corn and soybean roots (root water uptake), along with improved soil structure, increased porosity, and increased infiltration under the intercropping system. This observation is related to improved soil structure (because the intercropping roots increase aeration so that water absorbs more quickly (Lal, 2021). In addition, the decrease in soil water content in the corn and soybean *intercropping system* was influenced by increased biological activity in the rhizosphere, including root respiration and microbial activity, which led to greater fluctuations in soil moisture. The intercropping system of corn and soybeans can increase soil enzyme activity and improve the rhizosphere microbial environment, thereby altering soil physical properties (Liu & Zhao, 2023).

3.1.3. Bulk Density (BD)

the bulk density (BD) analysis in Table 1 shows a significant decrease from 1.37 g/cm3 to 0.63 g/cm3. The 54.01% decrease in *bulk density* in this study indicates a greater improvement in soil physical quality than in several previous intercropping studies. Other studies also show that maize *-pea* intercropping in the long term for 11 years showed a decrease in bulk density of 6.4–14.2% compared to the monoculture system (Yang et al., 2023). The magnitude of the decrease in *bulk density* (BD) in this study is thought to be influenced by a combination of changes in soil texture fractions, increased root activity of corn and soybean plants, biopore formation, and increased soil aggregation, which causes an increase in pore space and a decrease in soil mass density.

3.1.4. Particle Density (PD)

The particle density (PD) analysis value in Table 1 shows a very significant change from 34.37% with a fairly low criterion to 60.30% with a high (large) particle density criterion. The greater increase in particle density (PD) indicates that intercropping improves soil structure by forming denser, more stable aggregates. The activity of intercropping roots and microorganisms is known to produce exudates and polysaccharides that strengthen particle bonds, thereby increasing the density of the soil's solid fraction (Bünemann et al., 2018). In addition, plant roots act as aggregate-binding agents that encourage the formation of a more compact soil structure (Six et al., 2002). The *intercropping* system promotes the formation of more stable aggregates by increasing root biomass and soil biological activity (Thierfelder et al., 2012).

3.1.5. Total pore space (TRP)

The total pore space (TRP) value in Table 1 increased from 34.37% to 60.30%, indicating a significant improvement in soil structure after intercropping. This increase indicates that the final TRP value of 60.30% in this study is within the same range as the results of legume-based cover crop research and deep-rooted plants, which produced total porosities of 60.88–61.88% (Ahmadnia et al., 2025). The high porosity is associated with plant roots' ability to form biopores and improve soil pore distribution. The *intercropping system* is known to increase soil biological activity and biopore formation, thereby increasing total pore space (Thierfelder et al., 2012). In addition, Li et al. found that the maize–pea intercropping system increased total soil porosity by 2.98–4.50% compared with monoculture (Min et al., 2023).

3.1.6. Soil Permeability

The soil permeability value in the corn-soybean *intercropping system* under oil palm stands showed a clear increase, namely from 5.72 in *pre-intercropping* to 7.35 in post-intercropping. This increase indicates that the soil's ability to transmit water is improving, which is directly related to improved soil structure, increased macropore numbers and the formation of natural biopores due to the growth of intercrop roots. Mixed-cropping intercropping systems can increase permeability by expanding macropores produced by roots and soil organisms (Thierfelder et al., 2021). Another study also explains that soil permeability increases with decreasing bulk density (BD) and increasing aggregate stability, thereby creating more effective water flow pathways (Ray R. et al., 2021). Furthermore, other studies confirm that improving soil structure and aggregation directly increases infiltration rates and permeability (USDA Science & Staff, 2022).

This increase was supported by a 54.01% decrease in bulk density and a 75.44% increase in total pore space, indicating the formation of a better soil pore system. These results are consistent with research (Seidel et al., 2017) that reported that corn-soybean intercropping reduced soil density and increased porosity, as well as with research (Corneo et al., 2017) that showed an increase in macroporosity and soil structure quality due to intercropping corn with legumes.

3.2. Soil Chemical Properties

Soil chemical properties are among the important factors that determine soil fertility and productivity, supporting plant growth. Chemical parameters such as pH, organic carbon, total nitrogen, available phosphorus (P), cation exchange capacity (CEC), and base cation concentration play a major role in determining soil quality. Analysis of soil chemical properties provides an overview of soil chemical conditions, which can be used as a basis for targeted soil management and improvement. In this study, soil chemical property analysis tests were conducted at the pre- and post- intercropping stages to determine changes in each parameter, which will be evaluated based on the soil quality criteria listed in Table 2.

3.2.1. Soil pH

The soil pH value in Table 2 shows an increase of 0.51 units (10.60%) from 4.81 to 5.32. Other research on the corn-soybean intercropping system on suboptimal land also showed an increase in pH from 5.10 to 5.42, or only a 6.27% increase (Astiko et al., 2022). Even a relatively small increase in pH in acidic soil reflects an improvement in the functional quality of soil chemistry (Ray R. et al., 2021). This indicates that the intercropping system on TBM oil palm land converted from rubber has a strong ability to improve soil reactions.

The 0.51 unit increase in soil pH in this study is consistent with other studies (Thierfelder et al., 2012) that reported a 0.2–0.5 unit increase in pH in intercropping systems, and (Lal, 2020) that reported a 0.3–0.6 unit increase in diversified cropping systems. These results indicate that corn–soybean intercropping effectively improves the chemical quality of acidic Ultisol soils.

3.2.2. C-Organic

The organic C content increased significantly from 1.61% (low) to 3.33% (high) after *intercropping* (Table 2). This increase indicates the accumulation of organic matter derived from root residues, intercrop biomass, and decomposed litter in the soil. Furthermore, the soil-based cropping system is effective in increasing soil carbon storage and plays a significant role in improving soil quality (Lal, 2020). Therefore, this increase in organic carbon is a key indicator of soil quality improvement in the corn and soybean *intercropping system* on oil palm plantations, especially those originating from rubber plantation conversion.

Table 2. Intercropping of corn and soybean plants on oil palm land

Chemical Properties Parameters	Average value	
	Pre- *Intercrop*	Post- *Intercrop*
pH	4.81 R	5.32 R
C-Organic (%)	1.61 R	3.33 T
N Total (%)	0.20 R	0.43 S
C/N ratio	10.78 R	16.12 T
P available (ppm)	28.57 ST	31.21 ST
Cation Exchange Capacity (KTK)	8.43 R	18.16 S
K-dd (me %)	0.38 R	0.41 S
Ca-dd (me %)	1.00 SR	3.38 R
Mg-dd (me %)	0.20 SR	0.72 R
Na-dd (me %)	0.06 SR	0.47 S
Base Saturation	19.16 SR	26.32 R

Based on the Assessment Criteria Table of Soil Chemical Properties (Balittanah, 2005); Description: R: Low, ST: Very High, SR: Very Low, R: Low, S: Medium, T: High, AC:

3.2.3. Nitrogen

The soil nitrogen value in Table 2 increased from 0.20% (low) to 0.43% (moderate) after intercropping. This increase is quite significant and greatly affects the availability of N in the soil. This relates to the presence of soybean plants as legumes that can fix atmospheric nitrogen through symbiosis with Rhizobium bacteria (Peoples, MB et al., 2019). Other studies also show that the intercropping system of corn and soybeans can increase biological nitrogen fixation and the amount of nitrogen derived from the atmosphere compared to monoculture, thereby helping maintain soil fertility in the long term (Du et al., 2019).

3.2.4. d. C/N ratio

Table 2 shows that the C/N ratio increased from 10.78 (low) to 16.12 (high) after intercropping. The increased C/N ratio indicates a balance between carbon and nitrogen in soil organic matter, supporting a more stable nutrient mineralization process (Ray R. et al., 2021). Furthermore, other researchers have suggested that a balanced C/N ratio reflects more stable organic matter and the ability to sustainably support soil microbial activity (Lehmann & Kleber, 2015).

3.2.5. P-Available

The available P value increased from 28.57 ppm to 31.21 ppm, or 9.24%, after the implementation of corn-soybean intercropping. These results are consistent with previous research showing that *intercropping* can increase soil phosphorus availability by increasing phosphatase activity, microbial biomass, and the mobilization of bound phosphorus. The increase in available phosphorus was 24–103%, while in red soil it reached 70.4% compared to monoculture (G. Zhang et al., 2025). Although the increase in this study was lower, this is thought to be because the initial available P value was already in the very high category, limiting the potential for further increases in available phosphorus.

3.2.6. Cation Exchange Capacity (KTK)

The cation exchange capacity (CEC) value increased significantly from 8.43 cmol(+)/kg (low) in pre-intercropping to 18.16 cmol(+)/kg (medium) in post-intercropping, indicating an improvement in the soil's ability to retain and supply nutrient cations. This increase in CEC is closely related to the increase in soil organic C content due to the addition of biomass and root exudates from the corn and soybean *intercropping system*, which provides negatively charged functional groups as the main source of exchange charges in variable-charge tropical soils such as Ultisols (Lehmann & Kleber, 2015). The increase in CEC values in this study is higher than that reported in previous research, which showed a 19.53% increase in CEC in the corn-soybean intercropping system on marginal dry land (Riyanto et al., 2023). The significant increase in CEC in this study is thought to be related to higher organic carbon content and soil pH, which increase the soil's negative charge and nutrient retention capacity. Furthermore, these conditions indicate that CEC is a sensitive indicator of soil chemical quality improvement and plays a crucial role in increasing nutrient retention efficiency in Ultisols, which naturally have low CEC (Bünemann et al., 2018).

3.2.7. K-dd, Ca-dd, Mg-dd and Na-dd, and Base Saturation (KB)

Implementation of the *intercropping system* in Corn and soybean plants on TBM oil palm land, formerly rubber land, can increase the base content with K-dd values from 0.38 to 0.41 cmol(+)/kg (7.89%), Ca-dd from 1.00 to 3.38 cmol(+)/kg (238.00%), Mg-dd from 0.20 to 0.72 cmol(+)/kg (260.00%), and Na-dd from 0.06 to 0.47 cmol(+)/kg (683.33%). The 238% increase in Ca-dd and

260% increase in Mg-dd in this study is very high compared to previous research. Corn-soybean intercropping only increased Ca-dd by about 22.6% and Mg-dd by about 19.1%. (Pierre et al., 2018) . Thus, the increase in Ca-dd and Mg-dd in oil palm TBM land in former rubber plantations was approximately 10.5 and 13.6 times greater, respectively, compared to the intercropping system on conventional agricultural land. This indicates that the intercropping system on degraded land has greater potential to improve the soil base cation status by increasing nutrient cycling and cation retention in the soil absorption complex.

4. Conclusion

This study indicates that the intercropping system of corn and soybeans on former rubber plantations planted with oil palms in the TBM phase can also improve soil quality by enhancing soil physical and chemical properties, as evidenced by increased porosity, permeability, pH, organic carbon, CEC, base cations, and base saturation. In addition to increasing soil fertility, this system provides farmers with income opportunities while the oil palm plants are not yet producing. Therefore, the intercropping system of corn and soybeans from former rubber plantations can also be used as an alternative for effective, productive, and sustainable land management on TBM oil palm lands after rubber land conversion.

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