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Research Article
Physicochemical Properties of Polluted Soil Using Cassava Peels as Amendment and *Mariscus flabelliformis*

[1]Solomon Obinna Chuku, [2]Oghenetekevwe Efekemo, [3]Udomine Brantley Akuru, [3]Prince Aruchi Chikordi Amechi, [3]Chinule Davies Elendu, [4]George Nnabugwu Anaero-Nweke, [1]Tariah Julia Obaraemi, [1]Chibuzor Njoku and [3]Tamuno-Boma Odinga-Israel

[1]Department of Plant Science and Biotechnology, Faculty of Science, Rivers State University, Rivers State, Nigeria
[2]Department of Environmental Management and Toxicology, College of Sciences, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria
[3]Department of Biochemistry, Faculty of Science, Rivers State University, Rivers State, Nigeria
[4]Department of Animal and Environmental Biology, Faculty of Science, Rivers State University, Rivers State, Nigeria

Abstract
Background and Objective: Contamination of soil with organic pollutants poses a significant environmental challenge. Understanding *Mariscus flabelliformis* mechanisms in organic enhanced soil is crucial for effective phytoremediation strategies. This research investigated the potential of *Mariscus flabelliformis*, a hardy plant species, in conjunction with cassava peel as an organic amendment for phytoremediation purposes. **Materials and Methods:** An experiment was conducted with crude oil-polluted soil and agricultural soil with cassava peel waste which was taken to the laboratory for physicochemical and proximate analysis. A random complete block design was adapted for the entire experiment where a total of 15 experimental bags were filled with 10 kg of soil and amendment. Study of the degradation of total petroleum hydrocarbon (TPH), its accumulation in roots and shoots, plant growth and biomass production. **Results:** Plant morphological parameters showed values that increased due to the addition of cassava peel waste with an increase in time. The T3 which had 300 g of cassava peel recorded highest plant height at 4 weeks (23 cm) while the least was observed in T4 with no amendment at less than 15 cm at 4 weeks. The same was observed in leaf number on T3 which was significantly higher in weeks 1 and 2 and T5 which had no pollution recorded the highest number of leaves of over 10 cm in the first week. **Conclusion:** The study further demonstrates that cassava peels have the potential to degrade crude oil-polluted soils and are also capable of increasing soil beneficial nutrients like N, P and K. It is therefore recommended that further research be done on the use of cassava peels in petroleum hydrocarbon degradation and enhancement of agricultural soil.

Key words: Pollutants, cassava peels, crude oil, phytoremediation, *Mariscus flabelliformis*

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Corresponding Author: Tamuno-Boma Odinga-Israel, Department of Biochemistry, Faculty of Science, Rivers State University, Rivers State, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Crude oil, upon entering the soil, disrupts its structure and reduces porosity, leading to decreased water infiltration and increased erosion potential[1]. Soil microorganisms crucial for nutrient cycling and soil health are adversely affected by crude oil pollutants, leading to a reduction in microbial diversity and function[2].

Hydrocarbons in crude oil inhibit seed germination, stunt plant growth and interfere with nutrient uptake, affecting overall plant health and biomass production[3]. Conventional remediation techniques such as excavation are costly and disruptive, while bioremediation methods utilize microorganisms to break down contaminants, offering a more sustainable approach[4].

Some plant species demonstrate the ability to uptake, metabolize or sequester contaminant from the soil, presenting promising avenues for remediating oil-polluted sites[5]. Phytodegradation, a subset of phytoremediation, is a sustainable and environmentally friendly approach for the clean-up of contaminated soils and water using plants and their associated microorganisms[6]. This process involves the use of specialized plant species to facilitate the degradation, transformation or detoxification of various pollutants through natural metabolic pathways. Phytodegradation has gained significant attention due to its potential for the cost-effective and ecologically sound remediation of contaminated sites[7].

The effectiveness of phytodegradation in the remediation of hydrocarbon-contaminated sites has been highlighted in previous studies[8]. Their research emphasizes the potential of certain plant species to enhance the degradation of hydrocarbons, particularly in petroleum-contaminated soils. The authors argue that the use of native or adapted plant species can significantly improve the efficiency of phytodegradation processes, making it a valuable tool for environmental restoration.

Phytodegradation plays a crucial role in environmental remediation by offering a sustainable and ecologically sound solution for the clean-up of contaminated sites[9]. This approach is vital in addressing the ever-increasing issue of soil and water pollution, as it helps mitigate the adverse effects of contaminants while minimizing the use of expensive and potentially harmful chemical methods[10].

Contamination of soil with organic pollutants has posed to be hazardous to the environment, an understanding of the use of *Mariscus flabelliformis* in organic enhanced soil is crucial for effective phytoremediation strategies. Thus, this research investigated the potential of *Mariscus flabelliformis*, with cassava peel as an organic amendment for phytoremediation purposes.

MATERIALS AND METHODS

Study area: The duration of the study lasted for 4 months, between June, 2023 and September, 2023. The teaching and research farm of Rivers State University in Port Harcourt is located at a Latitude of 4.7923 and a Longitude of 6.9825. This study site features a tropical monsoon climate, with an annual temperature of 32.15°C, humidity of 0.9945 and atmospheric pressure. The soil typically consists of sandy, loamy or clayey textures underlain by an impervious pan. The study site was situated at the Rivers State University Research Farm, Faculty of Agriculture, Rivers State University, Port Harcourt, Nigeria. An area measuring 20 by 10 m was marked with a measuring tape and cleared to ground level. No covering was applied to allow direct sunlight and rain to reach the plants, creating a natural environment conducive to proper growth.

Planting material: Seedling of *Mariscus flabelliformis* is the planting material used for the experiment. It was sorted out around the University campus, from an area where the plant species is abundant. It was ensured that the initial seedling height was 5 cm and was of the same figure.

Experimental design: A random complete block design was adapted for the entire experiment.

Experimental bags: A total of 15 experimental bags filled with soil amendments (cassava peel) were prepared, using five bags for each plant, replicated trice. The bags were sourced from Mile 3 Market in Port Harcourt and each weighed and perforated on all sides and the bottom to prevent water logging.

Weighing scale: A weighing scale of 100, 200 and 300 g capacity of different amendments were used to measure cassava peels for the enhancement of the soil. Additionally, all Seedling bags contained 10 kg of soil.

Experimental soil: Two types of soil were obtained for this Experimental work, which include; polluted soil and agricultural soil. Polluted soil was gotten from a polluted site at Iwofe, around Ignatius Ajuru University, Port Harcourt. The agricultural soil was obtained from Rivers State University Teaching and Research Farm on the school premises which was taken to the greenhouse of the Rivers State University, Nigeria.

Amendment materials and treatment: The enhancement agent that was used; was cassava peel. The experiment was in 1 block for the plant. Block 1: 10 kg of soil was used with 100, 200 and 300 g of cassava peel.

T1: 100 g cassava peel+10 kg of polluted soil + *Mariscus flabelliformis*
T2: 200 g cassava peel+10 kg polluted of soil + *Mariscus flabelliformis*
T3: 300 g cassava peel+10 kg of polluted soil + *Mariscus flabelliformis*
T4: 10 kg of polluted soil+*Mariscus flabelliformis* (Control 1)
T5: 10 kg of agricultural soil + *Mariscus flabelliformis* (Control 2)

Analysis of soil characteristics: Samples of soil were taken from the experimental site for the analysis of physicochemical characteristics before planting.

Assessment of soil physicochemical properties

Determination of THC: The spectrophotometer method was employed to determine the total hydrocarbon content (THC)[11]. The oven dried sample was weighed immediately after drying and placed in a test tube. As 99.9% chloroform (10 mL) was mixed with the sample in the test tube which was then tightly corked and shaken for a few seconds and consequently placed on a rack till a supernatant and sediment that is clear enough was observed. A spectrophotometer was used to read the supernatant extract at 420 nm wavelength (Shoot spectrophotometer) (Thermo Fisher Scientific, Waltham, Massachusetts, USA) using pure chloroform as blank. The THC concentration was subsequently extrapolated from a standard bonny medium and the light crude graph plotted.

Determination of TOC: Assessment of TOC was carried out through the oxidation method[12]. A clean conical flask with 250 mL calibration was used to store 1g of the sample after weighing. Concentrated sulphuric acid solution (7.5 mL) and potassium dichromate (5 mL) were added. An electrothermal heater was used to heat the mixture for up to 15 min for the process of oxidation to take place. Consequently, the mixture was diluted to 100 mL with distilled water after it was allowed to cool at room temperature. As 25 mL of the solution was titrated with ferrous ammonium sulphate was used to titrate 25 mL of the solution while ferroin was used as an indicator. As described above, a blank was set up in the same manner and subsequently treated. Recording of the titre value was done and total organic carbon values were calculated thus the percentage of TOC Titre value of blank-titre value of the sample.

Determination of CEC: A measure of ammonium acetate solution (30 mL) of 1 M part was added and stirred for 15 min with 5 g of dried sample from the oven. A 1000 mL capacity flask was used in obtaining the supernatant which was repeated twice and the supernatant extract was up to 100 Ml by adding ammonium acetate solution. Atomic Absorption Spectrophotometer (AAS) (BUCK scientific 200A model)[13] was employed in determining the amounts of sodium, calcium and magnesium. The CEC was determined and mean soil CEC was calculated and expressed in meq/100 g of the sample from the different locations.

Determination of total nitrogen content: Spectrophotometry was used to determine the total nitrogen content. A blank solution consisting of only 25 mL sample supernatant and a sample solution consisting of 25 mL supernatant+nitraver-5 reagent powder was subsequently prepared Spectrophotometer (HACH, DR/890 colorimeter model) cell holder was employed in placing the blank solution and the spectrophotometer displayed zero as the reading of the blank solution. The blank solution served as a substitute for the sample solution and nitrate composition was read and recorded as it was projected by the machine. The mean total nitrogen was subsequently calculated and thus expressed in percentage[14].

Determination of phosphate (APHA 4500): Samples of soil (2 g) were added alongside Olsen's extracting solution (40 mL) and Whatman filter paper was used as a filter. The citrate (5 mL) was measured using a measuring cylinder (25 mL) and distilled water (10 mL) was added with B-reagent (4 mL) which was filled up to 25 mL using distilled water. This process stood for 10 min and absorbance readings were obtained with the use of a T60 UV-visible spectrophotometer (PG Instruments Limited, United Kingdom)[15].

Determination of potassium (APHA 4500): Samples of soil at 5 g were measured into a conical flask of 100 mL containing 1 N NHAOAC solution (25 mL). A mechanical shaker was employed to shake the mixture and subsequently filtered using the Whatman filter paper. The Flame Industrial Photometer model 410 (Sherwood Scientific Ltd, Cambridge, CB1 8DH UK) was used to extract potassium[16].

Statistical analysis: The data collected was subjected to Analysis of Variance (ANOVA). The means were separated using the least significant difference (LSD) at a 5% level of probability. The statistical tool employed was the Duncan's Multiple Range Test (DMRT). It is a *post hoc* test to measure specific differences between pairs of means.

RESULTS

The result from Table 1 shows the nutritional composition of cassava peels.

Effect of cassava peel on soil cation exchange capacity and potassium: Result in Fig. 1 showed a high level of CEC with waste cassava treatment. The highest increase of CEC with cassava treatment was recorded in T5 (control without treatment). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in CEC. The least in soil CEC was found in control polluted soil (T4) devoid of treatment. There is significant difference within and between treatment at p = 0.05.

Results in Fig. 2 showed a high level of K with waste cassava treatment. The highest increase of K with cassava treatment was recorded in (T3). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in K. The least in soil K was found in control polluted soil (T4) devoid of treatment. There is a significant difference within and between treatments at p = 0.05.

Table 1: Nutrient content of the amendment

Parameter	Cassava waste
pH	5.4
P (mg/kg)	2.87
N (%)	1.78
K (mg/kg)	248
Na (mg/kg)	548
CEC (meq/100 g)	73.0
Ca^2 (mg/kg)	210
TOC (%) (mg/kg)	1.02
THC (mg/kg)	Nil

pH: Hydrogen ion concentration, P: Phosphorus, N: Nitrogen, K: Potassium, Na: Sodium, CEC: Cation exchange capacity, Ca: Calcium, TOC: Total organic carbon and THC: Total hydrocarbon content

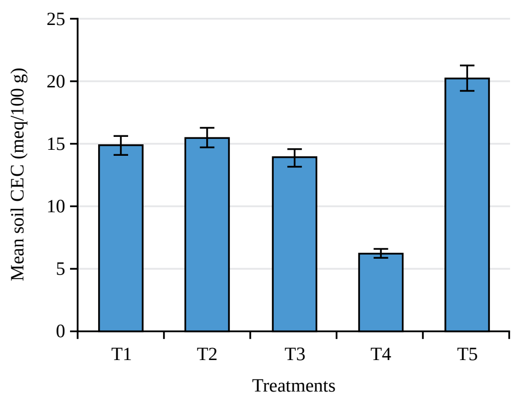

Fig. 1: Effect of different levels of treatments on soil CEC

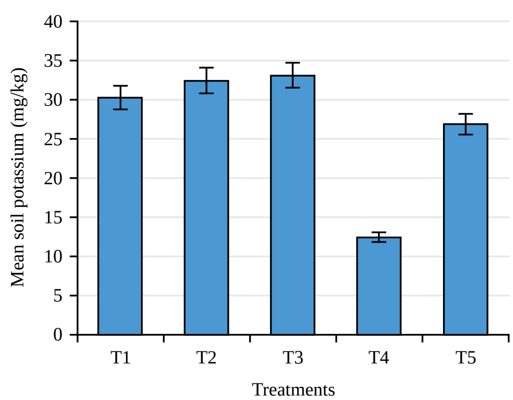

Fig. 2: Effect of different levels of treatments on soil potassium

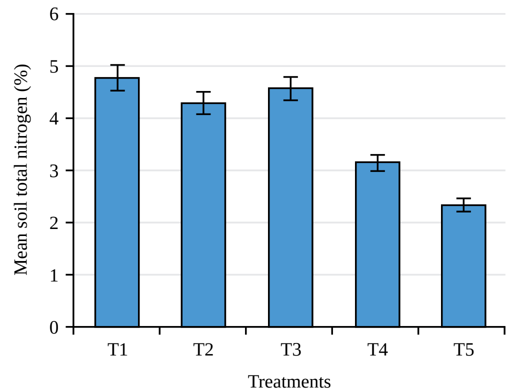

Fig. 3: Effect of different levels of treatments on soil total nitrogen

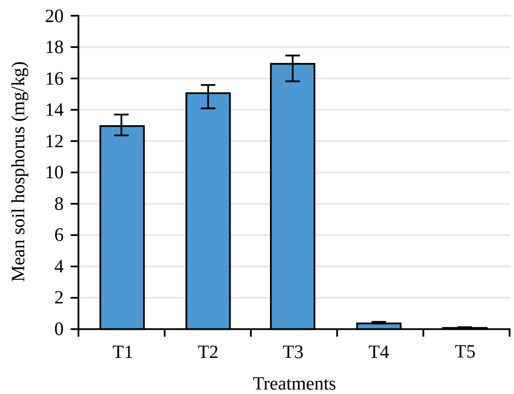

Fig. 4: Effect of different levels of treatments on soil phosphorus

Result in Fig. 3 showed high level of N with waste cassava treatment. The highest increase of N with cassava treatment was recorded in (T1). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in N. The least in soil N was found in control polluted soil (T4) devoid of treatment. There is significant difference within and between treatment at $p = 0.05$.

Result in Fig. 4 showed high level of P with waste cassava treatment. The highest increase of P with cassava treatment was recorded in (T3). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in P. The least in soil P was found in control unpolluted soil (T5) devoid of treatment. There is significant difference within and between treatment at $p = 0.05$.

Result in Fig. 5 showed a decrease level of THC with waste cassava treatment. The least decrease in THC with cassava treatment was recorded in (T3). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in THC. The highest increase in soil THC was found in control polluted soil (T4) devoid of treatment. There is significant difference within and between treatments at $p = 0.05$.

The result in Fig. 6 showed a decreased level of TOC with waste cassava treatment. The least decrease in TOC with cassava treatment was recorded in (T1). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in TOC. The highest increase in soil TOC was found in control polluted soil (T4) devoid of treatment. There is significant difference within and between treatment at $p = 0.05$.

The result showed a decreased level of TPH with waste cassava treatment. The least decrease in TPH with cassava treatment was recorded in (T1). However, the corresponding soils with various levels of cassava treatment also showed a significant increase in TPH. The highest increase in soil TPH was found in control polluted soil (T4) devoid of treatment. There is a significant difference within and between treatments at $p = 0.05$.

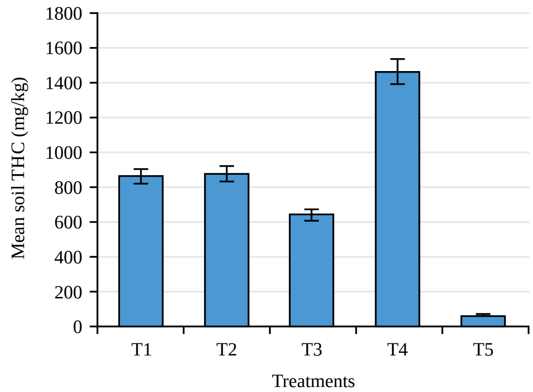

Fig. 5: Effect of different levels of treatments on soil THC

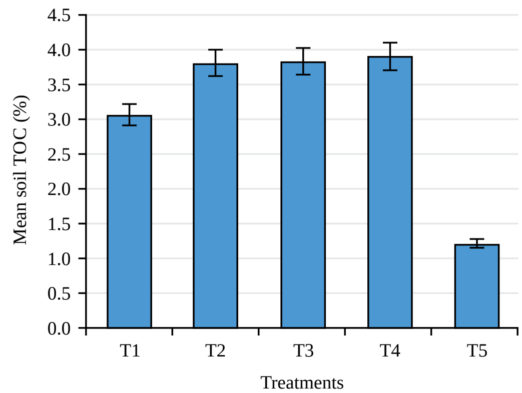

Fig. 6: Effect of different levels of treatments on soil TOC

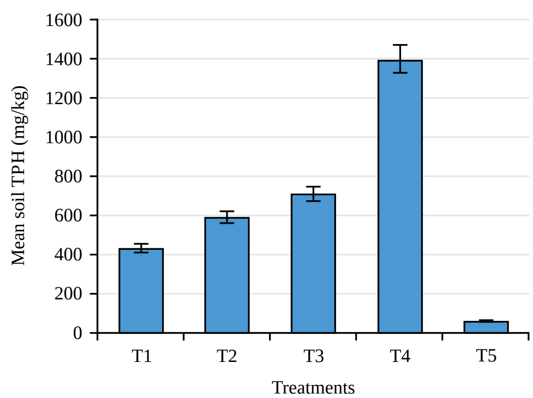

Fig. 7: Effect of different levels of treatments on soil TPH

DISCUSSION

Table 1 shows the nutrient content of the amendment. From the results, the amendment was observed to have appreciable percentages of sodium, phosphorus, nitrogen, potassium and calcium. These nutrients have been reported by da Silva Correa *et al.*[17] to be essential nutrients in sodium, thus their presence in the amendment will boost the integrity of the polluted soil.

From the results as shown in Fig. 1-7 on the soil cation exchange capacity, Treatment 5 recorded the highest CEC soil concentration which may have been a result of the absence of any pollutant that might hinder or alter the normal soil chemical properties. However, the lowest CEC concentration was recorded in Treatment 4 which had crude oil pollution with no amendment. This result may have been due to the densely polluted soil with no concentration of any type of remediation. Other treatments showed CEC levels that were below the acceptable soil ranges which was due to the impact of crude oil pollution or contamination on the soil. This study is in line with previous studies by Chen *et al.*[18] that reported the decline in the growth and reproduction of plants in pollution-laden environments.

From the results shown in the soil potassium may have been due to the introduction of cassava peels that aided in increasing the soil potassium. However, the lowest concentration of soil potassium was recorded in T4 which had crude oil pollution with no amendment. This reduction may have been due to the absence of organic amendments which led to the absence of essential soil nutrients like soil potassium which was lower than the permission limit at 300 mg/kg or less in soil.

Results on soil nitrogen showed an increase in the polluted and amended soils in all the treatments. This increase in the concentration of soil nitrogen may have been due to the introduction of cassava peel waste which contained a significant amount of nitrogen, hence, the increment in soil nitrogen values. This study agrees with that of Egobueze *et al.*[19], who reported the positive effects of organic amendments on the physicochemical properties of crude oil-polluted soil.

However, T5 which had no amendment, recorded the lowest soil nitrogen concentration which is an indication that the presence of cassava peels in the soil led to an increase in the concentration of soil nitrogen. However, nitrogen levels in all the soil were lower than the acceptable limits stipulated by the World Health Organisation (WHO) which is 40 ppm. This finding is in line with Chuku and Amadi[20], who reported the reduction of soil chemical properties due to crude oil pollution on soil.

Soil phosphorus showed a drastic decline in T4 and T5 which had no amendment. This is an implication that cassava peel waste helps increase soil phosphorus levels. This report agrees with that of the impact of crude oil on soil physicochemical properties of soil as reported by Otobo *et al.*[21].

Results on soil Total Organic Carbon (TOC) and soil total hydrocarbon (THC) showed the highest increase in T4 which might have been due to the presence of hydrocarbon in the soil. However, the lowest concentration of soil hydrocarbon was observed in T3 which had a high concentration of cassava peel and also observed in T5 which served as the control with no pollution[22].

Soil total petroleum hydrocarbon (TPH) recorded the highest increase in soil TPH in T4 which may have been as a result of the crude oil degraded soil with no amendment. The T1 recorded the lowest TPH values on the sample soils which may be due to the introduction of cassava peel waste. However, T5, which recorded the lowest TPH values was a result of the complete absence of any pollutant in the soil and its environment[23].

The effect of cassava peel in the enhancement of soil and its Physiochemical properties was evident, especially on the soil devoid of pollution (T5) in the leaf number.

The influence of organic amendments on soil quality cannot be overemphasized as it has greatly improved the growth of plants as reported by Calamai *et al.*[24]. Some soils are devoid of some beneficial microorganisms which leads to plant death in general, hence the need to utilize some organic amendments to increase the soil nutrient properties.

The presence of organic amendments in the soil aided in the enhancement of *Mariscus flabelliformis* on all the treated soils, excluding T4 which had pollution with no amendment and T5 which was not polluted with no amendment. This report agrees with other studies by researchers[25-27], which reported that oil in the soil creates unsatisfactory conditions for plant growth, ranging from retarded growth in plants to insufficiency in aeration of the soil. The implications of using cassava peels for the remediation of crude oil-polluted soils include; improved soil structure and enhanced microbial activity as cassava peels can stimulate indigenous microbial populations thereby promoting biodegradation of petroleum hydrocarbons; increased nutrient availability, soil carbon sequestration and improved soil fertility[24]. The application of this study includes environmental restoration, agricultural land remediation, wetland restoration, disaster response, sustainable agriculture and ecosystem service restoration[24].

It is therefore recommended that regular awareness be done to reduce or limit the regular disposal of pollutants especially petroleum hydrocarbons in undesignated areas. It is also recommended that cassava peel waste be employed for the remediation of crude oil-polluted soil as it proved to degrade hydrocarbons in the soil.

The limitations of this study entail a slow remediation process as organic amendments can take years to achieve significant remediation, a nutrient imbalance which might be as a result of over-application of amendments, limited depth remediation as amendments may not effectively remediate pollution deep in the soil profile.

CONCLUSION

The study showed the effect of cassava peel waste on the enhancement of soil physiochemical properties. The introduction of cassava peels led to an increase in beneficial soil nutrients and also led to a decrease in beneficial soil hydrocarbons that were below the acceptable ranges stipulated by the World Health Organization (WHO). Besides the fact that the levels of hydrocarbons observed in the present study decreased significantly due to the introduction of organic enhancers, significant fractions of these hydrocarbons were due to anthropogenic activities. It is evident from the results that cassava peels are good soil enhancers and good for hydrocarbon-degraded soils as it consist of beneficial soil nutrients.

RECOMMENDATIONS

The future recommendations of this study include:

- Developing tailored amendment blends by creating customized blends of organic amendments optimized for specific soil types and pollutant profiles
- Utilize microbe-enriched amendments by developing amendments with targeted microbial populations to enhance biodegradation
- Implement precision agriculture techniques by using advanced technologies like drones and satellite imaging to optimize amendment application and monitoring
- Foster interdisciplinary research collaborations by encouraging partnership among scientists, engineers and policymakers to advance remediation technologies and strategies

SIGNIFICANCE STATEMENT

The purpose of this study is to assess the impact of crude oil pollution on soil properties, evaluate the effectiveness of organic amendments in remediating polluted soils, understand how organic amendments alter soil physicochemical properties and develop strategies for restoring polluted soil health and fertility. The objective findings of this study include an increase in some soil physicochemical properties like plant height, total organic carbon, soil phosphorus, increased soil nitrogen and cation exchange capacity. *Mariscus flabelliformis* has been shown to possess some adaptive structures that can help to remove petroleum hydrocarbons from the soil which are tools for soil remediation. The future prospective of this study includes sustainable soil remediation, soil health management, soil pollution monitoring and environmental risk assessment.

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