Global Scientific JOURNALS

GSJ: Volume 11, Issue 6, June 2023, Online: ISSN 2320-9186

www.globalscientificjournal.com

EFFECT ON SOIL IMPROVEMENT PATTERNS IN CORN-GROWING AREAS FOR ANIMAL FEED IN ET DISTRICT, HOUAPHAN PROVINCE, LAOS

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KeyWords: planting methods, soil composition, soil conservation, corn yield, and upland soil.

ABSTRACT

The study focuses on soil improvement patterns in corn-growing areas for animal feed in Et District, Houaphan Province. The research examines the soil improvement model and economic returns in fodder corn cultivation using a Completely Randomized Block Design (RCBD) with three treatments: T1 = corn (maintain crop residues), T2 = Corn + Soybean (preserve crop residue after harvest), and T3 = Corn + Peanut (preserve crop residue after harvest). The study also considers a second factor, which is the use of fertilizers and non-fertilizers. The results for soil acidity-alkalinity (pH) before and after corn planting did not show a significant difference (P > 0.05). However, the amount of organic matter (OM%) displayed a significant difference (P < 0.05), with the fertilizer model showing the highest average value of 3.06%, followed by the non-fertilizer model with a value of 2.83%, and the control group with the lowest value of 1.78%. The amount of nitrogen (N%) also exhibited a significant difference (P < 0.05) between fertilized and non-fertilized treatments, with both having a value of 1.79%, while the control group had a lower value of 0.13%. Similarly, there was a significant difference (P < 0.05) in the amount of phosphorus content (P-avai), with the fertilizer model having the highest value of 42.1 mg/kg, followed by the non-fertilizer model with 28.28 mg/kg, and the control group with the lowest value of 12.9 mg/kg. The amount of available potassium (K-avai) also showed a significant difference (P < 0.05), with the fertilized treatment having the highest value of 86 mg/kg, followed closely by the non-fertilized treatment with a value of 81 mg/kg, and the control group with the lowest value of 65 mg/kg. The proportion of sand content in the soil exhibited a significant difference (P < 0.05). The control group had the highest value of 50.4%, followed by the non-fertilized model with 45.2%, and the fertilizer model with the lowest value of 40.99%. Similarly, the proportion of silt content showed a significant difference (P < 0.05), with the control group having the highest value of 34.26%, followed by the fertilizer treatment with 29.46%, and the non-fertilizer treatment with the lowest value of 27.27%. The proportion of clay content also exhibited a significant difference (P < 0.05), with the fertilizer treatment having the highest value of 33.11%, followed by the non-fertilizer treatment with a value of 27.31%, and the control group with the lowest value of 17.52%. The yield parameters, including corn plant weight, corn kernel count, number of corn pods per hectare, and height of corn plants at the end of harvest (123 days), did not show a significant difference (P > 0.05). However, the weight of corn grains in each experimental area was found to be significantly different (P < 0.05), with the highest weight recorded in T3 at 5,955.8 kg/ha, followed by T2 at 4,865 kg/ha, and T1 with the lowest value of 3,937 kg/ha. The total yield also showed a significant difference (P < 0.05), with the highest value observed in T3 at 8,069.2 kg/ha, followed by T2 at 7,112.4 kg/ha, and the lowest value in T1 at 5,836.8 kg/ha. In terms of economic returns, T3 demonstrated the highest profit of 19,450,667 kips, followed by T2 with 16,079,917 kips, and the lowest profit in T1 at 12,377,167 kips. Comparing the economic returns between the three planting methods and two types of fertilization (fertilizer and non-fertilizer), the non-fertilizer method showed a higher profit of 16,255,667 kips, followed by the fertilizer method with a profit of 15,682,833 kips. Based on this experimental study, it was found that the T3 planting method (corn + peanuts with preserved crop residue after harvest) resulted in the highest yield and profit. How-

ever, the use of fertilization or non-fertilization had an impact on the levels of nitrogen, phosphorus, and potassium. Further research is needed to assess the potential of cover crops and other soil-building practices in reducing drought stress, improving soil quality, increasing water-holding capacity, and ultimately enhancing yields and income.

Introduction

Corn is the second main crop cultivated in the upland areas of the Lao PDR, following rice. In the late 20th century, corn cultivation was primarily concentrated in Sayabouly province, specifically in the Botean and Keantao districts. However, during the early years of the 21st century, corn cultivation gradually expanded to other provinces such as Oudomxay, Bokeo, Xiengkhouang, Houaphanh, and others, resulting in a total cultivated area of 223,210 hectares by 2015. Subsequently, due to soil degradation, low productivity, and unfavorable market prices, the corn-cultivated area decreased to 176,130 hectares according to Agricultural Statistics in 2017. Notably, corn cultivation practices in these areas heavily rely on the natural fertility of the soil, with limited adoption of soil fertility improvement techniques or the use of fertilizers. Consequently, farmers in districts like Et, Sobbao, and Xiengkhor in Houaphanh face challenges in conserving soil fertility, controlling soil erosion, and achieving higher yields. The absence of inorganic fertilizer application, coupled with topsoil erosion caused by runoff, has resulted in rocky soil surfaces and significantly reduced yields.

However, intercropping has proven to be a valuable agricultural strategy wherein one plant species is cultivated alongside two or more crops within the same area and at the same time. This practice offers several benefits such as enhanced crop quality and increased yield. In comparison to monoculture, intercropping improves soil fertility, promotes plant diversity, suppresses weed growth, and optimizes light interception and utilization (Li et al., 2019; Farooq et al., 2021). Additionally, Shen et al. (2021) conducted a study investigating the short-term effects of soybean intercropping in a tea garden. The results revealed that the intercropping pattern not only increased soil electrical conductivity (EC) and the availability of phosphorus (P), potassium (K), and other microelements but also enriched the relative abundances of *Acidobacteriaceae, Burkholderiaceae, Rhodanobacteraceae,* and *Sphingomonadaceae*. These bacterial families are known as organic matter decomposers and/or facilitators of plant growth.

Corn yield has been shown to increase or decrease by over 50% following low- or high C: N-ratio cover crops, respectively (Finney et al. 2016, White et al. 2017). However, the effect of moisture limitation on the relationship between cover crop N supply and corn yield after plantation has never been tested on the chemical composition, particularly in Corn-Growing Areas for Animal Feed in Et District, Houaphan Province, Laos.

In this study, the effects of intercropping corn plantations with different types of legumes (soybean and peanut) were examined through smallholder farmer's field experiments. It was hypothesized that intercropping corn with legumes would contribute to the improvement of soil fertility and corn yield, as well as result in changes in the soil's chemical composition and increased income. Therefore, the first objective was to estimate the effects of intercropping on soil fertility and the performance of corn plants. The second objective aimed to screen various intercropping models for their potential to enhance yields and economic returns.

Material and methods

Field experiment

Field experiments were conducted at two locations in Et District, Houaphan Province, Laos: Khou village (E: 395199.492, N: 2310660.391) and Narghea (E: 387666.309, N: 2309618.306) from May to December 2022. The average annual rainfall in Houaphan Province for both 2021 and 2022 was 1,854.4 mm, which is consistent with the long-term average. The average minimum air temperature ranged from 16.7oC, while the average maximum air temperature was 25.9oC in March.

The field trial followed a randomized complete block design with three replications, utilizing a Completely Randomized Block Design (RCBD). The three treatments included T1 = corn (maintaining crop residues), T2 = Corn + Soybean (preserving crop residue after harvest), and T3 = Corn + Peanut (preserving crop residue after harvest). Two factors were considered: non-fertilizer type and fertilizer type. The trial period spanned 123 days for implementation and data collection.

Table1. experiment design and sampling methods

Block	Block1			Block2		
Treatment	R1	R2	R3	R1	R2	R3
T1						
T2						
T3						

Data collection

Planting dates and other management practices, including fertilization and weed control dates, were documented. For all three treatments, the upper portion of the corn plants was collected when the cob silk turned black. The entire crop grain was harvested at maturity, and the corn cobs were collected after the stover and leaves had dried. The grains were then separated and weighed. Similarly, in the case of soybeans and peanuts, both the pods and grains were harvested, and their weights were recorded. Sub-samples were taken for oven drying. This process was repeated multiple times throughout the growing season.

Soil analysis

For soil properties assessment before plot layout in all farmers' fields, soil samples were collected from 5-10 cores and then combined into a single sample. The collected soil sample was analyzed using the Walkley and Black method to determine organic matter content. Total nitrogen content was determined using Kjeldahl's method (AOAC 1990). Available phosphorus content was analyzed using the Bray II method, while available potassium content was measured using 1N ammonium acetate and read in a flame photometer. Soil pH was determined using a soil-to-water ratio of 1:2.5. Soil texture was assessed using a hydrometer.

Data analysis

The data were analyzed using the general linear model (GLM) in IBM-SPSS Statistics 23 (2016). Means were separated using the least significant difference (LSD) test. The significance level was set at P = 0.05.

Results

Based on the experimental research conducted on soil improvement in the fodder corn area through the intercropping of corn with legumes (soybeans, peanuts) and comparing the effects of fertilization and non-fertilization on corn growth, corn yield, changes in soil chemical composition, and economic returns, the following results can be summarized:

The analysis of the chemical composition of the soil before planting

Before conducting the experiment, soil samples were collected from each experimental plot and sent to the Soil, Fertilizer, and Plant Research Center of the Department of Land Acquisition and Development, Ministry of Agriculture and Forestry in Vientiane. The research center has conducted three experiments with the following treatments: T1 - Corn planting style (maintenance of plant residues), T2 - Corn + Soybean (preserving crop residue after harvest), and T3 - Corn + Peanut (preserving crop residue after harvest). The research results from these experiments are summarized in the table below:

Table 2. The chemical composition of the soil before planting

Parameter (Content)	Treatment			SEM	P-Value
	T1	T2	T3		
pH (H2O)	5.1 ab	4.53 b	5.36 a	0.16216	0.028
OM (%)	1.80	1.76	1.80	0.82210	0.911
N (%)	0.133	0.136	0.133	0.26460	0.995
P-avai (mg/kg)	12.856	13.186	12.676	5.57700	0.998
K-avai (mg/kg)	64.00	69.66	61.33	8.72841	0.796
Sand (%)	50.44 b	46.78 c	54.14 a	0.79095	0.002
Silt (%)	32.60	36.80	33.38	1.57226	0.213
Clay (%)	16.16	17.75	18.66	1.21256	0.393

Table 2 presented the results of the analysis for different parameters of the soil before planting, including pH, organic matter (OM) content, nitrogen (N) content, available phosphorus (P-avai), available potassium (K-avai), sand content, silt content, and clay content. The treatments (T1, T2, and T3) represent different planting styles or combinations of crops. It found

The analysis of the soil composition before planting revealed statistically significant differences ($P < 0.05$) among the treatments. The T3 experiment had the highest pH value of 5.36, indicating a more alkaline soil condition. The pH value of the T1 experiment was close to T3, with a pH value of 5.1. In contrast, the T2 experiment had the lowest pH value of 4.53, suggesting a more acidic soil environment. These variations in pH values indicate differences in soil acidity/alkalinity among the treatments. Furthermore, the percentage of sand showed a statistically significant difference ($P < 0.05$) among the treatments. Experiment T3 exhibited the highest value of 54.14%, followed by T1 at 50.44% and T2 at 46.78%. These findings indicate variations in the soil texture, with T3 having a higher proportion of sand compared to T1 and T2. Regarding other chemical elements such as organic matter (OM) (%), nitrogen (N) (%), phosphorus (P-avai) (mg/kg), potassium (K-avai) (mg/kg), silt (%), and clay (%), the values for each element were similar among the experiments, and there were no statistically significant differences ($P > 0.05$) observed. This suggests that the initial levels of these elements in the soil were comparable across all treatments.

The analysis of the chemical composition of the soil during planting without the use of fertilizer

The analysis results of the soil samples collected during the planting phase without fertilizer application, to analyze the chemical composition of each experiment, are presented in the table below.

Table 3. The chemical composition of the soil during planting without the use of fertilizer

Parameter (Content)	Treatment			SEM	P-Value
	T1	T2	T3		

pH (H_2O)	4.83b	5.07ab	5.4a	0.09813	0.018
OM (%)	2.05 b	3.16 ab	3.28a	0.28498	0.04
N (%)	0.15b	2.55a	2.69a	0.24726	0.001
P-avai (mg/kg)	17.94c	25.22b	41.68a	1.32687	0.001
K-avai (mg/kg)	73.00	79.67	90.33	5.51429	0.161
Sand (%)	50.99a	39.09 b	45.22ab	2.73577	0.05
Silt (%)	27.55	28.25	26.02	3.93631	0.921
Clay (%)	24.75	25.23	31.95	3.17035	0.275

Based on the analysis results, significant variations (P < 0.05) were observed in the chemical composition of the soil during planting without fertilizer application. The pH value demonstrated statistical significance, with experiment T3 exhibiting significantly higher alkalinity (pH 5.4) compared to experiments T2 (pH 5.07) and T1 (pH 4.83). The organic matter content (OM) also displayed significant differences (P < 0.05) among the experimental groups. Experiment T3 had the highest percentage of organic matter (3.28%), closely followed by experiment T2 (3.16%), while experiment T1 had the lowest organic matter content (2.05%). The nitrogen content (N) exhibited statistical differences (P < 0.05) across the experimental groups. Experiments T3 and T2 had relatively similar values of 2.69% and 2.55%, respectively, while experiment T1 showed a lower nitrogen percentage of 1.15%. Phosphorus availability (P-avai) showed significant variations (P < 0.05), with experiment T3 displaying the highest value (41.68 mg/kg), followed by experiment T2 (25.22 mg/kg), and experiment T1 with the lowest phosphorus content (17.94 mg/kg). The percentage of sand demonstrated statistical differences (P < 0.05). Experiment T1 had the highest sand content (50.99%), followed by Experiment T3 (45.22%), while Experiment T2 had the lowest sand percentage (39.09%). Regarding potassium availability (K-avai), silt percentage (%), and clay percentage (%), no statistical differences were observed among the experiments (P > 0.05), indicating similar values for each chemical element across the experimental groups.

The analysis of the chemical composition of the soil during planting using fertilizer

The analysis results of the chemical composition of the soil during planting with the addition of fertilizer are presented in the table below.

Table 4. The chemical composition of the soil during planting by using fertilizer

Parameter (Content)	Treatment			SEM	P-Value
	T1	T2	T3		
pH(H_2O)	4.86 b	5.36 ab	5.53 a	0.1414	0.037
OM (%)	2.24 b	3.31 a	3.65 a	0.2462	0.016
N (%)	0.18 b	2.67 a	3.07 a	0.2198	0.001
P-avai (mg/kg)	32.24 b	38.01 b	56.05 a	3.9137	0.012
K-avai (mg/kg)	73 b	83.33 ab	101.66 a	6.1252	0.042
Sand (%)	51.78 a	36.42 ab	34.77 b	3.5517	0.027
Silt (%)	25.30	30.85	32.25	2.7086	0.238
Clay (%)	29.22 b	34.23 a	35.9 a	1.0414	0.01

Based on the results of the analysis, significant differences in soil chemical composition were observed among the experimental groups. The pH value, indicating acidity or alkalinity, showed a significant difference (P < 0.05) among the experiments. Experiment T3 had the highest pH value of 5.53, followed by T2 with a pH value of 5.36, and T1 with the lowest pH value of 4.83. The content of organic matter (OM) also displayed a significant difference (P < 0.05) among the experimental groups. Experiment T3 exhibited the highest percentage of organic matter with a value of 3.65%, followed by T2 with 3.31%, while T1 had the lowest amount of organic matter at 2.24%. In terms of nitrogen content (N), a statistically significant difference (P < 0.05) was observed among the experimental groups. T3 and T2 had higher nitrogen values of 3.07% and 2.67%, respectively, whereas T1 had the lowest nitrogen content of 0.18%. The amount of available phosphorus (P-avai) varied significantly (P < 0.05) among the experimental groups. Experiment T3 had the highest phosphorus value of 56.05 mg/kg, followed by T2 with 38.01 mg/kg, and T1 with 32.24 mg/kg. Similarly, the amount of available potassium (K-avai) showed a significant difference (P < 0.05) among the experimental groups. T3 had the highest potassium value of 101.66 mg/kg, followed by T2 with 83.33 mg/kg, while T1 had a lower potassium content of 73 mg/kg. The percentage of sand differed significantly (P < 0.05) among the experimental groups. T1 had the highest sand content with a percentage of 51.78%, followed by T2 with 36.42%, and T3 with the lowest sand percentage of 34.77%. Regarding the percentage of clay, a statistical difference (P < 0.05) was observed. T3 and T2 showed relatively similar percentages of clay with 34.23% and 35.9%, respectively, while T1 had the lowest clay content at 29.22%. The percentage of silt did not show a significant difference (P > 0.05) among the experimental groups.

Comparison of soil chemical composition in fertilized and unfertilized crop planting.

The analysis results of growing crops with and without fertilization were presented in the table below:

Table 5. The chemical composition of soil chemical composition in control (before planting), fertilized, and unfertilized areas.

Parameter (Content)	Analyzed area			SEM	P-Value
	Control (before planting)	non-fertilizer	fertilizer		
pH (H_2O)	5.00	5.10	5.25	0.12	0.354
OM (%)	1.78 b	2.83 a	3.06 a	0.20	0.001
N (%)	0.13 b	1.79 a	1.79 a	0.36	0.003
P-avai (mg/kg)	12.9 c	28.28 b	42.1 a	3.52	0.001
K-avai (mg/kg)	65 b	81 a	86 a	4.52	0.008
Sand (%)	50.45 a	45.1 b	40.99 b	2.35	0.030
Silt (%)	34.26 a	27.27 b	29.46ab	1.63	0.018
Clay (%)	17.52 c	27.31 b	33.11 a	1.37	0.001

Upon analyzing the results, it was observed that there was no statistically significant difference in the acidity and alkalinity (pH) values among the control (before planting), fertilized, and non-fertilized areas (P>0.05). However, significant differences were identified in the chemical composition of the soil, specifically in terms of organic matter (OM) content (%), nitrogen (N) content (%), phosphorus availability (P-avai) (mg/kg), potassium availability (K-avai) (mg/kg), and content (%), silt content (%), and clay content (%). In terms of organic matter, the fertilized area exhibited a significantly higher value (3.06%) compared to the non-fertilized area (2.83%) and the control area (1.78%). Similarly, there was a significant difference in nitrogen content, with both the fertilized and non-fertilized areas showing the same value (1.79%), while the control area had the lowest nitrogen content (0.13%). The phosphorus availability in the soil was also found to be significantly different, with the fertilized area having the highest value (42.1 mg/kg), followed by the non-fertilized area (28.28 mg/kg), and the control area with the lowest value (12.9 mg/kg). Similarly, the potassium availability showed significant differences, with the fertilized area having the highest value (86 mg/kg), followed closely by the non-fertilized area (81 mg/kg), and the control area exhibiting the lowest value (65 mg/kg). Regarding the soil texture, the percentage of sand content differed significantly among the three areas. The control area had the highest sand content (50.4%), followed by the non-fertilized area (45.2%), and the fertilized area had the lowest sand content (40.99%). The percentage of silt content also exhibited significant differences, with the control area having the highest value (34.26%), while the non-fertilized and fertilized areas showed similar values (27.27% and 29.46%, respectively). Moreover, the clay content displayed statistical differences among the areas, with the fertilized area having the highest value (33.11%), followed by the non-fertilized area (27.31%), and the control area having the lowest value (17.52%).

Comparison of growth and yield performance in three experiments

Through the collection of data on the growth and production efficiency from three experiments, namely T1: the corn planting model with plant residue preservation, T2: the Corn + Soybean model with crop residue preservation, and T3: the Corn + Peanut model with crop residue preservation, the research results can be presented in the table below

Table 6. Comparison of growth and yield performance in 3 treatments

Parameter (Content)	Treatment			SEM	P-Value
	T1	T2	T3		
Corn plant weight (Kg/ha)	5,600	6,033	7,000	531.4	0.21
Cob weight (Kg/ha)	887.5	889.7	1013	55.2	0.23
Grain weight (Kg/ha)	3,937.8 c	4,865 b	5,955.8 a	183.4	0.0002
Productivity (Kg/ha)	5,836.8 c	7,112.4 b	8,069.2 a	137.7	0.0002
corn pods/ha	9,4333	9,4333	8,8333	1725	0.06
Height)cm)	173.9	178.1	175.7	2.9	0.60

Through the analysis of data on the weight of corn plants, grain, productivity, cob, the number of corn pods per hectare, and the height of corn plants at the end of harvest (123 days) in each experimental plot, no statistical difference (P > 0.05) was observed in the weight of grain weight and the number of corn pods per hectare. However, there were statistically significant differences ($P < 0.05$) in the weight of corn grains and the total yield. The weight of corn grains showed significant differences ($P < 0.05$) among the experimental areas. The highest weight was observed in experimental area T3, with a value of 5,955.8 kg/ha, followed by T2 with the same value of 4,865 kg/ha, and T1 had the lowest weight of 3,937 kg/ha. The total yield also exhibited statistically significant differences ($P < 0.05$). The highest yield was obtained in experimental group T3, with a value of 8,069.2 kg/ha, followed by T2 with a value of 7,112.4 kg/ha. Experimental group T1 had a lower total yield compared to the other groups, with a value of 5,836.8 kg/ha.

Comparison of yield efficiency in non-fertilizer and fertilizer cultivation

From the experiment on fodder corn cultivation in the experimental area, the results of the analysis comparing two factors, namely not applying fertilizer and applying fertilizer, can be seen in the table below:

Table 7. Comparison of yield efficiency in non-fertilizer and fertilizer cultivation

Parameter (Content)	cultivation		SEM	P-Value
	non-fertilizer	fertilizer		
	5911.1	6511.1	433.32	0.342
Corn plant weight (Kg/ha)	894.5	965.8	42.83	0.256
Cob weight (Kg/ha)	4387.1 b	5452.1 a	324.35	0.034
Grain weight (Kg/ha)	6235.6 b	7776.1 a	340.84	0.006
Productivity (Kg/ha)	88888.9 b	95777.8 a	179.6	0.011
corn pods/ha	172.2	179.6	3.57	0.161

From the table provided, it is evident that there are variations in the results of the experiment on fodder maize cultivation between the non-fertilized and fertilized areas. The weight of corn kernels and the height of corn plants at the end of the harvest did not show any significant statistical difference ($P>0.05$) between the two areas. However, there were significant statistical differences ($P<0.05$) in the weight of corn grains, total yield, and the number of corn pods. The weight of corn grains per hectare showed a significant statistical difference ($P<0.05$) between the fertilized and non-fertilized areas, with the fertilized area yielding a higher weight of 5,452 kg/ha compared to 4,387.1 kg/ha in the non-fertilized area. Similarly, the total yield per hectare exhibited a significant statistical difference ($P<0.05$), with the fertilized area producing a higher yield of 7,776.1 kg/ha compared to 6,235 kg/ha in the non-fertilized area. Furthermore, the number of corn pods per hectare also displayed a significant statistical difference ($P<0.05$) between the fertilized and non-fertilized areas. The fertilized area had a higher number of pods with an average of 9,577.8 pods/hectare, whereas the non-fertilized area had an average of 6,235 pods/hectare. These results indicate that the application of fertilizer in the cultivation of fodder maize significantly influenced the weight of corn grains, total yield, and the number of corn pods, demonstrating a higher yield efficiency compared to non-fertilized cultivation.

Evaluation of the economic rate of Returns

Through the collection of economic data from three corn cultivation experiments, namely T1: corn cultivation model (with plant residue maintenance), T2: Corn + Soybean (with crop residue maintenance after harvest), and T3: Corn + Peanut (with crop residue maintenance after harvest), the evaluation of economic returns yields the following results:

Table 8. Comparison of the average economic returns across different treatments.

Parameter (Content)	Treatment		
	T1	T2	T3
Fixed Capital (Kip)	83,333	83,333	83,333
Revolving capital (Kip)	7,965,500	8,730,500	8,707,500
Total investment cost (Kip)	8,048,833	8,813,833	8,790,833
Income (Kip)	20,426,000	24,893,750	28,241,500
Net income (Kip)	**12,377,167**	**16,079,917**	**19,450,667**

From the table was found that the fixed capital and working capital show similar average values across the experiments. However, the income varies significantly between the experiments: Experiment T3 yields the highest income at 28,241,500 (kip), followed by Experiment T2, while Experiment T1 generates the lowest income at 24,893,750 (kip) and 20,426,000 (kip) respectively. Consequently, the profit or production cost balance demonstrates a similar trend as the income: Experiment T3 shows the highest profit at 19,450,667 (kip), followed by Experiment T2, while Experiment T1 has the lowest profit at 16,079,917 (kip) and 12,377,167 (kip) respectively.

Evaluation of economic returns across non-fertilizer and fertilizer cultivation

The economic returns from the experimental results of fodder maize cultivation in the experimental area, considering the factors of no fertilization and fertilization are presented in the table below:

Table 9. Comparison of yield efficiency in non-fertilizer and fertilizer cultivation

Parameter (Content)	non-fertilizer	fertilizer
Fixed Capital (Kip)	83,333	83,333
Revolving capital (Kip)	5,484,667	11,451,000
Total investment cost (Kip)	5,568,000	11,534,333
Income (Kip)	21,823,667	27,217,167
Net income (Kip)	**16,255,667**	**15,682,833**

The table reveals that the average fixed capital is similar, but the working capital differs significantly, resulting in varying total costs. The fertilizer factor incurs higher total costs compared to the non-fertilizer factor: 11,534,333 kips and 5,568,000 kips, respectively. Regarding income, the fertilized factor shows higher returns with an income of 27,217,167 kips, while the non-fertilized factor has a lower income at 21,823,667 kips. However, the profit or income balance exhibits an opposite trend to costs and income. The non-fertilizer factor yields relatively better profits with 16,255,667 kips, while the fertilizer factor has a profit of 15,682,833 kips. This discrepancy arises from the higher cost associated with chemical fertilizers in the fertilizer factor, resulting in lower profitability.

Discussion

This study focuses on evaluating soil improvement methods for fodder corn cultivation and comparing the economic returns of two approaches: with fertilizer and without fertilizer, conducted across three experiments. Regarding soil analysis after corn harvest, each experiment exhibited statistically significant differences that were consistent with Sukoon's (2017) findings on the impact of nitrogen fertilizer application, which showed a nitrogen content of 0.2%. Tidaphon (2017) reported changes in soil fertility due to the application of corn fertilizer at a rate of N90-P50-K50 kg/ha. This resulted in a decrease in soil acidity (pH) from 8.08 to 7.50, an increase in soil organic matter (OM) from 1.40 to 1.77, and slight changes in phosphorus (P) and potassium (K) levels. These changes were statistically significant but reflected relatively lower values. Chirawat (2015) found that the yield of shelled corn increased to 9,188 kg/ha when applying chemical fertilizers. However, in this experiment, the yield remained lower. Following the planting method recommended by Sulael and the team (2010), applying chemical fertilizers at higher rates led to a statistically significant increase in shelled corn yield. Su Kung et al. (2017) conducted experiments on the growth and yield of corn using different fertilizer formulas. Their findings demonstrated that applying a mixture of fertilizer 15-15-15 and fertilizer 16-20-00 + 46-00-00 divided into 1, 2, or 3 applications resulted in better productivity ranging from 4,122 to 4,716 kg/ha. Using only fertilizer 15-15-15 led to a yield of 2,118 kg/ha, while no fertilizer application resulted in a yield of 906 kg/ha. Both fertilizer and non-fertilizer experiments showed higher productivity. Kittawit Sukung and Tanyalat Chaeping (2021) reported the production cost and returns from fodder corn cultivation in Pang Pax Ta Seng Nahai Luang Village, Bin Kaew District, Nan Province. They found a production cost of 14,900,838 kip/ha, an income from output of 23,054,869 kip/ha, and a balance of income of 8,154,031 kip. Comparatively, this experiment showed similar production income and higher income balance.

Conclusion and Recommendations

In the study on improving the soil in fodder corn areas through alternate planting of corn with legumes (soybeans, peanuts) and comparing fertilizer and non-fertilizer methods, the following key findings emerged:

The pH level showed no statistical difference (P>0.05) between soil conditions before planting, regardless of fertilizer application. However, parameters such as organic matter (OM), nitrogen (N) content, available phosphorus (P-avai), available potassium (K-avai), and soil composition exhibited significant differences (P<0.05) based on the experimental factors. Notably, nitrogen content, phosphorus availability, and potassium availability showed the most prominent changes. The weight of corn grains and total yield differed significantly (P<0.05). Experiment T3, which involved planting corn with a peanut model, yielded higher grain weight and total yield compared to the other groups. Experiment T2 followed with relatively lower values, while Experiment T1 had the lowest yields. However, other factors such as corn plant weight, corn grain weight, number of corn pods per hectare, and plant height did not show significant differences among the experiments.

The weight of corn grains, total yield, and number of corn pods per hectare varied between the two methods. Fertilizer application resulted in higher values compared to non-fertilizer cultivation. However, factors such as corn plant weight, cob weight, corn grains weight, and plant height did not differ significantly among the experiments. The economic return of corn cultivation: Experiment T3, involving the planting of corn with peanuts, generated higher income and profit compared to the other experiments. Experiment T2 followed with relatively higher values, while Experiment T1 had the lowest income and profit. The income and profit exhibited opposite trends between the two methods. Fertilizer application yielded higher income, while non-fertilizer cultivation proved more profitable. Therefore, considering the efficiency of soil restoration, production, income, and profit from the experiments, it can be concluded that Experiment T3, involving the planting of corn with peanuts, demonstrated the highest efficiency, followed by T2, while T1 had the lowest efficiency.

Acknowledgment

The authors are grateful for the support of the Faculty of Agriculture and Forest Resource, Souphanouvong University, Luangprabang, Laos for providing facilities support, research guideline, and Thanks to the project on Improving Maize-Based- Farming Systems on Sloping Land in Vietnam and Lao PDR for providing financial support, research facilities and experimental fields with smallholder farmers in Et District, Houaphan Province, Laos.

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