EFFECTS OF SLOPE AND ASPECTS ON SOIL PROPERTIES, LEAF NUTRIENT STATUS, AND OIL PALM YIELD IN A PLANTATION IN SELANGOR, MALAYSIA

By

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Chairman : Professor Gs. Ts. Mohd Hasmadi bin Ismail, PhD
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Oil palm is an important crop in Malaysia that has contributed significantly to the country's economy. However, with limited land for oil palm cultivation, Malaysia has moved to convert marginal areas, including hilly and sloping land, into plantations. This can lead to soil erosion in these areas, resulting in loss of nutrients and water through runoff, reducing soil fertility and negatively affecting oil palm growth and production. There is limited research on how slope and aspect affect soil fertility and oil palm yields. Therefore, this study aimed to determine the relationship between slope, aspect and soil depth, properties and leaf nutrient and their effect on yield productivity in oil palm plantations. The study took place at FELDA Gedangsa plantations in Selangor, and data were collected on two slopes: one facing north and one facing south. Each slope was divided into three observation plots based on topography: the lower, middle, and upper slope positions. Soil samples were collected from the upper, middle, and lower slope positions at two depths: surface (0-20 cm) and subsurface (20-40 cm). Leaf tissue samples were also collected according to a systematic sampling design. Statistical analysis was performed using ANOVA and a post hoc comparison test with a 95% confidence interval to evaluate differences between soil indicators of different land use types. A paired-sample T-test was used to evaluate the differences in TN, pH, EC, soil texture, P, K, Ca, and Mg between the two soil depths and the two aspects. The results showed no significant difference ($P<0.05$) among the soil's physical properties and slope positions between the north and south aspects, the pH level was acidic in both aspects. The statistical analysis revealed a significant difference ($P<0.05$) among the soil properties in different slope positions and soil depths. Slope position significantly affected ($p<0.05$) all soil properties studied. Soil depth had a significant effect ($p<0.05$) on soil P, exchangeable Mg and Ca. And on the contrary, exchangeable K content was significantly different in the subsoil. Leaf nutrient contents varied, with nitrogen and Mg, rated as optimum,

and K, Ca, and P rated as excess. Fresh fruit bunch (FFB) yield was highest at the base of the slope and lowest at the top at both study sites. Statistical analysis indicated a relationship between FFB and nutrients in the soil and leaf tissues, and there was no significant difference ($P<0.05$) between FFB and the aspect.

Keywords, soil properties, slope position, aspect, leaf status, oil palm yield,

SDG: GOAL 15: Life on Land

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN CERUN DAN ASPEK TERHADAP SIFAT TANAH, STATUS NUTRIEN DAUN DAN HASIL KELAPA SAWIT DI LADANG GEDANGSA, SELANGOR, MALAYSIA.

Oleh

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Kelapa sawit merupakan tanaman penting di Malaysia yang memberikan sumbangan besar kepada ekonomi negara. Namun, dengan keterbatasan lahan untuk budidaya kelapa sawit, Malaysia telah beralih ke pengubahan kawasan marjinal, termasuk lahan berbukit dan berlereng, menjadi perkebunan. Hal ini dapat menyebabkan erosi tanah di kawasan tersebut, mengakibatkan hilangnya nutrien dan air melalui aliran permukaan, mengurangi kesuburan tanah dan mempengaruhi negatif pertumbuhan dan produksi kelapa sawit. Terdapat kajian terbatas mengenai bagaimana lereng dan aspek mempengaruhi kesuburan tanah dan hasil kelapa sawit. Oleh karena itu, kajian ini bertujuan untuk menentukan hubungan antara lereng, aspek dan kedalaman tanah, sifat tanah dan nutrien daun serta pengaruhnya terhadap produktivitas hasil di perkebunan kelapa sawit. Kajian ini dilakukan di perkebunan FELDA Gedangsa di Selangor, dan data dikumpulkan pada dua lereng: satu menghadap utara dan satu lagi menghadap selatan. Setiap lereng dibahagikan kepada tiga plot pemerhatian berdasarkan topografi: posisi lereng bawah, posisi lereng tengah dan posisi lereng atas. Sampel tanah dikumpulkan dari posisi lereng atas, tengah, dan bawah pada dua kedalaman: permukaan (0-20 cm) dan subsuperfisial (20-40 cm). Sampel jaringan daun juga dikumpulkan mengikut reka bentuk pensampelan sistematik. Untuk menilai perbezaan antara petunjuk tanah dari jenis penggunaan tanah yang berbeza, analisis statistik dilakukan menggunakan ANOVA dan ujian perbandingan post hoc dengan selang kepercayaan 95%. Ujian T sampel berpasangan digunakan untuk menilai perbezaan dalam TN, pH, EC, tekstur tanah, P, K, Ca, dan Mg antara kedua-dua kedalaman tanah dan kedua-dua aspek. Hasilnya menunjukkan tidak ada perbezaan yang signifikan ($P<0.05$) di antara sifat fizikal tanah dan posisi lereng antara aspek utara dan selatan, tahap pH adalah asid dalam kedua-dua aspek. Analisis statistik menunjukkan perbezaan yang signifikan ($P<0.05$) di antara sifat-sifat tanah pada posisi lereng yang berbeza dan kedalaman tanah. Posisi lereng mempengaruhi secara signifikan ($p<0.05$) semua sifat tanah yang dikaji. Kedalaman tanah mempunyai kesan yang signifikan ($p<0.05$) terhadap P tanah, Mg dan Ca yang boleh ditukar. Sebaliknya, kandungan K yang boleh ditukar adalah berbeza secara signifikan dalam lapisan subsoil. Kandungan nutrien daun bervariasi, dengan nitrogen dan Mg, dinilai sebagai optimum, dan K, Ca, dan P dinilai sebagai berlebihan. Hasil tandan buah segar (FFB) tertinggi di dasar lereng dan terendah di puncak pada kedua-dua lokasi kajian. Analisis statistik menunjukkan hubungan antara FFB dan nutrien dalam tanah dan jaringan daun, dan tidak ada perbezaan yang signifikan ($P<0.05$) antara FFB dan aspek.

Kata Kunci, Sifat tanah, Kedudukan cerun, Aspek, Status daun, Hasil kelapa sawit

SDG: MATLAMAT 15: Kehidupan di Darat

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LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
UNCBD	United Nation's Convention on Biological Diversity
AHFR	Ayer Hitam Forest Reserve
MARDI	Malaysian Agricultural Research and Development Institute
RUGS	Research University Grant Scheme
USDA	United States Department of Agriculture
FAO	Food and Agriculture Organization
IAS	Invasive alien species
EIS	Exotic Invasive Species
ESI	Exotic Species Invasion
ISSG	Invasive Species Specialist Group
SSC	Species Survival Commission
SGH	Stress-gradient hypothesis
NFS	N-fixing species
OG	Open ground
AM	*Acacia mangium*
TZ	Transition Region
NF	Non-Invaded Natural Forest
GPS	Global Positioning System
Mg	Milligram
m	Meter
ha	Hectares
ml	Milliliter
GWC	Gravimetric water content
OM	Organic Matter

EC	Electrical Conductivity
CEC	Cation-exchange capacity
DS/m	DeciSiemens per meter
Cmol/kg	Centimole per kilogram; also written as cmol(+)kg-1
N	Nitrogen
K	Potassium
Ca	Calcium
Mg	Magnesium
CEC	Cation Exchange Capacity
Sq m	Square metres
Cbh	Circumference at Breast Height
µg	Microgram
Cm	Centimetres
Ht	Height
DBH	Diameter at Breast Height
IVI	Importance Value Indices
IV	Important Value
RD	Relative Density
RF	Relative frequency
RA	Relative abundance
RBA	Relative Basal Area
A/F	Ratio of Abundance to Frequency
H'	Shannon-Weiner Diversity Index
S	Number of species
N	Total Recorded Number of Individuals
Pi	Proportion of Individuals Belonging to Species
Ln	Natural Log (i.e., 2.718)

Cd	Concentration of Dominance
Jsw	Pielou's Evenness Index
Dmg	Margalef's index of species richness
RHGR	Relative Height Growth Rates
RRGR	Radial Growth Rates
Hf	Initial Height
Hi	Final Height
Rf	Initial Diameter
Ri	Final Diameter (Radial)
Tf	Initial Time
Ti	Final Time
Ln	Logarithm
MHa	Million Hectares
NFS	N-fixing species
α	Alpha
β	Beta
°C	Degree celsius
%	Percentage
A_{600nm}	Optical density at wavelength 600 nanometer
µL	Microliter
µm	Micrometer
µmoles	Micromoles
APS	Ammonium persulfate
ATCC	American Type Culture Collection
ATP	Adenosine triphosphate
bp	Base pair
$CaCl_2$	Calcium chloride

cAMP	Cyclic adenosine monophosphate
cDNA	Complementary deoxyribonucleic acid
Crp	cAMP receptor Protein
csc	Chromosomally encoded sucrose catabolism genes
DNA	Deoxyribonucleic acid
E. coli	*Escherichia coli*
EC	Enzyme Commission
EDTA	Ethylenediaminetetraacetic acid
g	Gram
IPTG	Isopropyl β-D-1-thiogalactopyranoside
kb	Kilobase
kDA	kilodaltons
L	Litre
LB	Luria-Bertani
M	Molar
mA	MilliAmps

CHAPTER 1

INTRODUCTION

1.1 Background

Understanding yields in specific landscape positions is vital for realizing the highest financial returns of plantation operations. Identifying soil limiting factors for the production of important crops helps policymakers with sustainable planning and management of soils, thereby increasing crop productivity (Balasundram et al., 2006; Ahmed, 2021).

Oil palm is Malaysia's most lucrative plantation crop, with 5.9 million hectares under cultivation (Ahmad. & Kadir, 2021). The history of oil palm in Malaysia began in 1890 when it was first introduced through the Botanical Gardens in Singapore. However, the first commercial planting did not occur until 1917 at Tennamaram Estate in Kuala Selangor. In 1968, the area under oil palm was 204,000 ha, and it increased significantly to 850,000 ha ten years later (Nambiappan et al., 2018). In 2000, the oil palm area in Malaysia was 3,463,000 ha (Ministry of Finance Malaysia, 2000), covering about 57.7% of the total area under selected crop plantations (Ministry of Primary Industries Malaysia, 2000). In 2019, oil palm production reached 19.86 million tons. However, in 2020, crude palm oil (CPO) production declined by 3.6%, to 19.14 million tons (Ahmad. & Kadir, 2021).

The palm oil industry in Malaysia continues to perform well, contributing significantly to the national economy. However, Malaysia has almost run out of suitable land for oil palm cultivation, leading to the transformation of marginal areas, including hilly and sloping lands, into oil palm plantations. High precipitation in these marginal areas can cause soil erosion, resulting in nutrient and water losses via runoff, which would lead to a decline in soil fertility and adversely affect the growth and productivity of oil palm. Therefore, site selection for oil palm planting is crucial in the oil palm business, as it affects crop productivity (Corley & Tinker, 2016). Paramananthan (2013) stated that the plantation corporation would suffer significant losses if the plantation were situated in an incorrect location. He further presented the best management practices to consider throughout the development of oil palm farming in terms of land selection (Paramananthan, 2013).

Despite the importance of soils in the Roundtable on Sustainable Palm Oil's (RSPO) principles and objectives, agronomists and planters in the business showed a noticeable lack of interest in soils during the 1990s (Goh & Chew, 1994) This situation contrasts with the early years of oil palm expansion in Malaysia when the extensive use of soil information was common. This included selecting suitable lands for oil palm, understanding the dynamic mechanism of soil water and nutrient relations, which are often the most limiting agronomic factors to oil palm production in Malaysia, and formulating fertilizer recommendations for oil palm. Furthermore, since oil palm is mostly rain-fed, most of its demands, except carbon dioxide for photosynthesis, are met by the soils. Goh & Chew (1994) speculated that the reason for this lack of interest is unknown. However, Goh et al. (1994) attributed it to the experience of achieving similar high fresh fruit bunch (FFB) yields in diverse soil types and current immediate challenges in the oil palm business that are not directly related to soils. Additionally, many, if not all, local colleges have de-emphasized soil science in agricultural courses, which is likely a key factor contributing to the lack of knowledge and use of soil science in oil palm agriculture (Goh et al., 2016; Sumathi et al., 2008).

No agricultural system can be called sustainable unless it is affordable for farmers and their society (Johnston, 1995). Therefore, the economic significance of high early yields and long-term yields is evident. Oil palm is a perennial crop with significant yield and input/output price volatility. Due to the industry's large investments and fixed costs, the optimal economic yield is typically found at or near the site yield potential (Goh & Chew, 1994a). Evidence now shows that the inputs required to enhance a site's production potential do not necessarily harm the environment, soil quality, or product quality (Goh et al., 1999; Ahmed, 2021).

Oil palm productivity results from a complex relationship between the palm's insatiable demand for nutrients to maintain its development and output, and the soil environment around it, which contains a range of materials. According to Goh et al. (2016) on oil palm nutrition, "Such a scenario can only be effectively resolved by extensive field research on diverse soil types, repeated under varied environmental conditions, which would, unfortunately, demand a large number of experiments and take a long time to complete," and/or substantial field management expertise on similar soil types and settings to better understand and alter soil parameters to increase production (Goh et al., 2016).

Goh et al., (2016) suggested that a tropical environment provides ideal conditions for high yields of a wide range of crops, but only when proper management, inputs, and other factors impacting outputs per unit area and unit time are employed. Soil management is one of the most significant aspects of this. For many years, the primary goals of soil management have been to maintain and improve soil fertility and synchronize soil productivity, both with and without improvement, with crop requirements for high-yielding, long-term growth. Consequently, we can create soil conditions conducive to crop productivity (Goh et al., 2016).

A reliable oil palm production system depends on good agronomic practices that preserve soil and water. Climate and rainfall patterns, soil type, slope gradient, soil cover, drainage, road pattern, and crop management all influence erosion risk. Terracing hilly areas, creating drains, managing water catchment areas, and using silt pits are recommended soil conservation measures to reduce soil erosion on sloping lands (Mohsen, B. et al., 2014). Using oil palm residues such as empty fruit bunches (EFB) and pruned fronds as mulches to encourage nutrient recycling can also reduce soil and nutrient loss via surface run-off. These residues contain essential plant nutrients that can be recycled into the soil during decomposition, and they provide organic matter to boost soil fertility properties (A M Afandi et al., 2017b). To assess the potential for increasing productivity in current stands and ongoing (re)planting initiatives, a full understanding and measurement of the contribution of key production parameters to oil palm output are critically needed (Woittiez, et al., 2017).

1.2 Importance of the Study

This study was conceptualized to examine the impact of slope and aspect on soil properties, leaf tissue, and oil palm yield in Malaysia. By understanding the relationship between these factors, we can improve nutrient management strategies and more effectively monitor soil properties in oil palm plantations. This information is vital for the proper monitoring of soil properties and oil palm plantations in Malaysia and for optimizing management strategies, particularly nutrient management.

1.3 Problem Statement

Oil palm cultivation is a vital industry in Malaysia, but suitable land for planting is becoming increasingly scarce. As a result, marginal areas like hilly and sloping lands are being transformed into oil palm plantations. However, high levels of precipitation in these areas can cause soil erosion, leading to nutrient and water losses through runoff. This can decrease soil fertility and negatively impact oil palm growth and productivity. Therefore, selecting the right location for oil palm planting is crucial to ensure high crop yields (Corley & Tinker, 2016). Paramananthan (2013) noted that choosing an unsuitable location could result in significant losses for plantation corporations. Understanding the dynamic relationship between soil water and nutrients is also crucial, as these are often limiting agronomic factors for palm oil production in Malaysia.

The study area is located in mountainous, hilly, or sloping terrain, which makes it susceptible to soil erosion and depression formation. This can affect soil properties and, in turn, oil palm yield (Balasundram et al., 2006). However, there is limited information on the impact of topographic characteristics on palm oil yield and soil physio-chemical properties (Balasundram et al., 2006).

This study aims to investigate the relationship between slope and aspect and their impact on soil properties and oil palm yield in different positions. Understanding these relationships can help with monitoring and managing soil features under oil palm plantations in Malaysia. This information is essential for developing effective management strategies, particularly for nutrient management.

1.4 Objectives

The aim of this study is to investigate the relationships among slope, aspect, soil properties to yield of the oil palm. Based on the main objective, the following specific objectives are formed.

1- To determine the status of Nitrogen (N), Phosphorous (P), Potassium (k), Calcium (Ca) and Magnesium (Mg) levels in the soil and leaf tissue in different slope positions and aspects in oil palm plantation.

2- To investigate the relationship between physio-graphic factors (i.e., slopes and aspects) and the yield oil palm.

3- To determine the relationship between soil and leaf nutrient status and FFB yield across different slope positions and aspects of oil palm plantations.

1.5 Scope and Limitation

The scope of the study is limited to studying selected areas on the northern and southern slopes of the FELDA oil palm plantation located at Hulu Bernam, in the Hulu Selangor region, Selangor. This plantation is known as FELDA Gedangsa.

The oil palm plantation at FELDA Gedangsa was selected as a study site due to the presence of slopes planted with oil palm trees, to find the relationship between these slopes and their direction, the extent of their influence on some of the soil physio-chemical properties, at two depths: surface (0-20 cm) and subsurface (20-40 cm), and their effect on yield quantity on three different levels from the top of the slope to the bottom of the slope, and the leaf content of nutrients. The field study lasted for 2 years, from September 2018 to August 2020.

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