

## Sustainability of Smallholder Oil Palm Plantations: A Multidimensional Scaling (MDS) Approach in North Konawe Regency, Indonesia

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### ABSTRAK/ABSTRACT

#### Keberlanjutan Perkebunan Kelapa Sawit Skala Kecil: Pendekatan Skala Multidimensi (MDS) di Kabupaten Konawe Utara, Indonesia

Kata Kunci:  
B Keberlanjutan; Kelapa sawit; RAPPO; MDS; Konawe Utara

Perkebunan kelapa sawit rakyat memiliki peran strategis dalam menopang mata pencaharian masyarakat lokal. Di Kabupaten Konawe Utara, sektor ini menjadi bagian tulang punggung ekonomi daerah, sehingga memastikan keberlanjutannya menjadi sangat krusial dalam menghadapi tantangan lingkungan dan fluktuasi pasar. Kajian sawit saat ini masih didominasi industri besar dan terbatas pada penggunaan atribut dimensi ekonomi, ekologi, kelembagaan dan social budaya khususnya di wilayah Sulawesi Tenggara. Penelitian ini bertujuan menilai status keberlanjutan multidimensi dan mengidentifikasi atribut sensitif yang memengaruhi resiliensi perkebunan rakyat. Penelitian dilakukan pada April–Juli 2025 terhadap 124 petani dan sembilan kelompok tani menggunakan metode *Rapid Appraisal for Palm Oil* (RAPPO) berbasis *Multidimensional Scaling* (MDS) serta analisis *leverage*. Hasil penelitian menunjukkan bahwa indeks keberlanjutan mencapai 66,01%, yang tergolong dalam kategori cukup berkelanjutan. Dimensi kelembagaan memiliki nilai tertinggi (70,00%), diikuti oleh dimensi ekologi (67,80%), ekonomi (67,72%), dan sosial budaya (58,48%). Analisis *leverage of attributes* mengidentifikasi atribut-atribut sensitif yang berpengaruh signifikan terhadap indeks keberlanjutan, yaitu keanekaragaman flora dan fauna pada dimensi ekologi, manfaat ekonomi bagi masyarakat lokal pada dimensi ekonomi, implementasi sertifikasi pada dimensi kelembagaan, serta frekuensi konflik antarpetani pada dimensi sosial budaya. Temuan ini, memberikan kontribusi baru melalui pemetaan profil keberlanjutan terintegrasi di Konawe Utara. Implikasinya menekankan pentingnya penguatan kelembagaan petani dan sinkronisasi kebijakan bantuan input untuk menjamin stabilitas ekonomi petani kecil serta kelestarian lingkungan secara simultan.

Keywords:  
MDS; North Konawe;  
Palm oil; RAPPO;  
Sustainability

Smallholder oil palm plantations play a strategic role in supporting local livelihoods and the national supply chain. In North Konawe Regency, this sector is a cornerstone of the regional economy, making its sustainability critical amid environmental challenges and market fluctuations. Current palm oil studies are predominantly focused on large-scale industries and often lack an integrated, multidimensional approach encompassing economic, ecological, institutional, and socio-cultural dimensions, particularly in the context of Southeast Sulawesi. This study aims to assess the multidimensional

sustainability status and identify sensitive attributes influencing the resilience of smallholder plantations. Research was conducted from April to July 2025, involving 124 farmers and nine farmer groups. Data were analyzed using the Rapid Appraisal for Palm Oil (RAPPO) method based on Multidimensional Scaling (MDS) and leverage analysis. The results reveal a sustainability index of 66.01%, categorized as fairly sustainable. The institutional dimension achieved the highest score (70.00%), followed by ecology (67.80%), economy (67.72%), and socio-cultural (58.48%). Leverage analysis identified key sensitive attributes: flora and fauna diversity (ecology), economic benefits for local communities (economy), certification implementation (institutional), and the frequency of inter-farmer conflicts (socio-cultural). This study contributes to the literature by providing an integrated sustainability profile of smallholder plantations in North Konawe. The implications underscore the need to strengthen farmer institutions and synchronize input subsidy policies to ensure the economic stability of smallholders while maintaining environmental integrity.

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## INTRODUCTION

The oil palm plantation sector has become one of the most strategic commodities in Indonesia's economic development. The continuous expansion of oil palm plantations is widely recognized as a driver of economic growth at national, regional, and rural levels, particularly through employment generation, increased farmer income, and contributions to foreign exchange earnings (Astari *et al.*, 2025; Dermoredjo *et al.*, 2025; Rifa'i, 2025; Rustiadi *et al.*, 2023; Setiajiati *et al.*, 2024). Empirically, the plantation area increased from 15,338,556 hectares in 2022 to 16,310,607 hectares in 2023, accompanied by rising Crude Palm Oil (CPO) production from 46,819,672 tons in 2020 to 47,084,299 tons in 2023 (Central Bureau of Statistics of Indonesia, 2023; Sari *et al.*, 2025; Supriatna *et al.*, 2024). This trend reflects the strong prospects and global demand for palm oil commodities (Zhao *et al.*, 2024).

However, the rapid expansion of oil palm plantations has raised serious sustainability concerns. Environmentally, plantation development is often associated with deforestation, peatland conversion, land degradation, and intensive use of chemical inputs (Ariesca *et al.*, 2023; Lestari *et al.*, 2022; McCalmont *et al.*, 2021; Yuslaini *et al.*, 2025). Socially, it may trigger land conflicts, labor exploitation, and socio-cultural transformations within rural communities (Ngan *et al.*, 2022; Sagrim & Iyai, 2025). Economically, instability in fresh fruit bunch (FFB) prices, income inequality among farmers, and long-term environmental costs also remain critical challenges (Cheah *et al.*, 2023).

Furthermore, increasing global demand, particularly from the European Union and the United States, requires compliance with sustainability standards such as the Roundtable on Sustainable Palm Oil (RSPO), Indonesian Sustainable Palm Oil (ISPO), and the EU Deforestation Regulation, which not all producers are able to fulfill (Anam *et al.*, 2025; Jamilah *et al.*, 2022; Setiyanto, 2024; Suhardjo & Suparman, 2025).

Several previous studies have examined the sustainability of oil palm plantations using multidimensional approaches, including economic, environmental, and social indicators, often based on certification frameworks such as RSPO and ISPO (Garlock *et al.*, 2024; Hák *et al.*, 2016; Reich & Musshoff, 2025; Supriatna *et al.*, 2024). These studies generally highlight the importance of balancing productivity with sustainability principles. However, most of the existing literature tends to focus on large-scale plantations or national-level analysis, while limited attention has been given to smallholder plantations, particularly in emerging production regions.

Therefore, the research gap in this study lies in the limited empirical assessment of the sustainability status of smallholder oil palm plantations at the regional level, especially in North Konawe Regency, Southeast Sulawesi, which is experiencing rapid plantation expansion but has not been comprehensively analyzed using an integrated multidimensional sustainability framework. In addition, previous studies rarely incorporate institutional dimensions alongside economic,

environmental, and social factors in assessing local sustainability performance.

North Konawe Regency represents a relevant case study, as its oil palm plantation area increased from 22,300 hectares in 2022 to 24,311 hectares in 2024, exceeding other plantation commodities such as coconut, cocoa, cashew, coffee, nutmeg, and pepper (Central Bureau of Statistics of Indonesia, 2024). The presence of major plantation companies, such as PT. Sultra Prima Lestari and PT. Damai Jaya Lestari, further strengthens the region's position as a strategic oil palm production area (Baka dkk., 2023).

This study aimed to assess the sustainability status of smallholder oil palm plantations in North Konawe Regency using a multidimensional approach encompassing economic, environmental, social, and institutional dimensions. The assessment is based on indicator indices derived from the ISPO and RSPO frameworks, complemented by empirical field observations, to provide a more comprehensive evaluation of sustainability performance at the local level.

## MATERIALS AND METHODS

### Time and Place of Research

This research was conducted in North Konawe Regency, Southeast Sulawesi Province, from April to July 2025. This regency was chosen as the case study location because it has experienced rapid development of oil palm plantations and reflects the social, economic, institutional, and environmental

dynamics representative of a sustainable oil palm plantation system in Indonesia.

### Data Collection

This study utilized both primary and secondary data. Primary data were collected through respondents' answers to a structured questionnaire assessing indicators of palm oil sustainability dimensions based on the Roundtable on Sustainable Palm Oil (RSPO) and Indonesian Sustainable Palm Oil (ISPO) frameworks, as well as expert judgments derived from field observations. Respondents evaluated each attribute using a scoring system ranging from poor (0) to good (3), following the Rapid Appraisal for Palm Oil approach and incorporating expert and stakeholder assessments. Secondary data were obtained from relevant literature and from institutional and organizational sources related to the study. The respondents consisted of oil palm farmers, including both members and non-members of farmer groups.

According to data from the Department of Plantation and Horticulture of South East Sulawesi (2024), the total population of oil palm farmers was 601 households. The sample size was determined using Slovin's formula with an 8% margin of error, resulting in 124 respondents. To enhance the sample's representativeness, data collection also involved nine farmer groups. The variables measured in this study are described in detail for each sustainability dimension in Table 1.

Table 1. Attribute dimensions and measurements

Dimensions	Measurement Attributes
Ecology	Flora and fauna diversity; planting along riverbanks; new land clearing; potential for new land clearing; use of oil palm seedlings; use of fruit bunches for manure; environmentally friendly production processes (use of organic fertilizers); oil palm cultivation systems.
Economy	Economic benefits for local communities; Fresh fruit bunch (FFB) sales market; Palm oil plantation business income; FFB price; FFB production quality; Fertilizer subsidies; Other sources of income; Farmers' access to financial institutions
Institutional	Implementation of sustainable palm oil plantation certification; Availability of local regulations related to palm oil; Palm oil farmer groups; Availability of palm oil farmer corporations; Microfinance institutions or cooperatives; Quality assurance institutions; Local customary/cultural rules.
Socio-cultural	Frequency of conflicts among smallholders; Formal education of smallholders; Frequency of counseling and training from the government; Family participation; Cultivation knowledge; Frequency of counseling and training from companies.

### Data Analysis Methods

The measurement of sustainability indices and status is carried out using Multidimensional Scaling

(MDS). This method was first introduced through Rapid Appraisal for Fisheries (RAPFISH), which was developed to assess the sustainability of fisheries

systems (Fauzi, 2019; Pitcher & Kavanagh, 2004). In line with the need for cross-sector adaptation, RAPFISH was subsequently modified into Rapid Appraisal for Palm Oil (RAPPO), which can be used to assess the sustainability status of smallholder oil palm plantation businesses (Suardi *et al.*, 2022) and implemented via an Excel add-in. Overcoming the limitations of the add-in platform, this study used Rapython, part of a Python-based RAPFISH implementation that leverages the scikit-learn library for more stable computation, easier replication across operating systems, and integrated sensitivity and uncertainty testing.

Pitcher and Kavanagh (2004) recommend five steps in the RAPFISH procedure: (1) determination of assessment criteria and identification of current conditions, (2) scoring of each indicator, (3) ordination of indicators, (4) sensitivity analysis, and (5) sustainability assessment. The goodness of fit of the model was evaluated using S-Stress and R<sup>2</sup> values. The model is considered acceptable when the S-Stress value is less than 0.25, and the R<sup>2</sup> value approaches 1.

Subsequently, the sustainability position was visualized along the ordination axis and further analyzed using leverage and Monte Carlo analyses. Leverage analysis was applied to identify the most sensitive attributes based on Root Mean Square (RMS) values, whereas Monte Carlo analysis was used to assess the robustness of the results against random

errors at a 95% confidence level. The results of these analyses were then used to determine the sustainability status according to the classification presented in Table 2.

Table 2. Criteria and Index Values and Sustainability Status

Index Value (%)	Sustainability Status Category
<25	Unsustainable
25.01 – 50.00	Less Sustainable
50.01 – 75.00	Sustainable Sufficient
>75.01	Very Sustainable

Source: Suardi *et al.* (2022)

## RESULTS AND DISCUSSION

Based on the RAPPO analysis using Multidimensional Scaling (MDS) across four dimensions evaluated, the overall sustainability index was 66.01%. The institutional dimension recorded the highest value (70.00%), followed by the ecological (67.80%), economic (67.72%), and socio-cultural (58.48%) dimensions. Despite variation among dimensions, with the institutional dimension showing the highest performance and the socio-cultural dimension the lowest, all four dimensions fall within the sustainable sufficient category, corresponding to an index range of 50.01–75.00 (Figure 1, Table 3).

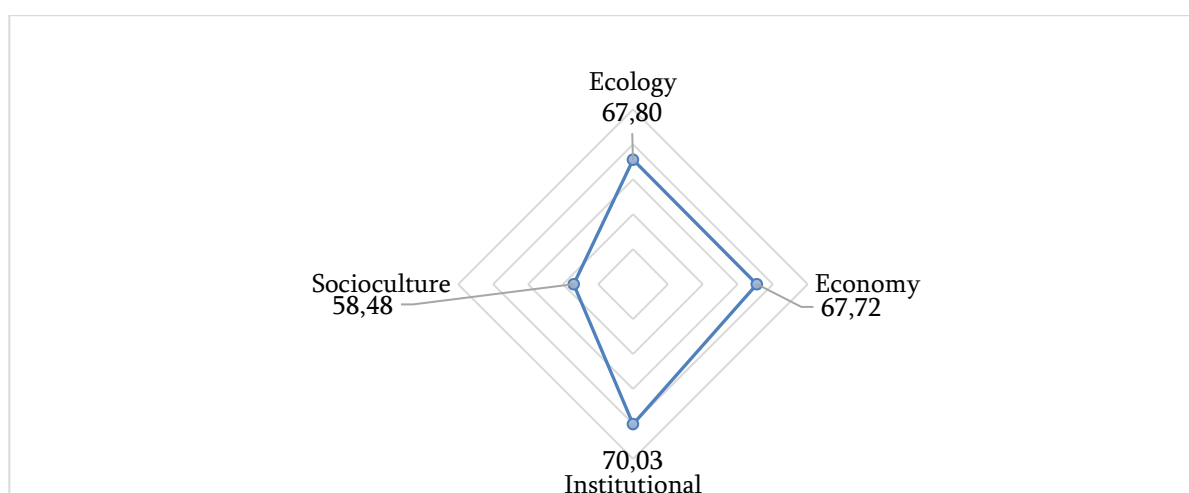


Figure 1. Kite diagram of the sustainability status of smallholder oil palm plantations in North Konawe regency.

Sustainability analysis of smallholder oil palm plantations was conducted using a multidimensional assessment approach. The validity of the results was evaluated by comparing the Monte Carlo values with the sustainability index. A difference value of less

than one indicates a high level of accuracy, thereby confirming the reliability of the dimensional measurements (Fauzi, 2019; Yusuf dkk., 2025). The sustainability index values and associated measurement parameters are presented in Table 3.

Table 3. Index values and measurement parameters

Dimension	Sustainability Index	Sustainability Status	Monte Carlo	Differences	S-Stress	R <sup>2</sup>
Ecology	67.80	Sustainable Sufficient	69.14	1.34	0.12	0.98
Economy	67.72	Sustainable Sufficient	66.31	1.41	0.11	0.98
Institutional	70.00	Sustainable Sufficient	70.02	0.01	0.11	0.98
Socioculture	58.48	Sustainable Sufficient	57.65	0.83	0.11	0.98
Multidimensional	66.01	Sustainable Sufficient	65.78	0.23	0.11	0.98

Based on Table 3, the sustainability index has an average value of 66.01, while the average Monte Carlo value is 65.78, resulting in a difference of 0.23. This difference indicated that the index results have an accuracy level above 95% (Fauzi, 2019). The contribution of sensitive attributes to the sustainability index, based on smallholder oil palm plantation criteria, was examined using leverage analysis. This analysis aims to identify the attributes that most influence sustainability. The higher the RMS value, the greater the attribute's role in determining sustainability (Pitcher & Kavanagh, 2004). The results of the leverage analysis across four dimensions are key factors in providing basic information on aspects that need improvement or

enhancement through various programs to support the sustainability of smallholder oil palm plantations.

### Ecological Dimension Analysis

The results of the MDS analysis conducted through the RAPPO approach reveal that the ecological dimension of smallholder oil palm plantations in North Konawe Regency has a sustainability index of 67.80. According to the classification criteria in Table 2, this value falls within the sustainable sufficient category (50.01–75.00). This finding suggests that, in general, smallholder cultivation practices in the region have integrated environmental conservation principles, although significant room for optimization remains regarding several sensitive attributes.

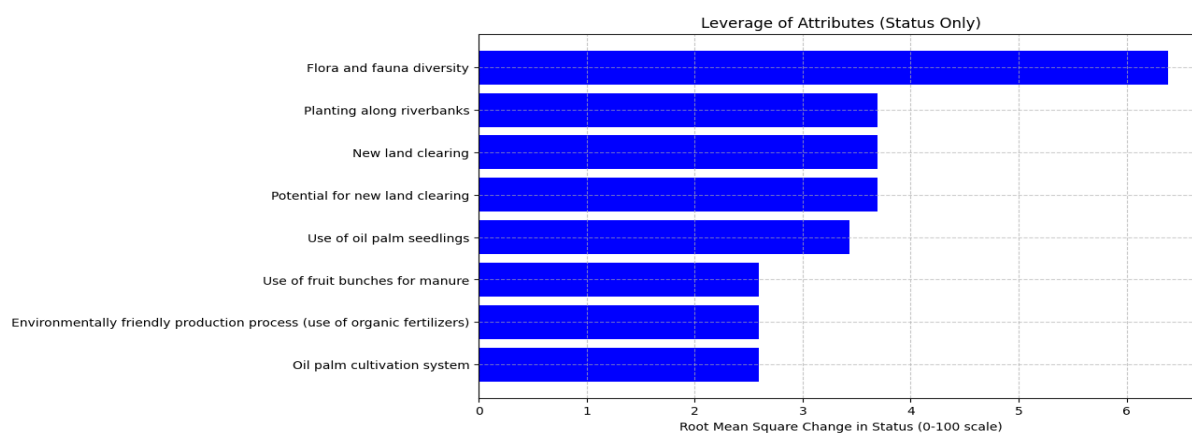


Figure 3. Leverage analysis of attributes for the ecological dimension.

Based on the leverage analysis of attributes presented in Figure 3, the highest RMS value indicated that the flora and fauna diversity attribute is most sensitive in the ecological dimension. Variations in species composition and habitat quality significantly influence the ecological performance of smallholder oil palm plantations. Areas with higher levels of vegetation diversity and wildlife presence tend to exhibit greater environmental resilience and sustainability (Nahriyah, 2024). Therefore,

maintaining and enhancing biodiversity constitutes a critical component of ecological balance.

The diversity of plant and animal species plays a significant role in determining ecological sustainability by maintaining ecosystem stability. A decline in biodiversity can directly affect key ecological functions, including soil fertility, trophic interactions, and the capacity of agricultural systems to adapt to environmental changes (Nahlunnisa & Kwatrina, 2023; Ronaulu, 2024). Accordingly, conservation of local flora and fauna should be

prioritized within smallholder oil palm plantation management strategies to improve overall sustainability performance in the ecological dimension.

### Economic Dimension Analysis

The economic sustainability of smallholder oil palm plantations in North Konawe Regency was assessed using eight primary attributes integrated within the MDS framework via the RAPPO method. The analysis yielded a sustainability index of 67.72, as presented in Table 3. Based on the classification criteria defined in Table 2, this index value places the economic dimension of the smallholder plantation system in the sustainable sufficient category (50.01-75.00). This status indicates a relatively stable economic foundation, underpinned by moderate levels of income generation and existing market integration among the surveyed farmers.

Leverage analysis of attributes was conducted to identify the economic attributes that most strongly influence the sustainability index. The results indicate that the RMS value for economic benefits to local communities shows the highest sensitivity (Figure 4). This finding suggests that the sustainability of smallholder oil palm plantations is closely associated with income distribution, market stability, and improvements in local livelihoods. Economic benefits generated by smallholder oil palm activities contribute significantly to community welfare through various pathways, including employment generation, increased household income, and stimulation of local business activity (Aziz *et al.*, 2021). Furthermore, the utilization of local economic resources can stimulate rural economies, enhance household purchasing power, and promote the growth of supporting sectors such as transportation, trade, and agricultural processing (Hariyanti *et al.*, 2024; Yuslaini *et al.*, 2023).

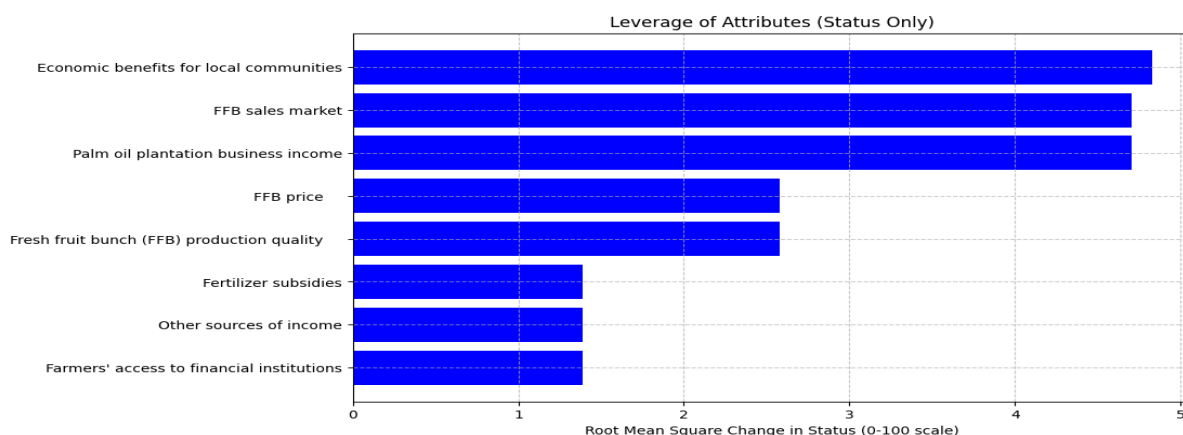


Figure 4. Leverage analysis of attributes for the economic dimension.

The high sensitivity of this attribute implies that policy interventions and management strategies should prioritize strengthening local economic systems. This can be achieved by improving market access, promoting value-added processing, and supporting community-based enterprises, thereby enhancing the resilience and economic inclusiveness of smallholder oil palm farmers. These findings underscore that sustainable economic performance cannot be achieved solely through productivity enhancement but must also incorporate local empowerment as a central component of sustainability within the regional oil palm sector.

### Institutional Dimension Analysis

The institutional sustainability of smallholder oil palm plantations in North Konawe Regency was

evaluated through the RAPPO method using MDS analysis. The results, as detailed in Table 3, yielded a sustainability index of 70.00. According to the classification criteria presented in Table 2, this value places the institutional dimension in the sustainable sufficient category (50.01-75.00). While this index reflects a relatively stable institutional performance, it highlights significant opportunities for further enhancement in governance structures and institutional capacity-building among smallholder groups.

The results of leverage analysis indicate that the certification of smallholder oil palm plantations exhibits the highest RMS value among all assessed attributes (Figure 5). This finding is consistent with previous studies (Judijanto, 2025; Oliphant & Simon, 2022), highlighting the critical role of certification in

enhancing supply chain transparency, improving production efficiency, and strengthening environmental management practices. Certification functions as an institutional mechanism that supports farmers' capacity to implement sustainability principles, including land conservation, emission reduction, and improved local community welfare (de Vos *et al.*, 2023).

The implementation of certification among smallholder oil palm plantations is primarily assessed through the Indonesian Sustainable Palm Oil (ISPO) scheme, which has not yet been fully adopted by farmers in North Konawe Regency. Many

smallholders have not fulfilled the required environmental and legal standards, particularly those related to natural resource sustainability and biodiversity conservation. In addition, certification under the Roundtable on Sustainable Palm Oil (RSPO) has also not been widely implemented. Although most farmers possess land certificates as proof of ownership or land-use rights, they often lack comprehensive farm management planning, including cost considerations for maintenance, replanting, land expansion, and certification processes.

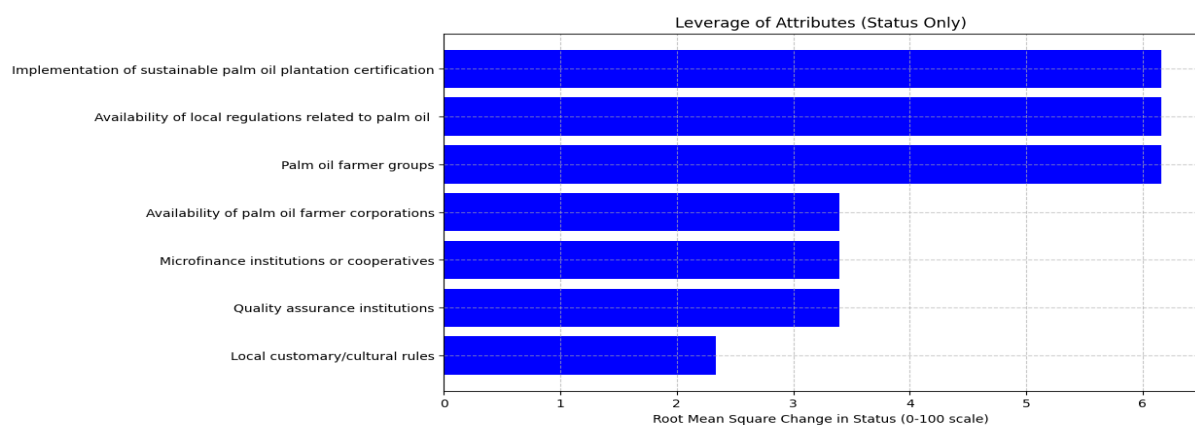


Figure 5. Leverage analysis of attributes for the institutional dimension.

### Sensitive Attributes of Socio-Cultural Dimensions

The sustainability of the socio-cultural dimension in smallholder oil palm plantations in North Konawe Regency was assessed through MDS analysis via the RAPPO method. The analysis yielded a sustainability index of 58.48, as shown in Table 3. Based on the classification criteria established in Table 2, this value categorizes the socio-cultural performance of the smallholder plantation system as sustainable sufficient (50.01–75.00). Although this indicates a relatively stable socio-cultural environment, this dimension recorded the lowest index value among all evaluated dimensions, highlighting significant vulnerabilities that require strategic attention.

Based on the RMS values across six attributes, conflict frequency showed the highest sensitivity within the socio-cultural dimension (Figure 6). This finding indicates that the dynamics of social relations among farmers play a critical role in determining the sustainability of smallholder plantation systems. Accordingly, effective conflict management strategies are required, including strengthening farmer group institutions, enhancing communication

and mediation capacities, and implementing participatory decision-making mechanisms (Grasse, 2022; Lundsgaard-Hansen *et al.*, 2022). Furthermore, a collaborative approach has been shown to reduce conflict intensity, strengthen social cohesion, and improve socio-cultural sustainability performance in smallholder oil palm plantations (Herdiansyah & Mamola, 2025).

Conflicts among oil palm farmers commonly occur within plasma schemes involving partnerships with companies. Farmers often perceive these arrangements as disadvantageous due to a lack of transparency in profit-sharing agreements and inequitable distribution of benefits. Typically, the profit-sharing ratio is set at 40% for farmers and 60% for companies; however, in practice, farmers' shares are frequently reduced due to company-imposed deductions for production and investment costs. As a result, farmers receive significantly lower incomes than anticipated. In addition, uncertainty regarding land tenure and limited access to information further exacerbate perceptions of injustice, thereby intensifying conflicts.

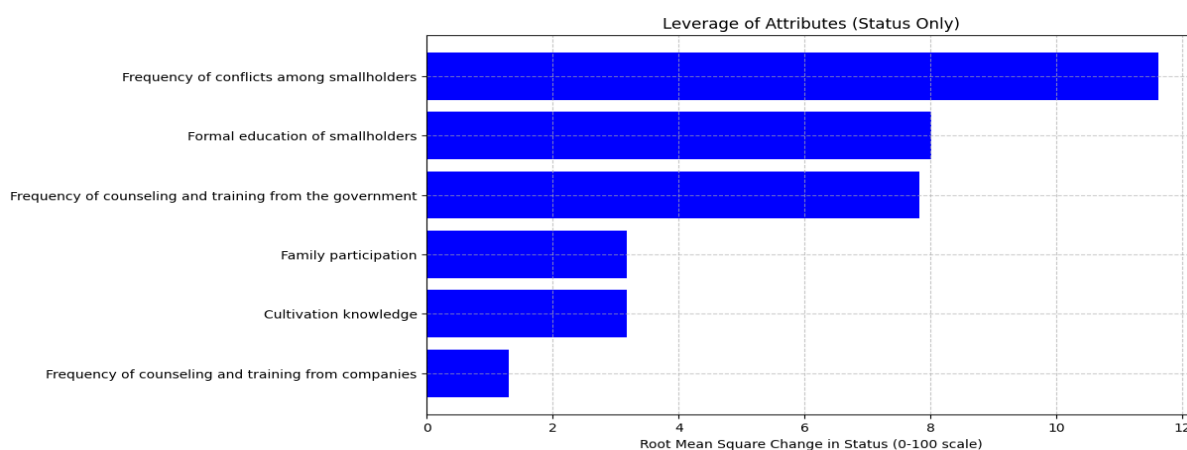


Figure 6. Leverage analysis of attributes for the socio-cultural dimension.

## CONCLUSION

The sustainability of smallholder oil palm plantations in North Konawe Regency is classified as sustainable sufficient, with a multidimensional index value of 66.01% across four assessed dimensions. Among these, the institutional dimension performed best (70.00%), followed by the ecological (67.80%), economic (67.72%), and socio-cultural (58.48%) dimensions. These findings suggest that the smallholder plantation system possesses a relatively strong foundation for sustainability; however, further improvements are required, particularly in socio-cultural aspects and institutional governance. This study has several limitations, including the reliance on sustainability indicators derived from ISPO and RSPO frameworks, which may not fully capture local socio-cultural dynamics and informal governance systems. From a policy perspective, enhancing sustainability should prioritize the effective implementation of ISPO and RSPO certification schemes, strengthening the institutional capacity of farmer groups, conserving biodiversity, and promoting participatory and collaborative approaches to social conflict management. These strategies are expected to foster a more inclusive, equitable, and environmentally sustainable plantation system while improving the welfare of smallholder farmers.

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