JOURNAL OF WATER AND LAND DEVELOPMENT
e-ISSN 2083-4535

Polish Academy of Sciences (PAN) Institute of Technology and Life Sciences – National Research Institute (ITP – PIB)

JOURNAL OF WATER AND LAND DEVELOPMENT
DOI: 10.24425/jwld.2024.149118
2024, No. 60 (I–III): 167–176

Sustainability evaluation of a smallholder cocoa plantation on the Sebatik Island, Indonesia, using a multidimensional scaling approach

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RECEIVED 04.06.2023 ACCEPTED 05.12.2023 AVAILABLE ONLINE 29.03.2024

Abstract: The Sebatik Island is one of the main cocoa-producing regions in Indonesia, but its productivity has been reported to be below the potential production volume. Therefore, this study aims to evaluate the sustainability index for smallholder cocoa plantations on the Sebatik Island using the multidimensional scaling (MDS), known as the RAP-SEBATIK (rapid appraisal for cocoa on Sebatik Island) that adopts from the RAPFISH (Rapid Appraisal for Fisheries). The MDS was used to evaluate the sustainability status of cocoa across six dimensions, while the leverage analysis was applied to identify the status of the most influential attributes of each dimension. The results showed that the average sustainability index value for such dimensions as ecological, economic, sociocultural, infrastructural and technological, law and institutional, as well as defence and security was 46.23, 48.58, 75.20, 40.49, 36.39, and 36.39%, respectively, based on the current conditions. According to these findings, only the sociocultural dimension was sustainable in smallholder cocoa plantations on the Sebatik Island. The main attributes that need improvement for the sake of sustainability apply to the following dimensions: ecological, economic, sociocultural, infrastructure and technology, law and institutional, as well as defence and security. Attributes that need intervention are the average age of cocoa, the community's level of formal education, fertilisers application for cocoa, the operation of a shop for agricultural production facilities, and defence and security facilities and infrastructure.

Keywords: attribute, cocoa, multidimensional scaling (MDS), Sebatik Island, sustainability index

INTRODUCTION

Being the front porch of the country, the border area has a very strategic role to play, especially regarding state sovereignty, defence and security, and national development. Indonesia has several border areas, one of which is on the Sebatik Island, Nunukan Regency, North Kalimantan Province. The northern part of the Sebatik Island is the territory of Malaysia, while the southern part is Indonesia. The orientation of the Sebatik Island population towards Malaysia is relatively high, both in terms of economic and sociocultural issues (Hidayanto *et al.*, 2009; Husain, Puryanti and Setijowati, 2021).

The topography of the Sebatik Island consists of basins (tidal areas, swamps, and coastal sediments), sea and land terraces, hills, waves and mountains. The coastal areas are dominated by mangrove vegetation, while the hilly areas in the central part includes secondary forests, agricultural land and plantations. The potential of land resources on the Sebatik Island is very supportive for agricultural development, especially for growing cocoa. People on the Sebatik Island have been cultivated cocoa, a superior commodity, since the 1980s and it is a commodity exported to Malaysia. The agricultural sector on the Sebatik Island is expected to become the backbone of the local community's economy. Various considerations make agriculture

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a mainstay sector on the Sebatik Island (Hidayanto *et al.*, 2009), including (1) provider of regional food needs, (2) foreign exchange earner, (3) GRDP (Gross Regional Domestic Product) contributor, (4) field provider work, and (5) renewable sector.

The productivity and quality of the crop does not meet the growing demand for cocoa commodities from the Sebatik Island designated for export. Data from the BPS (Badan Pusat Statistik) (BPS, 2020) shows that in 2020 the area of smallholder cocoa plantations in North Kalimantan, especially on the Sebatik Island, was 2,662 ha, production 1,047 Mg, and productivity 552 kg·ha^{-1}. The land used has shrunk when compared to the area in 2012, which was 6,491 ha with a productivity of 2,243 Mg (Hidayanto *et al.*, 2020). The decrease in the crop's productivity in this area was caused by several factors, including aging plants (>20 years), pest and disease attacks, and decreasing land fertility. This problem has led to the development of various economic, social, and environmental challenges (Bandanaa *et al.*, 2021). A previous study reported that the low cocoa productivity in Ghana was caused by biological and socio-economic factors (Dormon *et al.*, 2004; Bandanaa *et al.*, 2021).

To determine sustainability of smallholder cocoa plantation on the Sebatik Island, various influential aspects need to be considered. One of the common assessment methods is the RAP-SEBATIK. The method adopts from the RAPFISH, which uses simple, fast, and accessible attributes to evaluate a fishery sustainability status (Pitcher and Preikshot, 2001; Kavanagh and Pitcher, 2004). Several studies have also reported the use of the RAPFISH technique for the assessment of fisheries sustainability (Tesfamichael and Pitcher, 2006; Maouel, Maynou and Bedrani, 2014; Ririn *et al.*, 2021).

Therefore, this study aims to analyse the sustainability index for smallholder cocoa plantations on the Sebatik Island using a modified RAPFISH method, called the RAP-SEBATIK. The results are expected to provide information on how to optimise the management of the border area for agricultural development.

MATERIALS AND METHODS

SITE AND TIME

This study was conducted on the Sebatik Island, Nunukan Regency, North Kalimantan Province, Indonesia (Fig. 1), in March–December 2019. The border area in North-East Kalimantan is directly adjacent to Malaysia with the border length of approximately 1.02 thous. km, stretching from Nunukan, Malinau, to West Kutai Regencies. The Sebatik Island in the Nunukan Regency, North Kalimantan, is one of Indonesia's border areas which occupies 24.4 thous. ha. Furthermore, it is one of the outermost islands in the region (Sangkala, Burhanuddin and Yani, 2019) and is directly adjacent to Malaysia (Irna, Masyunani and Sasongko, 2020). A previous study revealed that its inhabitants have a unique life, setting them apart from those living on the mainland (Husain, Puryanti and Setijowati, 2021).

Smallholder cocoa plantations on the Sebatik Island cover an area of only 0.17% when compared to the area of smallholder cocoa plantations in Indonesia (BPS, 2020). However, the productivity of smallholder cocoa plantations has dropped compared to the volumes recorded in previous years. In 2012, smallholder cocoa on the Sebatik Island covered 6,491 ha, produced 12,163 Mg·y^{-1}, and productivity was 2,243 kg·ha^{-1} (Rahayu and Sumarmiyati, 2015), whereas in 2019, the area was 2,622 ha, production 1,047 Mg·y^{-1}, and the productivity was 552 kg·ha^{-1} (BPS, 2020).

Furthermore, the island is located in the northern part of the Nunukan Regency, at 117°35'20"–117°55'31" E and 4°01'37"–4°10'00" N. It is bordered to the north by Sabah (State of East Malaysia), to the west by the Nunukan Strait, and to the south and east by the Sulawesi Sea. The Sebatik Island was selected as the study location because the border area was one of major cocoa development centres in the Nunukan Regency, Indonesia.

DATA COLLECTION

The data collection comprised 62 attributes grouped into six dimensions. The evaluated attributes included 13, 9, 13, 9, 9, and 9 for the following dimensions: ecological, economic, socio-cultural, infrastructural and technological, law and institutional, as well as defence and security, respectively. Furthermore, some of them described the sustainable condition of smallholder cocoa plantations on the Sebatik Island. The assessment or score for each attribute was determined based on field surveys, interactive discussions with experts, information from relevant agencies and institutions, literature studies, Focus Group Discussions (FGD), and selected scientific journals (Hidayanto *et al.*, 2009; Sriwana *et al.*, 2017; Prazeres, Lucas and Marta-Costa, 2022).

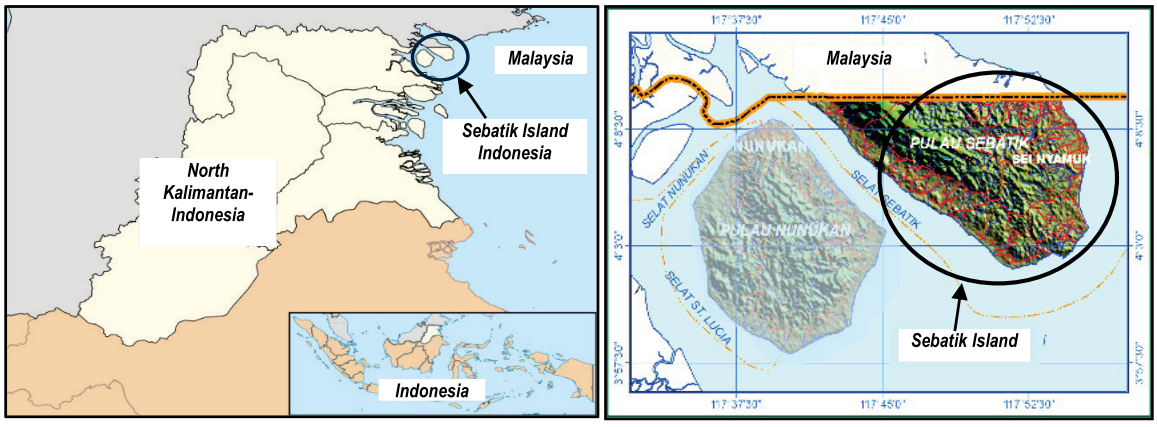

Fig. 1. Sebatik Island-North Kalimantan Province, Indonesia; source: own elaboration based on Google Maps

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THE ANALYSIS OF MULTIDIMENSIONAL SCALING (MDS)

The analysis used was an ordination technique known as the Rapid Assessment of Cocoa on Sebatik Island (RAP-SEBATIK). This statistical technique transformed multidimensional data into simpler dimensions. Furthermore, the method represented a modified approach from the RAPFISH programme (Rapid Appraisal for Fisheries), which was developed by the Institute for the Oceans and Fisheries, University of British Columbia (Kavanagh and Pitcher, 2004). The Multidimensional Scaling (MDS) was used to assess sustainability indices and statuses, and to identify the most sensitive attributes of each sustainability dimension (Sriwana *et al.*, 2017; Tenreiro Machado and Mata, 2017; Yusuf *et al.*, 2019).

The RAP-SEBATIK ordination technique using the MDS method was carried out in several stages: (1) determining the attributes of each sustainability dimension and defining them through field survey and literature review; (2) evaluating each attribute on an ordinal scale (scoring) based on the results of the field survey; (3) providing ordination analysis with MDS to determine the position of sustainability status on each dimension in sustainability index scale; (4) assessing the index and status of sustainability on each dimension; (5) performing sensitivity analysis (leverage analysis) to determine sensitive variables affecting sustainability, and (6) implementing Monte Carlo analysis to account for the dimension of uncertainty (Kavanagh and Pitcher, 2004). The Chart analysing the sustainability of smallholder cocoa plantations on the Sebatik Island is shown in Figure 2.

The MDS leverage analysis determines sensitive attributes that need intervention or improvement. Sensitive attributes are obtained based on the results of the leverage analysis, represented by changes in the root mean square (*RMS*) ordinate on the *X* axis. The greater the *RMS* change, the more sensitive the role of this attribute is in increasing the sustainability status.

The Monte Carlo analysis was used to estimate the effect of the error at the 95% confidence interval. In the sustainability analysis, the value of the Monte Carlo index is compared with the MDS index. The stress value and the coefficient of determination (R^2) are used to determine the need for additional attributes and to describe the accuracy of the dimensions studied with the actual situation. A low stress value (*S*) indicates good fit, while a high *S* indicates the opposite. A good model has *S* below 0.25 ($S < 0.25$), and R^2 close to 1 (100%) (Kavanagh and Pitcher, 2004). The analysis of the stress value <25 is a validation technique for the MDS model with Equation (1):

$$S = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\frac{\left[\sum_i \sum_j \left(D_{ijk}^2 - d_{ijk}^2\right)^2\right]}{\sum_i \sum_j d_{ijk}^2}} \quad (1)$$

where: *i*, *j*, *k*, *m* = dimensions analysed, *d* = Euclidean distance.

The sustainability index scale of the system had an interval of 0–100 (Kavanagh and Pitcher, 2004) and is divided into four categories of sustainability. The sustainability assessment index used in this study is presented in Table 1.

Table 1. Category of sustainability index value

Index value (%)	Category
0.00–25.00	unsustainable (poor)
25.01–50.00	less sustainable (less)
50.01–75.00	quite sustainable (enough)
75.01–100.00	sustainable (good)

Source: Kavanagh and Pitcher (2004), modified.

The MDS, leverage, Monte Carlo analyses, and measurement of stress value and coefficient of determination (R^2) were also carried out. The leverage analysis was used to determine the attributes that were sensitive and affected the sustainability of each dimension, while the Monte Carlo analysis was performed to assess the uncertainty in the MDS.

A comparison of sustainability index values between dimensions is visualised in the form of a kite diagram which depicts the sustainability status in an integrated manner among various dimensions. If the index value is closer to point 0, the sustainability is lower, and the farther from point 0, the sustainability index is higher.

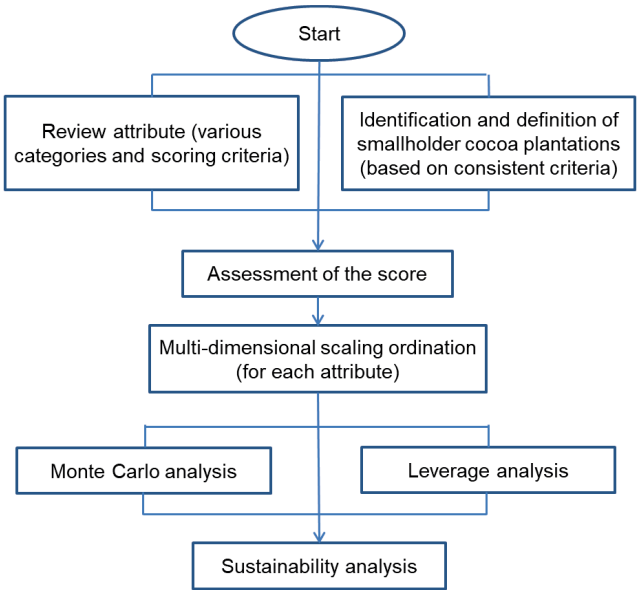

Fig. 2. Chart of the application process RAP-SEBATIK; source: Hidayanto *et al.* (2009), modified

RESULTS AND DISCUSSION

THE SUSTAINABILITY STATUS OF MULTIDIMENSIONAL SMALLHOLDER COCOA PLANTATION

The analysis of sustainability status was carried out using the MDS, namely the RAP-SEBATIK. The study examined six dimensions: ecology, economy, socio-culture, technology and infrastructure, law and institutions, and defence and security. Furthermore, the analysis showed that in existing conditions, the sustainability index for the ecological dimension was 46.23 (less sustainable), economic 48.58 (less sustainable), sociocultural 75.20 (sustainable), infrastructural and technology 40.49 (less sustainable), law and institutional 36.39 (less sustainable), and

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defence and security 36.39 (less sustainable). The 2009 research results on the five dimensions of sustainability (ecological, economy, sociocultural, technological and infrastructural, law and institutional) also show that only the sociocultural dimension is sustainable, while the other dimensions are less sustainable (Hidayanto *et al*., 2009). Figures 3 and 4 display the kite diagram (radar chart) resulting from the MDS ordinations for all dimension aspects.

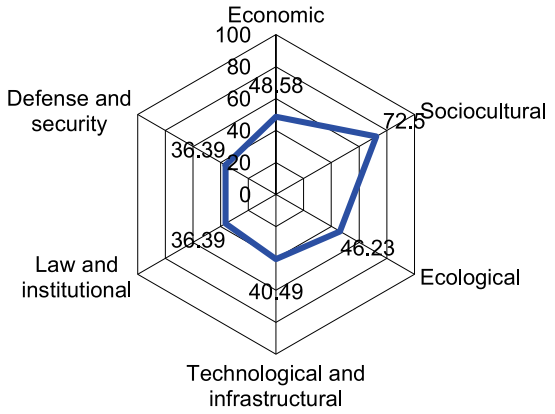

Fig. 3. Kite diagram for all dimension aspects from multidimensional scaling ordinations, based on RAP-SEBATIK analysis of smallholder cocoa plantation on the Sebatik Island; source: own study

THE SUSTAINABILITY INDEX AND SENSITIVE ATTRIBUTES IN EACH DIMENSION

The dimensions analysed included ecological, economic, sociocultural, technological and infrastructural, law and institutional, and defence and security. Sustainability analysis result (Fig. 3) showed that in existing conditions, sustainability index of ecological was 46.23% (less sustainable), economic – 48.58% (less sustainable), sociocultural – 75.20% (sustainable), infrastructural and technological – 40.49% (less sustainable), law and institutional – 36.39% (less sustainable), and defence and security – 36.39% (less sustainable).

Based on the sustainability analysis results, real smallholder cocoa plantations, reference anchors, and anchors are obtained. Real smallholder cocoa plantations results are based on the analysis of the data obtained. Reference figures are used for determining the value of anchors, which consist of four elements: good, bad, up, and down. Anchors are the result of the RAP-SEBATIK analysis for each attribute. The determination of anchor in the RAP-SEBATIK programme is adjusted to the number of attributes from each dimension being analysed.

THE LEVERAGE ANALYSIS

The leverage analysis was used to determine the sensitive attributes and interventions or improvements needed. Furthermore, the sensitive attribute was derived from the results of the leverage analysis, which was seen in the change of root mean square (*RMS*) ordination on the *X*-axis. Significant *RMS* changes were more sensitive to the role of these attributes in improving the sustainability status.

Sustainability of a smallholder cocoa plantation in the ecological dimension

Based on the results of field surveys and analysis using the RAP-SEBATIK, the sustainability index for the ecological dimension is 46.23 % (less sustainable), with a value of $S = 0.139$ and a value of $R^2 = 0.952$. The stress value is accepted if it is <0.25 (Kavanagh and Pitcher, 2004). The *S* value of 0.139 means that the analysis results on the ecological dimension are quite good, and $R^2 = 0.952$ indicates that the model using the variables at that time explained 95.20% of the actual conditions.

The leverage analysis showed that the main leverage factors in the ecological dimension were (1) the average age of cocoa, (2) the rate of attack by pests and diseases, (3) cocoa productivity, and (4) the use of superior cocoa seeds, as shown in Figure 5. In Indonesia, especially on the Sebatik Island, there has been a decrease in land area and cocoa productivity for the last five years (Wijaya *et al*., 2018; Hidayanto *et al*., 2020). Another study at a different location reported that smallholder farmers needed to learn how to improve their farming and postharvest skills (Praseptiangga *et al*., 2020).

The most sensitive attribute was the age of the plant. The results of this study showed that the average age of cocoa was generally between 15–20 years. This period was characterised by a decrease in productivity, with the occurrence of a suboptimal susceptibility to disease pests and maintenance (pruning, fertilisation, eradication of pests and diseases). This decrease was caused by the land suitability classes for cocoa (S2 and S3), as well as the presence of nutrient availability limiting factors (nr) (Hidayanto *et al*., 2020). Low soil fertility and crop damage due to pests and diseases have also reduced the productivity of smallholder plantations in this area (Mulia *et al*., 2017).

Other attributes that need intervention are the attack rate by other pests and diseases. Field survey results show that pests and diseases that are harmful include the cocoa pod borer (*Conopomorpha cramella* Snellen) fruit rot, or fruit-sucking ladybugs (*Helopeltis antonii* Sign), stem cancer and fungi. Cocoa plants on the Sebatik Island generally come from Malaysia and residents call them species or clones 23, 25, or 28 with an average productivity of only 552 kg·ha^{-1} dry bean. Therefore, in the future, to increase the index and status of sustainability in the ecological dimension, it is necessary to replant cocoa plants or replace new plants, carry out more intensive eradication of pests and diseases, and use superior seeds that are resistant to pests and have high productivity.

Sustainability of smallholder cocoa plantation in the economic dimension

The sustainability analysis results using the RAP-SEBATIK (Fig. 4), which includes nine attributes, show that the magnitude of the sustainability index is 48.58% (less sustainable), and the value of $S = 0.133$ and $R = 0.950$. Based on the economic dimension leverage analysis, the attributes that were sensitive to sustainability index included (1) competitiveness of cocoa from the Sebatik Island, (2) cocoa marketing, (3) dependence on foreign market cocoa (Malaysia), and (4) market access, as shown in Figure 6.

Smallholder cocoa plantations on the Sebatik Island are quite profitable. However, cocoa competitiveness is low because it is not supported by good quality due to inadequate cultivation

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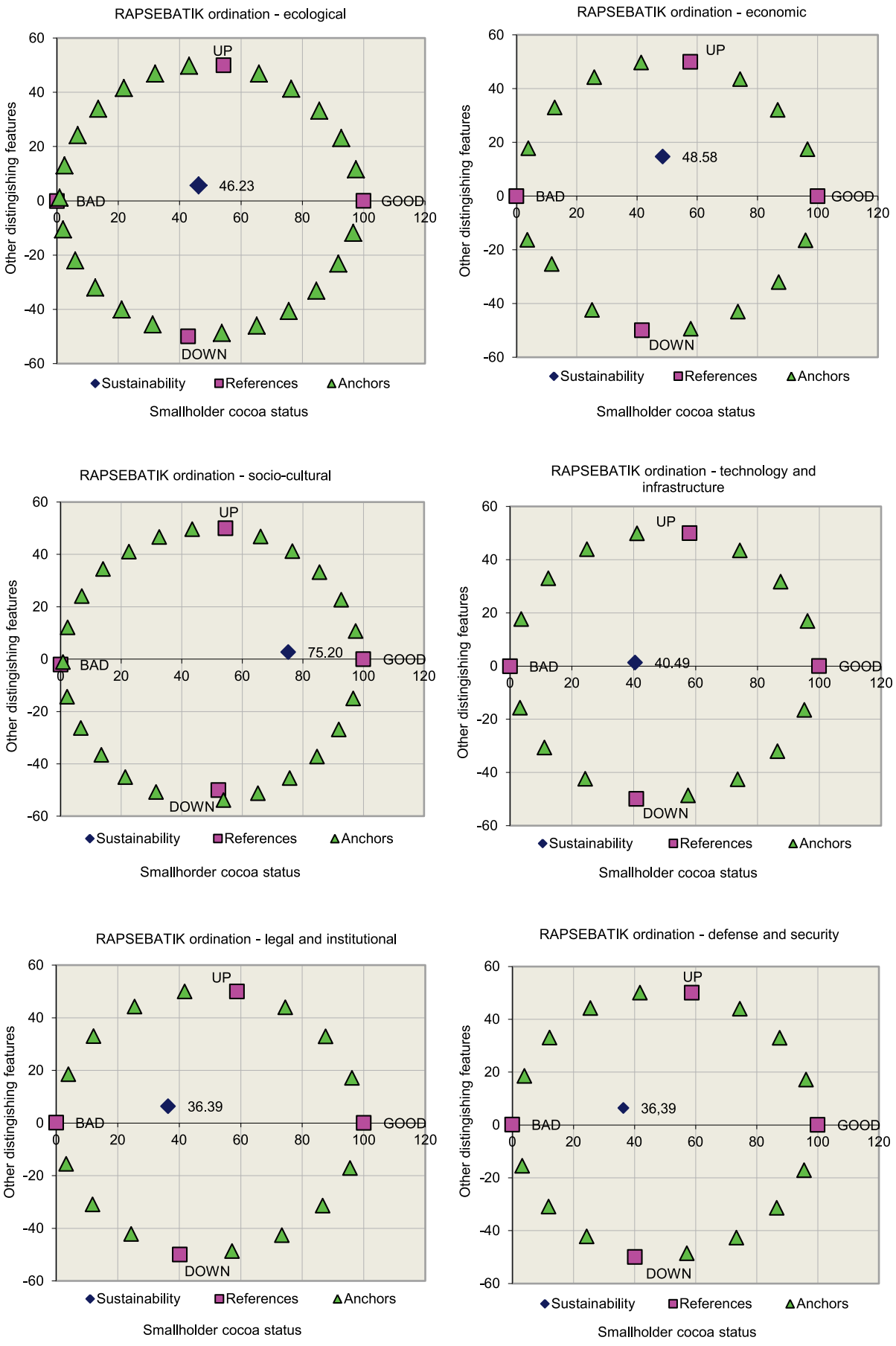

Fig. 4. Two-dimensional plots of multidimensional scaling ordination of smallholder cocoa plantation in Sebatik Island; source: own study

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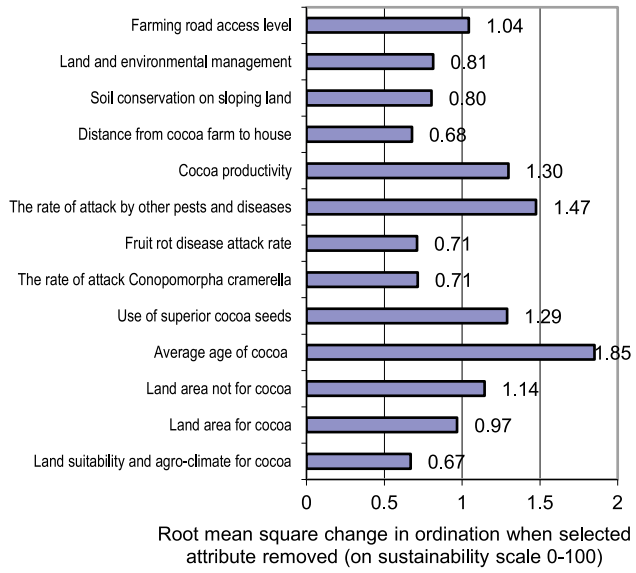

Fig. 5. The leverage analysis of the ecological dimension for a smallholder cocoa plantation on the Sebatik Island; source: own study

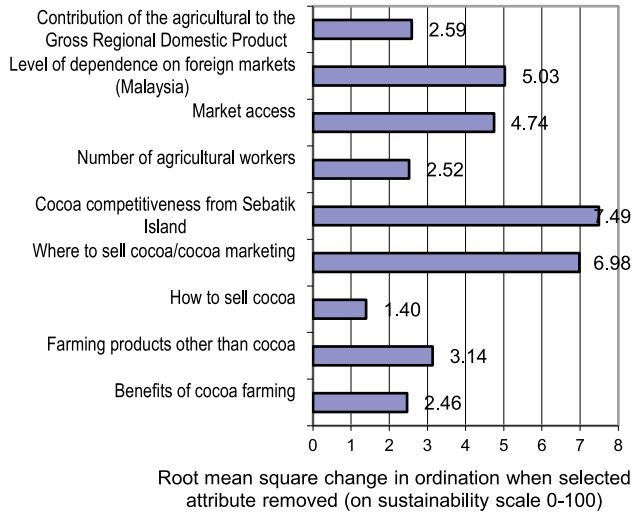

Fig. 6. The leverage analysis of economic dimension for smallholder cocoa plantation on the Sebatik Island; source: own study

and postharvest systems. Then, another sensitive attribute is cocoa marketing. The marketing of cocoa beans from the area is provided only by collecting traders, and the traders determine the price. The price at the collector level is determined by the price of cocoa in Tawau (Malaysia). Cocoa farmers on this island have market access to Malaysia only, so their dependence on the country's cocoa market is relatively high.

Therefore, to increase the index and status of sustainability in the economic dimension, it is necessary to improve these sensitive attributes through enhanced cultural and postharvest technology to increase cocoa competitiveness, provide cocoa marketing places that are viable and easily accessible to farmers, and seek marketing opportunities or access cocoa markets other than Tawau (Malaysia).

The Sebatik Island national border trading system was an interrelated network of social dimensions, politics, culture, kinship, and ethnic groups (Rudiatin, 2016). The people of the Sebatik Island often bought food processed from Tawau, whereas raw materials were obtained from Sebatik, Indonesia. The raw material, namely chocolate, was collected from the Sebatik Island and sold to Tawau, Malaysia. The Sebatik community then purchased "Milo" chocolate from Tawau (Irna, Masyunani and Sasongko, 2020; Rudiatin *et al.*, 2021). The value of ringgit and rupiah in trade was determined by the sociocultural environment at the border of Indonesia and Malaysia (Safriadi, Ardi and Yusuf, 2021). Based on the agricultural analysis, smallholder cocoa plantations on the Sebatik Island were relatively profitable, but the competitiveness of cocoa from this region was low due to low quality. The quality of cocoa was reduced due to the suboptimal cultivation system and improper postharvest treatment.

The sustainability of a smallholder cocoa plantation in the sociocultural dimension

The results of the RAP-SEBATIK sustainability analysis show that the magnitude of the sustainability index is 75.20% (sustainable), the value of $S = 0.127$, and $R^2 = 0.951$. The analysis showed that the sociocultural dimension was sustainable. However, based on the leverage analysis, some attributes were more sensitive to the sustainability index, including (a) formal education at the community level, (b) status of non-cocoa farmland, (c) average age of farmers, and (d) public opinion on cocoa farming, as shown in Figure 7. The state border with Malaysia on the Sebatik Island, and two different community groups, both ethnic and religious, pose social life challenges (Wahyudi, 2017). However, so far these communities have lived in harmony and need each other.

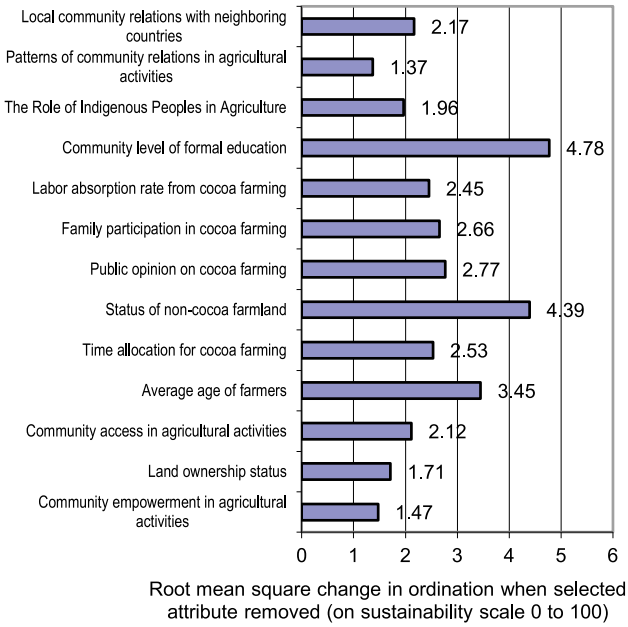

Fig. 7. The leverage analysis of the sociocultural dimension for a smallholder cocoa plantation on the Sebatik Island; source: own study

The education level on the Sebatik Island is relatively low, and the majority of cocoa farmers have not graduated from elementary school. Farmers had a low level of education due to, among other things, shortage of educational facilities and infrastructure, as well as unfavourable socio-economic conditions. Additionally, the survey showed that community empowerment in agriculture, especially for cocoa cultivation, was

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suboptimal. Based on these findings, most farmers still need to be counselled about their farming capacity that can be developed on the Sebatik Island.

Sustainability of a smallholder cocoa plantation in the technology and infrastructure dimension

RAP-SEBATIK sustainability analysis results shows that the sustainability index is 40.49% (less sustainable), S = 0.138, and R^2 = 0.950. Based on the leverage analysis, the attributes of technology and infrastructure that were sensitive to the sustainability index included: (1) application of fertilisers, (2) command of agricultural technology, (3) support for the development of roads and infrastructure, and (4) standardisation of agriculture produce quality (Fig. 8). In smallholder cocoa plantations on the Sebatik Island, farmers still do not have sufficient information on proper cultivation, especially location-specific fertilisation. Farmers in smallholder cocoa plantations on the island fail to apply fertilisers according to the actual needs of the plants, their age, and the level of soil fertility (Hidayanto *et al*., 2020). The results of research elsewhere also show that farmers in smallholder cocoa plantations have not implemented the recommended fertilisation and postharvest systems (Ramírez Sulvarán, Sigarroa Rieche and Valle Vargas del, 2014).

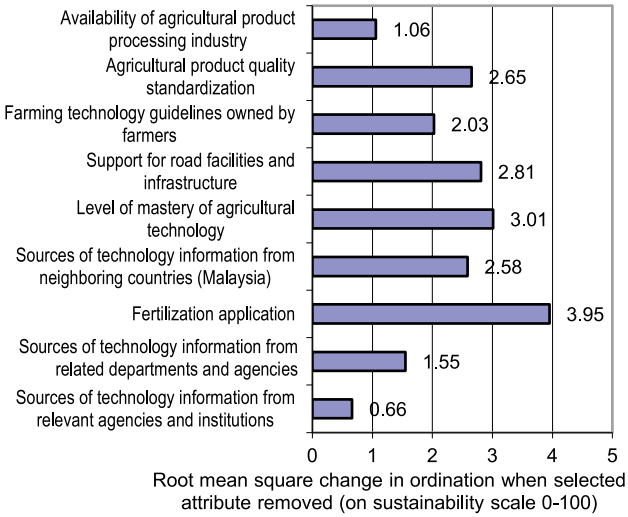

Fig. 8. The leverage analysis of the technology and infrastructure dimension for a smallholder cocoa plantation on the Sebatik Island; source: own study

The results showed that the plantation system on the Sebatik Island was unsustainable. Hence, it was essential to implement a conservation farming system in the border area. The command of technology on the island was relatively low due to limited information on cocoa farming. Most information sources originated from Malaysia.

Sustainability of a smallholder cocoa plantation in the legal and institutional dimension

The results of the RAP-SEBATIK sustainability analysis show that the sustainability index for this dimension is 36.39% (less sustainable), the value of S = 0.139, and R^2 = 0.951. In the leveraged analysis, the attributes of the legal and institutional dimension that were sensitive to sustainability included: (1) existence of a shop for agricultural production equipment, (2) synchronisation between central and regional policies, (3) existence of farmer groups, (4) existence of Microfinance Institutions (MFI), and (5) cross-sectoral collaboration mechanism (Fig. 9). There are three small shops for agricultural production equipment on the Sebatik Island. Agricultural products sold in the small shops are still limited and depend on the supplies from Malaysia. This is because the distance is too large to import from Indonesia, it takes a long time, and it is expensive.

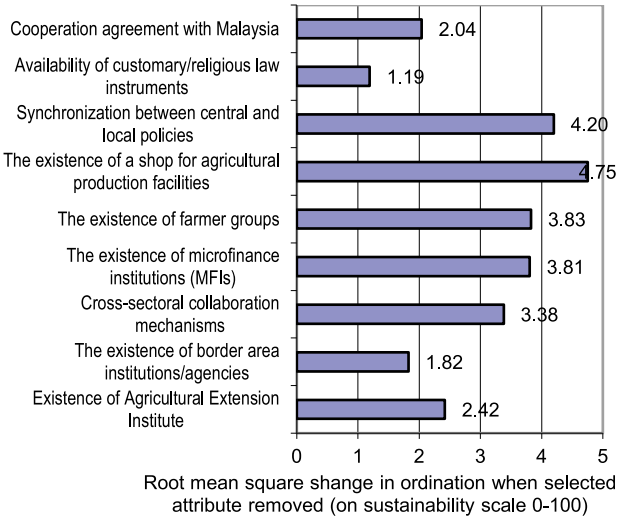

Fig. 9. The leverage analysis of legal and institution dimensions for a smallholder cocoa plantation on the Sebatik Island; source: own study

Another attribute that needs intervention is the synchronisation of central and regional policies. So far, the central government agricultural development policies have been more general and interfered less with those of local governments. Apart from that, the attributes of farmer groups also need to be intervened. Farmer groups on the Sebatik Island have developed but do not yet function well (Hidayanto *et al*., 2009). The role of farmer groups is very important in agricultural development (Rahmadanih *et al*., 2018).

Furthermore, other sensitive attributes are the existence of Microfinance Institutions (MFI). On the Sebatik Island, there are still few MFIs, cooperatives, and other financial institutions. However, farmers need MFIs to obtain their farming capital. In Ghana, microfinance products were recommended to develop local smallholder cocoa plantations (Quartey and Asamoah, 2018). Furthermore, the Bank of Ghana encouraged the establishment of MFIs, especially in rural areas. Smallholder cocoa plantations depended on capital loans from MFIs to finance their farming activity. Cross-sector cooperation mechanisms in developing border areas were reported to be the most sensitive attributes. Several studies revealed that the coordination of relevant sectors or agencies has not been far from optimal. The programmes were partial and conducted with low involvement of other sectors.

Sustainability of a smallholder cocoa plantation in the defence and security dimension

The results of the RAP-SEBATIK sustainability analysis show that the sustainability index for this dimension is 36.39% (less sustainable), the value of S = 0.139, and R^2 = 0.951. Based on

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the leverage analysis, the attributes of the defence and security dimension that were sensitive to sustainability included: (1) defence and security facilities and infrastructure, (2) cross-border facilities and infrastructure, (3) national border security posts (Ind.: Pos Pengamanan Terbatas – PAMTAS), and (4) breach of territorial boundaries by neighbouring countries (Fig. 10). Furthermore, the Sebatik Island was one of the outermost islands that bordered directly neighbouring countries (Malaysia).

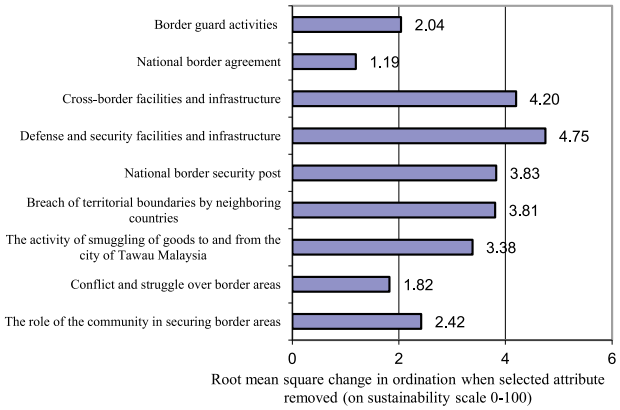

Fig. 10. The leverage analysis of the defence and security dimension for a smallholder cocoa plantation on the Sebatik Island; source: own study

Defence and security issues have become very important due to their association with sovereignty and territorial integrity. The border areas in Indonesia have played an important role in the economy, politics, and national defence (Christyanto and Mayulu, 2021). With strong capabilities, the country can deal with various threats from within and abroad. A borderline length of 2004 km was expected to be difficult for the TNI, especially Kodam VI/Tanjungpura, who were members of the Border Security Task Force (Task Force PAMTAS), to provide physical defence in the region.

Being a land and sea border area, the Sebatik Island urgently need defence and security facilities and infrastructure to maintain security and sovereignty. Border monitoring posts (PAMTAS) on the Sebatik Island have now been prepared and built, but there are only four posts and not yet supported by adequate defence equipment. In addition, border disputes with other countries have not yet been solved, and in the future this could trigger conflicts on state borders. Defence and security facilities and infrastructure in the border area of the Sebatik Island need to be improved to provide calm and a conducive atmosphere for the community to develop farming and the Sebatik Island in general as the national front porch.

THE MONTE CARLO ANALYSIS

The Monte Carlo analysis was used to assess the uncertainty in the MDS. The results showed that the difference was relatively small at the 95% confidence level for each dimension. Furthermore, this situation indicated that the simulation using the RAP-SEBATIK (MDS) had a high level of confidence (Kavanagh and Pitcher, 2004). Table 2 shows the difference between MDS and Monte Carlo sustainability indices.

The RAP-SEBATIK study revealed that the stress varied from 0.127 to 0.139, and the determination value (R^2) was between 0.950 and 0.952, as shown in Table 3. Therefore, the S was less than 0.25, R^2 value was close to 1.0. These results were

Table 2. Differences in sustainability index of RAP-SEBATIK (MDS) and Monte Carlo

Dimension of sustainability	Sustainability index (%)		Difference
	MDS	Monte Carlo	
Ecology	46.23	45.70	0.53
Economy	48.58	47.86	0.72
Sociocultural	75.20	73.27	1.93
Infrastructure and technology	36.39	37.38	0.99
Law and institutions	40.49	41.00	0.51
Defence and security	36.39	37.62	123

Source: own study.

Table 3. Stress value (S) and determination coefficient (R^2) sustainability dimension

Parameter	Dimension of sustainability					
	ecology	economy	sociocultural	infrastructure and technology	law and institutions	defence and security
S	0.139	0.133	0.127	0.138	0.139	0.139
R^2	0.952	0.950	0.951	0.950	0.951	0.951
Sustainability index (%)	46.23	48.58	75.20	40.49	36.39	36.39
Sustainable status	less sustainable	less sustainable	sustainable	less sustainable	less sustainable	less sustainable

Source: own study.

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relatively accurate and reliable. The R^2 of more than 80% for the social model was considered to be excellent based on the standard. The magnitude of S between 0.127 and 0.139 (<0.25) indicated that the accuracy of the configuration of points (goodness of fit) of the model built was good with accurate variables (Kavanagh and Pitcher, 2004).

CONCLUSIONS

The productivity of smallholder cocoa plantations on the Sebatik Island is currently below the optimal level due to complex problems. The sustainability analysis showed that in existing conditions, only the sociocultural dimension was sustainable (75.20%). Other dimensions were less sustainable, including ecological (46.23%), economic (48.58%), infrastructural and technological (40.49%), law and institutional (36.39%), as well as defence and security (36.39%). This indicates that a balance is needed to promote sustainable management of the cocoa community on the Sebatik Island. The management of smallholder cocoa plantations must be improved in all dimensions to increase productivity, production, and sustainability of superior commodities in the border island region of Indonesia. The main factors that need to be intervened to improve the sustainability of all dimensions are the average age of cocoa, formal education at the community level, fertilisation application for cocoa, availability of a shop for agricultural production equipment, and defence and security facilities and infrastructure.

ACKNOWLEDGEMENTS

The authors are grateful to the Agency for Agricultural Research and Development, Ministry of Agriculture, Republic of Indonesia, for funding this study.

CONFLICT OF INTERESTS

All authors declare that they have no conflicts of interests.

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