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DEVELOPING LOCAL-LEVEL INDICATORS TO MEASURE THE SUSTAINABILITY OF RICE-PRODUCTION AREAS IN SABAH

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Abstract: The development of local sustainability indicators has become a primary concern in implementing and monitoring sustainable development agenda and progress. Following the execution of local Agenda 21, researchers and managers continue to debate the appropriate methods for developing indicators that suit local circumstances, i.e. the dichotomy between top-down and bottom-up approaches. The input level from local stakeholders and experts are also concerned. This study served to initiate a sustainable development indicator for rice-cultivation areas in Sabah, Malaysia. It also addressed the need to ensure the continuity of rice production for food security and self-sufficiency. Therefore, in an effort to guide policy-makers in addressing the issue, the identification of indicators for sustainable rice production is critical. The Delphi method was applied in collecting information and opinions from stakeholders to develop a set of indicators for sustainable development in Sabah rice-growing areas. The Delphi survey method enables potential indicators to be evaluated and short-listed, before additional filtering using factor analysis. Indicators derived from this process were applied in the field to measure the sustainability level of rice cultivation in four different villages in the study area. Results of the analysis showed that a set of 14 indicators developed through this study measures various dimensions of sustainable development of rice growing areas such as economic, social, support services and environmental. The ability of the developed set of indicators to differentiate the level of sustainability of the study areas showed that it can be used as a tool to measure the sustainable development of rice-growing areas, particularly in Sabah. The findings also indicated that extensive involvement from local people and experts in the development of indicators provide a good foundation for the integration of top-down and bottom-up approaches in the development of sustainable indicators at the local level, particularly in developing countries.

KEYWORDS: *Sustainable indicators, rice-growing areas, local stakeholders, community/public participation*

Introduction

The international community's growing concerns regarding poverty and hunger, and the bridge between these problematic issues and the degradation of natural resources, have driven the acceptance of a global action programme for Sustainable Agriculture and Rural Development (SARD) at an international level; as described in Chapter 14 of Agenda 21 in the UN Department of Economic and Social Affairs. The primary goals of SARD are to strengthen food security by the sustainable increase of food production, generate employment opportunities and income in rural areas, eradicate poverty, and effectively manage rural natural resources (UNCED, 1992). In developing countries, particularly within Asia, rice-production areas are one of the most important agricultural features that can be used to achieve sustainable agriculture and rural-development goals. These regions are not only major food-production areas, but rice satisfies the economic needs of the numerous rural poor.

One of the increasingly applied tools for monitoring progress towards sustainable development is the sustainability indicator (Boyd & Charles, 2006; Zhen & Jayant–Routray, 2003). Consistent with the rice-production movement to reach sustainable levels in rural areas, efforts

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have been made by a few parties to develop sustainability indicators to measure progress in specific regional localities (Gowda & Jayaramaiah, 1998; Praneetvatakul, 2001). However, the efforts to date have not called for exclusive participation of local residents, although this is the key element in efforts to develop sustainability indicators at the local level (Rosenstrom & Kllonen, 2006; Walis, 2006; UNCED, 1992).

The importance of local participation in sustainability-indicator development has been noted in several studies (Boyd & Charles, 2006; Bell & Morse, 2004; Freebairn & King, 2003; Yuen et al., 2003; Bell & Morse, 2003; Gunderson & Holling, 2002; Reed & Dougill, 2002; Riley, 2001; Valentine & Spangenberg, 2000). This research indicates participation of local parties to identify indicators and provides a context to understand local issues. Consequently, indicators generated at the local level measure what is important for a geographically narrow region, and is therefore more practical in making decisions at the local level.

Considering this advantage, this study explores the potential to develop sustainability indicators via a wide range of participation. In developing sustainability indicators, this study included participation from local residents in rice-production areas, and regional professionals (experts) with both direct and indirect interests and roles in rice-production development. The discussion in this paper focuses on the following three topics: 1) development of sustainability indicators via a wide range of local stakeholder participation; 2) field application of the indicators; and 3) the advantages and limitations of indicator development revealed by the study.

Materials and Methods

Study Area

Sabah is located on the northern part of the island of Borneo. It is the second largest state in Malaysia, with an area of 73, 619 square kilometres. In 2010, the population was estimated to have reached 3.1 million, making it the third-highest state population in Malaysia. Approximately 50% of the population reside in rural areas. Agriculture is the second largest economic sector (after service sector) in Sabah, contributing about 24% of the GDP, approximately a third of the employment, and 40% of the export value (2004 statistical data). Palm oil is historically the dominant crop, covering approximately 87% of the total crop area, followed by rubber (at 5%) and rice (at 3%).

Rice is an important food crop for Sabah, particularly for the rural population. In addition to serving as a source of food and an important economic crop, rice also significantly shapes the cultural systems, beliefs, and traditions. Historically, rice was grown for subsistence, using traditional practices, and cultivated on a small scale. Most rice was grown in the hills, and rice-production levels were very low. At the end of the 1960s, in conjunction with an increasing demand due to rapid population growth and development in Sabah, rice was sown on a larger scale. Potential areas for rice cultivation were identified, and irrigation facilities and modern rice-farming practices were introduced, to further improve rice-production. The total land area dedicated to rice-cultivation gradually declined from 53, 000 hectares in 1990 to 41, 000 hectares in 2004 and finally 34, 594 hectares in 2009. The majority of rice (86%) is wet rice; planted on low land, the major rice producing regions are Kota Belud and Kota Marudu. Currently, nearly 50% of the rice cultivation areas in Sabah are located in these two regions, which contribute more than 70% of the total rice production of Sabah. Less than 50% of the rice cultivation is equipped with irrigation facilities provided by the government, and 40% of the farmers harvest their rice fields twice a year (Anonymous, 2005).

Currently, rice production in the state is only able to accommodate approximately 30-40% of the population needs. Rice is in high demand due to a large population and rapid population growth. Therefore, it is vital for Sabah to increase rice production. The state aims to achieve at least 60% of its own rice needs. The National Food Security Policy, launched by the Malaysian government in 2008, identified Sabah as one Malaysian state requiring improvement in rice production. The existing resources have not yet reached their optimum production level, and a large labour force and suitable rice-growing conditions exist in the state.

However, it is difficult for Sabah to ensure its target roles are achieved if rice-production development areas are not sustainable. The problem is Sabah has limited land-space resources, especially for rice cultivation, as large areas in Sabah are mountainous. Twenty-nine percent of its land is suitable for agriculture; and approximately 84% of that land has been cultivated, and largely planted with industrial export crops, including palm oil, rubber, cocoa, and coconut (Sabah, 2006). Exclusive of rival crop industries, the existing rice-plantation areas are also affected by rapid urbanisation. Many rice fields, particularly fields cultivated near urban areas, towns, and major roads, have been claimed for development, including homes, shops, and factories. In addition to rapid urbanisation, the absence of economic opportunities in rice-production areas motivates some of the population, especially youths, to move to other sectors of the economy, which results in a loss of labour in rice-production areas, and the land remains uncultivated.

The limitations in agricultural land resources, competition of land use from other sectors, labour-force migration, and high demand for rice, gives rise to the need for further monitoring and management of rice-production area development, with the aim of sustainable development. This goal will not only ensure stable and continuous rice production, but also improve the socio-economic welfare of the people, in regions where the large majority of the population are poor.

Methodology

The overall process for developing a set of local-level indicators for this study is depicted in Figure 1. The process comprised four steps, enriched by a wide range of elements. The process begins by establishing the context of the study. Two important primary components had to be taken into account at this stage: an understanding of the sustainability issues in rice-production areas, and identifying the key stakeholders. Relevant literature and reports from local agencies were reviewed to assess sustainability issues in Sabah rice-production regions. In addition, informal interviews were conducted with two local government officers from the Department of Agriculture Sabah, a researcher from the Institute of Development Studies (Sabah), and five local-district-level leaders who were referred by district agricultural officers based on their integral roles in their district's rice-production development. These interviews were crucial in delimiting local issues, and to assist in identifying potential participants in the sustainability indicator-development process.

The purpose of the second and third stages was to generate and evaluate potential indicators, which may be effective in measuring sustainable rice-production development areas in Sabah. A group of 80 local residents from the two main rice-producing regions (Kota Belud and Kota Marudu), and 68 local experts (from various agencies at both district and state levels) associated with rice-production development were identified to participate in generating potential indicators. The selected participants were required to meet at least one of the following criteria: (i) be actively involved in the chain of rice-farming activities; (ii) have at least five years of direct involvement in the management, planning, and implementation of rice-cultivation development in Sabah; and/or (iii) be indirectly involved in rice development in rural Sabah regions (e.g. active research in related disciplines, and hold positions at branch associations at the district or state levels. A purposive approach was applied to identify participants, assisted by officers at the District Office, District Office of Agriculture, Ministry of Agriculture and Food Industry, and the head of each relevant agency. The selected participants were from varied geographic locations, so it was logistically unrealistic to gather all contributors in one place at the same time to discuss and achieve a consensus on specialised areas (i.e., sustainability indicators for rice-cultivation areas). Therefore, to explore and identify potential indicators for this study, the Delphi technique was adopted. The Delphi technique allows discourse among participants, without requiring face-to-face

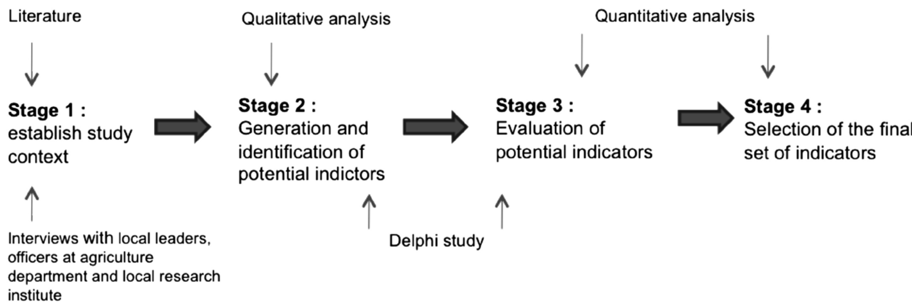

Figure 1: Indicator development process.

exchange. Individuals respond without pressure, analogous to a traditional discussion-group setting, where individuals receive immediate and direct feedback. In other words, the Delphi method facilitates a frank and genuine 'group' discussion on a specialised area, without the experts necessarily being together.

The Delphi process used in this study comprised two rounds. A survey instrument was constructed based on a thorough review of the relevant literature and discussions with experts i.e., a group of researchers at University Malaysia Sabah, and a group of officers at Sabah's Agriculture Department. The first-round questionnaire was made available to 148 potential participants, via three routes i.e., hand delivery, mail, or email; 104 (70%) were returned. In round one, participants were individually asked to list measurable sustainability indicators in rice-production areas. A list of definitions of sustainable development and sustainable agriculture as well as some findings on a set of indicators related to sustainable agriculture were provided to the participants as their reference. Participants identified a total of 499 potential indicators in the first round, which were subsequently analysed using a qualitative method, which utilised three main processes, i.e., listing, categorising, and filtering. Listing was employed to examine the potential indicators individually. Indicators with the same or similar meaning were grouped and investigated further, and reinterpreted into a simple and easily-understood indicator language. The short list of these potential indicators was then finalised through discussion with experienced local leaders and experts from the District Agriculture Office, local university, and research institutes. At the end of this process, 144 potential indicators were identified. The second-round questionnaire was distributed to the 104 first-round participants, and 82 (78.8%) were returned. During the second round of the Delphi study, participants were asked to rate the importance of each of the 144 indicators. The importance levels of the 144 indicators were measured by participants using a Likert Scale of five levels i.e., least important, less important, important, very important, and most important.

The last stage was to select the final set of indicators, based on the importance level of data obtained from the second round of the Delphi study. The data was analysed using a quantitative method. For early-stage filtering, after consultation with local experts, indicators with a mean value of less than 4.0, and a standard deviation of more than 1.0 were eliminated. Ultimately, 58 indicators were retained, which were subjected to an internal consistency test. Indicators that exhibited a high correlation value with a total mean score for all indicators were retained. Based on an *a priori* cut-off point i.e., item-total score 0.3 and above, 32 indicators were retained (Table 1).

Finally, factor analysis was conducted on all 32 indicators, to ascertain the similarities in the structural relationship between indicators.

Results

Factor analysis results, which were assessed following rotation for ease in interpretation of factors, revealed six groups of indicator

Table 1:List of indicators according to item total score more than 0.3 and a loading factor based on indicator structural relationship groups.

Group	Indicators	Item total Score	Loading Factor	Variance (%)
1	P9 Education level	0.6360	0.724	34.0
	P15 Standard of living	0.7801	0.830	
	P18 Adequate food	0.7651	0.885	
	P19 Adequate expenditure (i.e., paying household bills)	0.8240	0.900	
	P20 Level of debt burden	0.3273	0.478	
	P34 Tolerance level in solving problem	0.6229	0.796	
	P47 Rice-field ownership status	0.8514	0.899	
	P50 Total income	0.7034	0.787	
	P54 Rice-yield production trends	0.8277	0.878	
	P64 Farmers with additional economic activities	0.7460	0.767	
	P75 Profitable turnover	0.7568	0.830	
	P89 Pests and rice disease control levels	0.6379	0.755	
	P110 Machine accessibility level	0.6906	0.740	
	P112 Water Shortage	0.5670	0.685	
	P113 Good and systematic irrigation system	0.6664	0.734	
	P141 Rice-field size	0.8484	0.873	
2	P49 Income trend	0.6891	0.737	10.3
	P83 Irrigation quality	0.6737	0.779	
	P111 Agricultural input accessibility level	0.6018	0.760	
	P120 Existence of adequate rice-field infrastructure	0.6844	0.680	
	P125 Coordination level of rice plantation	0.4164	0.428	
3	P81 Soil fertility care	0.3471	0.795	9.0
	P114 Well managed and maintained irrigation system	0.4212	0.826	
	P123 Existence of adequate rice factory	0.4721	0.787	
	P116 Accessibility level to basic facilities	0.3380	0.590	
4	P40 Pattern of farmer expenditures	0.3113	0.721	6.3
	P71 Existence of downstream industry	0.4120	0.628	
5	P97 Perfect rice-field water control	0.3125	0.620	5.8
	P37 Time management	0.3413	0.858	
6	P126 Level of government involvement	0.3628	0.801	5.4
	P7 Farmers level of independence	0.3982	0.478	
	P11 Farmers level of motivation	0.4405	0.431	

relationships (Table 1). However, based on eigenvalues and variance for each factor structure group, 14 indicators with loading factor more than 0.7 from the first structure relationship group were selected as a sustainability-indicator set. These indicators included education level, standard of living, food sufficiency, expense sufficiency, tolerance level, land ownership, total income, yield trends, economic-activities diversification, return on capital, rice-pest control, machinery sufficiency, irrigation system, and rice-field size..

Field-indicator application

The indicators were applied in the field to examine indicator effectiveness and measure sustainability of rice-production development. The study instrument was a survey form, developed using the 14 indicators from the first structure relationship group selected as a sustainability-indicator set. Four villages were chosen to survey from the main rice-production district in Sabah, including Kesapang and Sangkir in the Kota Belud district, and Seronsob and Longob in the Kota Marudu district. The four villages have distinct characteristics. Kesapang and Seronsob are located adjacent to the main town of their respective districts, and are closed to roads that connect their districts to other main towns, such as Kota Kinabalu, Tuaran, and Kudat. The other two villages are more isolated, within 15-20 kilometres from the main road, and the main town of their respective districts. Five final-year students from the University Malaysia Sabah conducted the survey. The total number of respondents interviewed was 54 (67.5%) in Kesapang, 40 (80%) in Sangkir, 44 (80%) in Seronsob and 48 (68.6%) in Longob.

Table 2: Sustainability-level scores based on indicators and study area.

Indicator	Indicator Measurement	Kesapang		Sangkir		Soronsob		Longob	
		%	SK	%	SK	%	SK	%	SK
P9 Level of education	Form 3 and above	46.3	1	50	2	72.7	3	29.2	1
	Participated in an agricultural course	61.1	2	40	1	97.7	4	37.5	1
P15 Standard of living	Lives in a home with three bedrooms or more	66.7	3	70	3	100	4	41.7	1
	Positive changes in living standards	66.7	3	52.5	2	97.7	4	39.6	1
P18 Adequate food	Adequate food	55.6	2	77.5	3	65.9	3	83.3	4
P19 Adequate expenditure	No loans to pay household bills	57.4	2	72.5	3	75	3	35.4	1
P34 Tolerance level	Choose to solve problems through negotiation	85.2	4	92.5	4	100	4	91.7	4
	No difficulties negotiating with other farmers to solve problems	35.2	1	62.5	2	65.9	3	60.4	2
P47 Rice field ownership status	Cultivate own land	44.4	1	52.5	2	56.8	2	77.1	3
P50 Total income	Monthly income of more than RM503	64.8	2	62.5	2	84.1	4	41.7	1
P54 Trend of rice-production yield	Trend of positive production yield	44.4	1	25	1	50.0	2	29.2	1
P64 Farmers with additional economic activities	Gardening/breeding at home	85.2	4	85	4	86.6	4	58.3	2
	Owns plantation field/breeding ground	9.3	1	7.5	1	54.5	2	33.3	1
	Part-time job	85.2	4	55	2	93.2	4	35.4	1
P75 Profitable turnover	Turnover above RM1000	50.0	2	25	1	68.2	3	45.8	1
P141Rice-field size	Cultivate rice field of five acres or more	38.9	1	60	2	9.1	1	25	1
P89 Pest and rice disease control level	Below 10% of rice yield affected by disease or pests	44.4	1	25	1	43.2	1	33.3	1
P110 Level of accessibility to machines	No problems obtaining the service of harvesting contractors	63.0	2	75	3	97.7	4	47.9	1
P113 Good and systematic irrigation system	No irrigation problems - water reaches the rice field at the required time	55.6	2	25	1	75	3	75	3
	Irrigation system supplies sufficient water for the needs of rice fields throughout the planting season	74.1	3	92.5	4	88.6	4	87.5	4
Sustainability Score Total		42/80 (52.5%)		44/80 (55.0%)		62/80 (77.5%)		35/80 (43.7%)	

The results from the indicators-application data analysis are shown in Table 3. The indicator achievement percentage is the total percentage that fulfils the fixed standard value (Table 2, Column 2). This percentage is used to determine a sustainability score for each indicator, a value given to the indicator based on an achievement percentage. In the present study, an indicator-achievement percentage less than 50% was considered weak, and assigned a score of 1. Indicator-achievement percentages between 50 and 64 were assigned a score of 2, a score of 3 was assigned to indicator-achievement percentages between 65 and 79, and a score of 4 was assigned

Table 3: Indicator-achievement score value and sustainability levels.

Performance percentage	Indicator performance score value	Stability levels
< 50	1 – Weak	Not sustainable
50 - 64	2 – Moderate	Moderately sustainable
65 - 79	3 – Good	Sustainable
80 - 100	4 – Excellent	Very sustainable

to achievement percentages between 80 and 100. The level of development sustainability for each study area was determined by summing all indicator sustainability-achievement scores. Sustainability score details derived from indicator-achievement percentages, and the four levels of sustainability are reported in Table 3.

This study has produced a set of sustainability indicators through a variety of participants. Based on measurement of the indicator set, only Seronsob displayed sustainable achievement. Meanwhile, Kesapang and Sangkir exhibited moderate sustainability, and Longob was not sustainable. The most obvious sustainability issue in the study areas was from an economic perspective (Figure 2). Land size (P141) and land ownership status indicators (P47) were among the weak achievements (refer to Figure 2). The majority of respondents in the study areas do not work their own land, and land size is less than five acres. Consequently, they pay rent or share the rice yield with the landowner. Therefore, the incentive to maintain rented land in optimum production condition was very low. Low accessibility to the main resources can result in low capital return (P75) and low yield (P54). Returns on capital and rice yield were also influenced by incidents of pest infestation and disease. More than half of the respondents reported 10% decreased yields as a result of pest infestation and rice diseases (P89). Consequently, the rice yield trend (P54) was unstable. Based on a study of annual rice yields per acre between 2005 and 2007, more than 50% of respondents reported an unstable trend. Sangkir was the most severely affected area. Exclusive of pest infestation problems, such as *Pomacea incerlarus* and *P. canaliculata* (Golden Apple Snail), locally known as Dolium (Siput Gondang Emas), this village was among the Kota Belut district rice-production areas severely affected by rice tungro bacilliform virus (RTBV) during the study period.

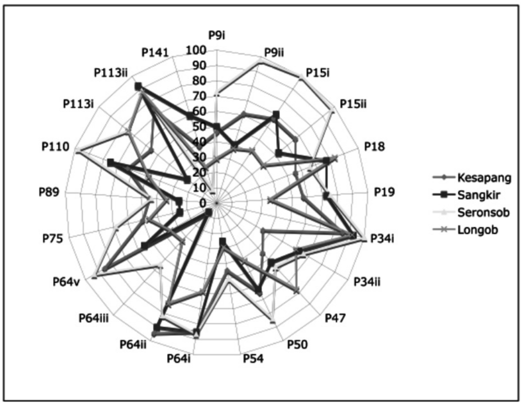

Figure 2: Comparison of the levels of sustainability.

Longob not only faced economic problems but also socio-economic challenges, and accessibility to modern farming facilities i.e., machinery (P110). The village showed low competitiveness in the rice-production sector, and the population engages in minor secondary economic activities (P64iv), which contributed to low achievement in standard of living (P15i, P15ii), expense sufficiency (P19), income (P50), and access to machinery (P110). Similar to Longob, Seronsob exhibited low rice economic competitiveness. However, most of the Seronsob population owned rubber plantations, and participated in other secondary economic activities, including trading and selling at the local market. The initiative to diversify economic activities increased monthly income, and therefore, assisted the population in fulfilling other social and economic needs.

Compared to other study areas in the Kota Marudu district, the Kota Belud district was facing a sustainability problem in the form of irrigation systems efficiency (P113i). The majority of the respondents in the district study areas received adequate water supplies for their rice fields (P113i). However, most were experiencing untimely water delivery. The primary reason for this problem was that rice planting in the district was not conducted simultaneously, and this affects water-supply distribution efficiency. In addition, study areas in Kota Belud were also facing negligible secondary agricultural activities

Table 4: Comparison of sustainability indicators deduced for the literature and the set developed in this study.

Sustainability Indicators	Literature citation	Designation
Water shortages	Praneetvatakul et al., 2001	/
Land tenure	Praneetvatakul et al., 2001	/
Land size	Praneetvatakul et al., 2001	/
Health impacts	Praneetvatakul et al., 2001	x
Labour	Praneetvatakul et al., 2001	x
Education level	Praneetvatakul et al., 2001	/
Rice yield	Praneetvatakul et al., 2001; Gowda and Jayaramiah, 1998	/
Soil erosion	Praneetvatakul et al., 2001	x
Food sufficiency	Praneetvatakul et al., 2001; Gowda, C and Jayaramiah, 1998	/
Integrated nutrient management	Gowda and Jayaramiah, 1998	x
Integrated water management	Gowda and Jayaramiah, 1998	x
Integrated pest management	Gowda and Jayaramiah, 1998	x
Self-input sufficiency	Gowda and Jayaramiah, 1998	/
Crop yield security	Gowda and Jayaramiah, 1998	/
Information on self reliance	Gowda and Jayaramiah, 1998	x
Benefit-cost ratio	Gowda and Jayaramiah, 1998	/
Standard of living	X	/
Expenditure sufficiency	X	/
Tolerance level	X	/
Total income	X	/
Participation in additional economic activities	X	/

Note: / - cited in the literature and/or developed indicators
x - not cited in the literature or developed indicators

(P64iii) to generate additional income. Only ten percent of the respondents in the Kota Belud district study area owned livestock, farms, or crops.

Discussion

The increased awareness to achieve sustainable food production, generate employment opportunities and income in rural areas has intensified efforts to establish sustainability indicators. Sustainability indicators, especially those developed via top-down approaches, have most often been identified, assessed, and selected by expert groups and researchers. Evidence of bottom-up elements in sustainability indicators suggests the involvement of stakeholders in generating, assessing, and selecting indicators, which are very limited and often conducted during the final stages of the process. In the present study, involvement began at the onset of the indicator-development process i.e., from the origination stage through the indicator assessment stage. This study also demonstrated extensive involvement from two participant levels. Locals and upper-class levels represented the indicator target groups that have the potential to influence the development direction of local-level rice-producing areas. Government and private officials, NGOs, politicians, and researchers from local universities and research institutions represented the upper class. Therefore, the primary advantage of adopting the sustainability-indicator development approach was the capacity to enrich local input during indicator establishment, which was subsequently adopted at different levels (e.g. farmers through policy-makers), and exhibited feasibility at the level of sustainability measurement.

Furthermore, the set of indicators successfully identified local sustainable-development priorities. Table 4 summarises a list of indicators for measuring the sustainability of rice-producing areas from the literature, compared to the set of indicators developed in this study. Some indicators from this study overlap with those deduced from the literature. Therefore, the indicators developed in this study have an empirical basis. Nevertheless, a few indicators were not found in the literature, and are included in the reference list as new indicators (Table 4). The new indicators highlight sustainable development priorities in rice-producing areas in the study community, and are more relevant to goals of local sustainable development. The study also contributed to a wider scope of sustainability indicators for rice-producing areas i.e., a focus on the rice farmer's quality of life, recognition of socio-cultural aspects of the community, and the existence of secondary economic endeavours. Note: / - cited in the literature and/or developed indicators

This study also illustrates the successful utilisation of the Delphi method to generate, identify, and assess sustainability-indicators, and subsequently achieves a consensus on sustainability indicator sets. In the context of this study, a component of the indicator-development process was assisted by the Delphi method.

First, the method facilitated extensive participation in the indicators development process. Due to geographic constraints, excessive logistical costs, and a full commitment from the respondents, gathering all respondents together at the same time was not practical. Furthermore, participants had different levels of education, employment, knowledge, and experience, which could hinder open dialogue in a face-to-face setting with all respondents. The Delphi method enabled every respondent access and opportunity to provide responses to the issues raised in the Delphi study from home or work. This eased participation in the indicator development process, and subsequently increased participation, especially among respondents who lived in remote areas and lacked transportation.

Secondly, because the Delphi method does not call for face-to-face discussion, it allowed information on sustainability indicators to be considered by the respondent, without outside influence. Through this process, baseline information from respondents was acquired as a pioneering study.

Finally, the level of participation in the Delphi method generated sustainability information from varied perspectives. Based on the data acquired, diverse elements of sustainability development were identified. Therefore, this study resulted in a comprehensive suite of sustainability-indicator measurements. As a result, a viable and quality set of indicators was formed. Table 4 illustrates that the set of indicators comprised more extensive measurement components, including social stability, culture, economic strength, environment, and infrastructure accessibility .

Despite all the advantages of this study, limitations to the approach could not be avoided in the development design. The Delphi approach effectiveness remains subject to the respondent's ability to provide independent responses. The low education levels and exposure to external development by some study participants resulted in responses limited by knowledge and experience. This unintentionally influenced the nature of the indicator set developed by the study; it is more suitable for local use and issues. Exclusive to this limitation, the methodology does not require scientific measurement or utilisation of specific tools. For example, Table 4 shows that many of the indicators related to biological sustainability measurements in the rice-production sector are not listed. Integrated pest and nutrient management, and soil erosion are not in the newly-developed indicators list. Furthermore, the indicator-development process using the Delphi method is time-consuming. The Delphi study is conducted in more than one response round, and is subject to the speed of responses, and the commitment of respondents. Processing Delphi respondent data was also time-consuming. This was due to overlapping data, which required filtering, before it was presented for the subsequent round.

Conclusion

This study resulted in the participation and subsequent integration of responses by local residents and experts in the successful establishment of a set of indicators to measure and monitor the sustainable development of rice-production areas in Sabah, Malaysia. The set of indicators identified several major sustainable-development problems in the study areas i.e., Kesapang, Sangkir, Seronsob, and Longob. This enables the agricultural and policy-making departments to plan short- and long-term practical management actions towards sustainable development, and the capacity to monitor progress.

Developing sustainability indicators for this study provided three vital learning experiences. First, the process of generating indicators from a broad range of participants was challenging. However, it was invaluable in garnering a large body of information on potential sustainability indicators. The various elements of sustainable development identified, and the set of indicators measured from the resulting process were deemed comprehensive. Second, the range of participation included in this study is a viable alternative to integrating a bottom-up and top-down approach. Local participation ensures community-level priorities are addressed, and local professional participation completes the sustainability-indicator development process. Third, utilisation of the Delphi method to generate indicator information ensures a balanced approach when local residents and professionals are vital to the process, and therefore, the resulting indicator set encompasses the views and opinions of both parties.

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