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Exploratory Review of Ecological Indicators in Oil Palm Cultivation

Mohd Murshid Amir [+], Nor Zalina Harun, and Khalilah Zakariya

Department of Landscape Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Kuala Lumpur, Malaysia

Abstract. Over the past 50 years, oil palm has become an important major crop in the agricultural sector in Southeast Asia. Its expansion is widely distributed in countries such as Malaysia, Indonesia, Thailand and Vietnam. This phenomenon is response to the large increase in the world demand for vegetable oils and biofuel needs, which is expected to double by 2020. Oil palm industry can be seen as one of the key factors to contribute in establishing the economic that largely benefits major holders like estates companies and smallholders in rural areas. However, aside from the positive impacts of socioeconomic growth, rapid expansion of the oil palm industry has brought negative impacts to the environment particularly in the air, water, land, soil, habitat, biodiversity and landscape pattern. Through monocultures practices within the plantation, a lot of chemical fertilizers and pesticides are used, which contribute to a dramatic change of the environment that affect climate and human health. The effects of oil palm have been broadly discussed in Asia particularly pertaining social and environmental issues. Methods to assess the sustainability of oil palm cultivation to promote balance in the ecosystem that might loss during the conversion is still vague. Previous studies have researched on measuring the sustainability of oil palm cultivation through the development of indicators. However, there are still gaps in identifying the dimensions and levels of the relevant indicators. The indicators should be developed by referring to the present socioeconomic and ecological situation. Development of ecological indicators is important component in the sustainability of oil palm cultivation. This paper reviews the basic concepts of the current development of ecological indicators in oil palm cultivation through identifying relevant indicators and challenges for development and implementing the indicators.

Keyword: ecological indicator, oil palm cultivation, environmental impact

1. Introduction

In recent years, there has been an increasing interest in identifying and refining ecological indicators as tool to manage the sustainability of agricultural practices. Ecological indicators, be regarded as a resource management tool (Dale and Beyeler, 2001) as they are designed to assess processes and product that have value to people (National Research Council, 2000). The indicators are developed to meet the purpose of achieving sustainable agricultural practices that primarily focus on three main goals: economic profitability, environmental stewardship and social responsibility (Keating and Jacobson, 2012). Sustainability in agriculture often involves a complex concept, where numbers of research have been conducted to measure its sustainability. However, the basic viewpoint of its dimension is still unclear (Hayati et al., 2010). The most common method used to measure sustainability is by using indicators. This is an important tool to assess the sustainability of agricultural systems but it is not suitable for the assessment of new land use options without a guiding framework (Pearce et al. 1989). Schiller (2001), pointed that ecological indicators are important assessment to assess the condition of ecosystem developed by scientist. This view is supported by Niemi et al. (2002) where ecological indicator has an ability to detect anthropogenic change against background variability. Several attempts have been made to define ecological indicators, among them is "to assess the condition of the environment, to provide an early warning signal of changes in the environment, or to

[+] Corresponding author Tel.: +60176948500
E-mail address: bohemiian_84@yahoo.com

diagnose the cause of an environmental problem" (Dale and Beyeler, 2001). Ecological indicators can be best described as a complete system, that provide information about the presence of each species, populations, communities and the existence of ecological processes at the appropriate measurement (Angermeier and Karr, 1991).

In oil palm industry, development of ecological indicators can act as monitoring tools to assess the sustainability within the plantation (Smith et al., 2001). The set of indicators is developed to support the sustainability principles and criteria that have been set out in the agricultural practices (Caliman et al., 2001; Smith et al., 2001; Rodrigues et al., 2010). As oil palm expansion has brought many negative impacts socially and environmentally through the loss of biodiversity, it needs to promote a more balanced social-environmental development. Ecological indicator would be one of sustainability elements that can act as a monitoring tool to mitigate the negative impacts in oil palm cultivation. In 2004, Round Table on Sustainable Palm Oil (RSPO), an International Multi Stakeholder Organization Certification Scheme for Sustainable Palm Oil has implemented Principles, Criteria and Indicators (PC&I) for sustainable oil palm (Rodrigues et al. 2010). However, in the process to develop the indicators, it dealt with different conceptual frameworks that primarily work as the individual indicators for certain areas only (Niemjer and Groot, 2006). Furthermore, most of the developed ecological indicators are applicable at aggregate level and cannot be used at a farm- scale level (Hayati et al., 2010). As described by Nelson et al., (2010) the development of an indicator for oil palm must take account all the growers, including the smallholders. The indicators must relate and applicable to methods that farmers or smallholders can easily practice (Smith et al., 2001). The aim of this paper is to review the development of ecological indicators in oil palm cultivation. This includes identifying the existing ecological indicators used in agriculture to gain information about measuring oil palm sustainability which can be adapted to outline key indicators for oil palm cultivation in the future.

1.2. Ecological Indicators for Sustainable Agriculture

The sustainable dimensions commonly used to measure farm performance are environmental, economic and social dimensions. As the focus of this study is to review the environmental or ecological aspects, the list of policy category for the indicators can be divided into soil, water, air, natural resource base, nutrient, biodiversity and agro-ecological management (Sydorovych and Wossink, 2008; Dantsis et al., 2010). In the last 10 years, the interest in sustainable agricultural development has drawn to the development of several sets of ecological indicators and numbers of framework and method that have been used as a tool to derive ecological indicators (see Table 1).

Table 1 : Framework to derive ecological indicators

Organization / Bodies / Author	Framework
Organisation for Economic Co-operative Development (OECD)	Drive – State – Response (DSR)
European Environmental Agency	Drive – Pressure – State - Impact – Response (DPSIR)
David et al. (2006)	eDPSIR + Causal Network
Environmental Protection Agency	Conceptual Model of Cause and Effect Relationship
United States Environmental Protection Agency	Conceptual Relevance – Feasibility of Implementation – Response Variability – Interpretation and Application

1.3. Measuring Oil Palm Sustainability

Measuring sustainability in oil palm cultivation for sustainable agricultural practice is essential as it brings beneficial and harmful impacts. Basiron (2007), highlighted the need to have a more sustainable oil palm plantation encouraged the establishment of the Round Table on Sustainable Palm Oil (RSPO) in 2004, which has drawn interest among Malaysian plantations. Nelson et al. (2010), found that RSPO has provided a set of principles and criteria for sustainable oil palm practices that encompass the legal, economic, environmental and social needs to produce sustainable palm oil. In 2011, United Nation of Environmental Protection (UNEP) pointed out few sustainable programs and strategies for oil palm plantations among them are sustainable certification systems by RSPO in 2007, REDD+ program, Palm Oil Timber Carbon Offset (POTICO) and application of remote sensing for monitoring programs. As these tools are applicable to oil

palm cultivation, they can guide a more practical and effective management and mitigation tools in oil palm plantation.

Edwards et al. (2012), has reviewed that Nestle and Unilever is supporting on the initiatives of Greenpeace campaigns to boycott the use of unsustainably produced agricultural products from their supply chain. One of the best efforts taken by Unilever to support sustainable agriculture within oil palm plantations is by providing a good agricultural practice guideline by using the sustainable agriculture indicators assessment. The Unilever system comprises 10 indicators: soil fertility and health, soil loss, nutrients, pest management, biodiversity, value nutrients, water, local economy, social and human capital. Smith et al. (2001) in his study in agri-biodiversity indicators for Unilever sustainable initiative claims that the indicators that have been developed are different from those appropriate to an Organization of Economic and Co-operative Development (OECD) program because it only relates more easily to geographical regions or political units. Previous studies have found that there are several systems in ecological indicator currently in use or being developed for oil palm, including the Unilever system (Pretty et al. 2008) and the INDIGO system of the institute National de la Recherche Agronomique (INRA), which is being developed for oil palm by PT SMART and other collaborators (Calliman et al. 2005, 2006; Girardin et al. 2007). The INDIGO method is based on a matrix that crosses agricultural practices and the components of the agro-ecosystem.

2. Ecological Indicators for Environmental Sustainability in Oil Palm Cultivation

Recent literatures have found contradictory findings about oil palm expansion, Sayer et al. (2012), reported that it has become a greater debate between environmentalist and oil palm developer but there is still no clear evidence to support these and yet reviewed that oil palm has significant environmental attributes over its full life cycle. This view is supported by Malaysian Oil Palm Council (2006) in a published paper that described "the oil palm is a true friend of the earth". However, a number of studies has found that oil palm cultivation has brought a lot of negative impacts specifically on environmental degradation, where its expansion gives a tremendous effect to the loss of biodiversity (Yaap et al., 2009; Lord and Clay, 2010; Ritcher, 2009; Abdullah and Nakagoshi, 2008; Arhem, 2011). All the studies reviewed so far, delineated that it is a major challenge to stop oil palm plantation due to its contribution to economic growth for tropical countries (Arhem, 2011). Realizing that the production of biofuels by oil palm can mitigate fossil fuel anthropogenic carbon emissions (Danielson et al., 2008), a more comprehensive study of environmental and scientific research is important to strengthen its value in biodiversity and shaping its development to control the impacts (Yaap et al. 2009; Sayer et al., 2012).

One question that needs to be asked is whether a quest to develop and propose environmental sustainability indicators in oil palm cultivation meets the purpose? Nelson et al. (2010) claimed that it is important to review the purpose and requirements of indicators. In 2010, Rodrigues et al. reported on an assessment tool and integrated index for sustainable oil palm production that discusses efforts made by stakeholders after the establishment of RSPO in 2004. There has been a kick-start to a movement of developing agro-ecological and socio-environmental indicators for a sustainable oil palm production. These sets of indicators are integrated with the Principles, Criteria and Indicators (PC&I) by RSPO with an appropriate quantitative measurement to provide an easily applicable assessment system for producers.

2.1. Current Development of Ecological Indicator in Oil Palm Cultivation

Recent developments in the field of agricultural sustainability have led to a renewed interest in the efforts of developing ecological indicators for oil palm cultivation and have drawn interest among the responsible stakeholders. Table 2 below shows the current development of ecological indicators.

3. Challenges in the Development and Implementing Ecological Indicators

There has been little discussion about the challenges of implementing ecological indicators for sustainability assessment in agriculture. In an investigation into the development of ecological indicators, the key points of challenges can be summarised and classified into purpose of the indicators, spatial, temporal, assessment, scientific and detailed information, framework and method of developing indicators, reliability, participation of stakeholder and appropriateness of indicators (See Table 3).

Table 2 : Current ecological indicators developed by oil palm stakeholders

Criteria	Indicator	Organisation/Bodies/Author
Soil	Soil organic matter	APOIA-Oil Palm (Rodrigues et al.,2010) ; Malaysian Palm Oil Board (MPOB)
	pH	
	Phosphate	
	Exchangeable Kalium	
	Exchangeable Magnesium	
	Potential acidity	
	Sum of bases	
	Cation exchange capacity (CEC)	
	Base saturation	
	Erosion	APOIA-Oil Palm (Rodrigues et al.,2010); Malaysian Palm Oil Board (MPOB); Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.)
	Soil fertility	UNILEVER (Smith et al., 2001)
	Soil loss	ACIAR (Nelson et al., 2010)
Water	Dissolved oxygen	APOIA-Oil Palm (Rodrigues et al.,2010) ; Malaysian Palm Oil Board (MPOB)
	Fecal coliform	
	BOD	
	pH	
	Nitrate	
	Phosphate	
	Turbidity	
	Cholophyll	
	Conductivity	
	Visual water pollution	
	Pesticides potential impact	
	Groundwater	
	Health of aquatic ecosystem	ACIAR (Nelson et al., 2010)
	Water resources	Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.); UNILEVER (Smith et al., 2001)
	Eutrophication of aquatic environment	Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.)
	Quality of water	Malaysian Palm Oil Board (MPOB)
	Supply of water	
	Water harvesting	
Air	Particulates/smoke	APOIA-Oil Palm (Rodrigues et al.,2010); Malaysian Palm Oil Board (MPOB)
	Odor	
	Noise	
	Carbon oxide/hydrocarbon emissions	
	Nitrogen oxide emissions	
	Air quality and emissions	Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.)
Biodiversity	Genetic diversity	UNILEVER (Smith et al. 2001)
	Species diversity	
	Ecosystem diversity	
	Natural habitat physiognomy and status	APOIA-Oil Palm (Rodrigues et al.,2010)
	Preservation of high conservation value habitats	
	Ecological corridors	
	Degraded areas reclamation	
	Extinction risk of ecologically relevant species	
	Loss of critical natural habitats	Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.)
	Forest fragmentation	
	Over exploitation of natural resources	
	Wildlife and biodiversity	Malaysian Palm Oil Board (MPOB)
Nutrient	Nitrogen	French Agriculture Research Organisation (CIRAD) (Caliman et al.)
	Fertilizer and nutrient management	Malaysian Palm Oil Board (MPOB)
Pesticides	Pest management	UNILEVER (Smith et al., 2001)
	Pesticides use	French Agriculture Research Organisation (CIRAD) (Caliman et al.); Malaysian Palm Oil Council (MPOC) and Wild Asia (Bakewell et al.)
Landscape	Landscape diversity	APOIA-Oil Palm (Rodrigues et al.,2010)

Such explanations tend to overlook the fact that indicators are essential to measure whether an agriculture system is striving towards sustainability or away from it. Indicators act as a tool for stakeholders to measure sustainability in their agriculture practices (Hayati et al. 2010). The challenges described above would help other researchers or stakeholders in the development and implementation process of ecological indicators in the future.

Table 3 : Issues and challenges in developing and implementing ecological indicators

Authors	Issues and Challenges	Key Points
Bates S. and Scarlett L. (2013)	Inadequate information to monitored and unreliable measurement procedure because of different purpose and application.	Scientific and detailed information
	Absence in involvement of farmers or small scale can caused in deficiency of information.	
	No specific measurement as the selection vary on different purpose of indicators.	Appropriateness of indicators
	Different purpose of indicators may leads to lack of specific monitoring and modelling programs to assess the indicators.	Purpose of indicators
	Inconsistencies of indicators in different level restrict it expediency (farm, plantation and regional scale)	Implementation and assessment of indicators
Roy R., Chan N. W. and Rainis R. (2013)	Lack in term of suitable framework in developing the indicators.	Framework and method to develop indicators
	Less involvement of multi – disciplinary group in project activities.	Participations of stakeholder
	Less number of developed indicators at the community level	
	Lack of the sense of multi stakeholders participations.	
Rombouts I. et al. (2013)	Characterizing the features of ecological in an objective way	Purpose of indicators
	Inadequacies of historic data to examine long term trends	Scientific and detailed information
	Separating natural fluctuations in the systems from long term trends	Framework and method of developing indicators
	Lack of appropriate analytical methods	
Valtyniova S. and Kren J. (2011)	Keep and analyse data not only on the level of farm, but also at individual plots	Spatial
	Adjust required input data to standard records available farm	Framework and method of developing indicators
	Clear interpretations of indicators	
Ruiz R. et al. (2011)	Difficulties in obtaining data or information	Scientific and detailed information
Hayati D., Ranjbar Z. and Karami E. (2010)	Recent available indicators are not interrelated between the sustainability component due to validity of assessment.	Temporal
	Short term strategies for sustainability, indicators (5-10 years).	
	Different indicators at different location or situation.	Spatial
	Current indicators are not particularly useful for farmers	Reliability
Zahm F., Viaux P., Vilain L., Girardin P. and Mouchet C. (2008)	Need to adapt the method to local context and specific agriculture	Framework and method to develop indicators
	The need to adapt the framework to the specific aspects of the farms	
	Detailed study of the relation of each environmental issues at different farm to get a precise data.	Scientific and detailed information
Niemeijer D. and Groot R.S. (2008)	Method of choosing right indicators often inadequate in term of system.	Framework and method to develop indicators
	Often depending on criteria applied to individuals indicators, do not include criteria pertaining to the inter-relation of selected indicators	
Tailliez B., Calliman J.P., Verwilghen A. and Omont H. (2006)	Less participation of farmers in developing indicators to get detail information.	Participation of stakeholder

4. Conclusion

In a broader context, ecological indicators can be implemented for many purposes to act as mitigation tools in environmental management of agricultural cultivation. Indicators help to minimize the impacts of environmental problems and provide opportunities to improve the conditions. Establishment of ecological indicators can provide strong framework for policy and offer option for decision making. Ultimately, a suitable set of indicators can encourages public participation involvement, as oil palm cultivation involves a lot of stakeholders from a variety background including smallholders. It has been shown that the development of indicators for oil palm sustainability is increasing rapidly. Future development of ecological

indicators in oil palm cultivation should encourage participation among all oil palm growers from small-scale to large-scale plantations. However, the effectiveness in identifying the ecological indicators lies upon its framework as it involves detailed ecological studies to provide measurement for sustainability. The system in ecological indicators should cater the sociocultural and economic dimensions applicable to be implemented. This exploratory review has found that among the key challenges in identifying suitable indicators are, purpose of the indicators, spatial, temporal, assessment, scientific and detailed information, framework and method of developing indicators, reliability, participation of stakeholder and appropriateness of indicators. In conclusion, there is still room for improvement in developing ecological indicators towards the sustainability of oil palm cultivation within the plantation area.

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