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Research Article

A Community-Based Qualitative Vulnerability Assessment Tools for Rivers in Developing Participatory Response to Land-Use Changes

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Abstract

Vulnerability assessment is the process of identifying areas at risks to threats and developing strategies to reduce the impact of these threats. A wide array of vulnerability assessment tools is present to assess rivers for different hazards. However, there is no particular tool to assess the vulnerability of rivers to changing land-use. There are a few existing assessing frameworks for rivers use top-down approaches which require a large pool of data and highly trained experts. The output of this paper is a new river vulnerability assessment tool (RVAT) that assesses the impacts of changing land-use towards the health and socioeconomic value of the aquatic environment as well as the livelihood of the communities. RVAT comprises a total of 23 criteria, with a conceptual framework and rubrics to assess the river environment, economic and social factors affected by land-use change. This tool was tested and validated in two river systems (Maludam River and Simunjan River) with results showing >0.8 reliability and significant correlation between the criteria. RVAT was able to capture and compare vulnerability in both rivers with minimal data collection efforts. The verbal and visual data needed for the assessment such as types of erosion, water condition and perception on river condition enable the community to assess their rivers thus opening opportunities for the application of citizen science.

Keywords: Anthropogenic Land-Use Change; Socio-Economic Criteria; Cross-Tabulation Method; Vulnerability Components

1. Introduction

Rivers play an essential role by providing both ecological and economic importance as they support the livelihoods of a variety of plants and animals as well as serving areas for human settlements and human activities. However, river conditions have worsened over the years due to disturbances such as organic and nutrient pollution and physical alterations and land-use (Feio et al., 2014). Disturbances in a river system refer to events that cause the system to structurally or functionally decline at either ecosystem, community or population level (Sparks et al., 1990).

Land-use denotes the way human utilises land according to the purpose it serves (agricultural, commercial, residential, transportation) and is mainly driven by population growth and the needs to accommodate to this growing population (Dale et al., 2000; Meyer & Turner, 1992; Rendana et al., 2015). Urban development and agricultural use such as large-scale farming and massive cropland expansion lead to the most changes in land-use (Bouma et al., 1998; Goldewijk, 2001; Ramankutty et al., 2002). In Sarawak, the expansion of oil palm plantations has come at the expense of losing vast areas of peat swamp forests in the state.

The negative impacts of land-use on socio-economy and the environment must be considered, although multiple benefits are gained from it (DeFries & Eshleman, 2004; Turner et al., 2007). The alteration of global land cover coupled with poor land management affects environmental conditions including the aquatic environment, soil condition and water flow. Hydrological and morphological changes caused by land-use and increasing agricultural land further increase the nutrients, pesticides and sediment input into the river system and deteriorates water quality (Bu et al., 2014; Feio et al., 2014; Sponseller et al., 2001). Other impacts include significant alterations to the communities socioeconomically and dominating agricultural landscapes instead of natural landscapes (Abdullah & Hezri, 2008; Don et al., 2011; Fearnside, 2000). Livelihoods of the local community are jeopardised, with increasing land conflicts and resettlement of local communities due to changes in ecosystem services, flood risks and land subsidence particularly in the peats (Colchester, 2011), along with the predicted decline of the global average species richness by 3.4% in the next 100 years if there are no interventions in land-use practice (Newbold et al., 2015). Effects of land-use towards rivers may vary spatially and temporally, depending on the scale of the river (Allan, 2004). Land-use changes are two-edged, bringing both advantages and disadvantages back to its drivers. The disadvantages can be overcome by conducting assessments to find the balance

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between human needs and the capacity of the ecosystem to cater to these needs (Defries et al., 2004), hence the need to monitor the vulnerability of rivers in response to land-use changes aforementioned.

Vulnerability is a term that was initially used in natural hazards and is now extensively used in numerous research disciplines especially natural and social sciences (Birkmann, 2013; Füssel, 2007; Roberts et al., 2009). White (1974) defines vulnerability as “the degree to which a system, sub-system, or component is likely to experience harm due to exposure to a hazard, either a perturbation or stress.” UNEP (2002) defines vulnerability as “the interface between exposure to the physical threats to human well-being and the capacity of the people and communities to cope with those threats,” which suits the context of this paper. Other researchers have contributed to the various definition of vulnerability and unanimously agree that the definition differs based on the context of use (Birkmann & Fernando, 2008; Eakin & Luers, 2006; Kasperson et al., 2005).

Researchers from different backgrounds have tried bridging the gap to produce multidisciplinary indices and tools to combine natural science with social science. This resulted in social vulnerability tools in response to hazards. Vulnerability assessment enables the identification of areas or resources at risk, types of threats posed, development of plans and strategies to reduce the impacts based on the type and severity of it which allows proper planning and implementation of adaptive measures to reduce vulnerability (Berry et al., 2006; Füssel & Klein, 2006; Hammill et al., 2013; Hay & Mimura, 2006). Normally, assessments of these hazards require a clear conceptual framework with most approaches focusing on three vulnerability components which are exposure, sensitivity and adaptive capacity. Exposure and sensitivity determine the potential impacts of hazards while potential impact coupled with adaptive capacity determines the overall vulnerability (MERF, 2013). Also, there is no unique method to assess vulnerability as these tasks are subject to specific aims as well as influences from various factors including social, economic and environmental factors to be considered.

As of now, the existing assessment tools to determine the vulnerability of rivers are only present for hazards like climate change (Aleksanyan et al., 2015; Peiying et al., 1999; Roy & Inamdar, 2014), water scarcity (Men & Liu, 2018), erosion (Khan, 2012; Saini et al., 2015) and floods (Moazzam et al., 2018, Zeleňáková et al., 2018). There are also tools covering various threats to the freshwater system which include resource stresses, development pressures and management challenges (Babel & Wahid, 2013). These tools are mostly large-scale, complex and data-intensive. Pinto and Maheshwari (2011) stated that the assessment of river health yields a large volume of data that is expensive in terms of collection and storage. Plummer et al. (2012) conducted a review on 50 water vulnerability assessment tools and found that only seven tools are applied at small local scale while the remaining tools are for regional and national application. Hence, this paper serves to introduce a new river vulnerability assessment tool (RVAT) that assesses the impacts of changing land-use brought upon by deforestation for oil palm plantations and commercial cropping towards the health and socioeconomic value of the aquatic environment as well as the livelihood of the communities.

2. Methodology

2.1. Study area

The creation of this tool along with the testing for validity and reliability is based on two sites of apparent different levels of disturbances which are the pristine Maludam River and the anthropogenically influenced Simunjan River (

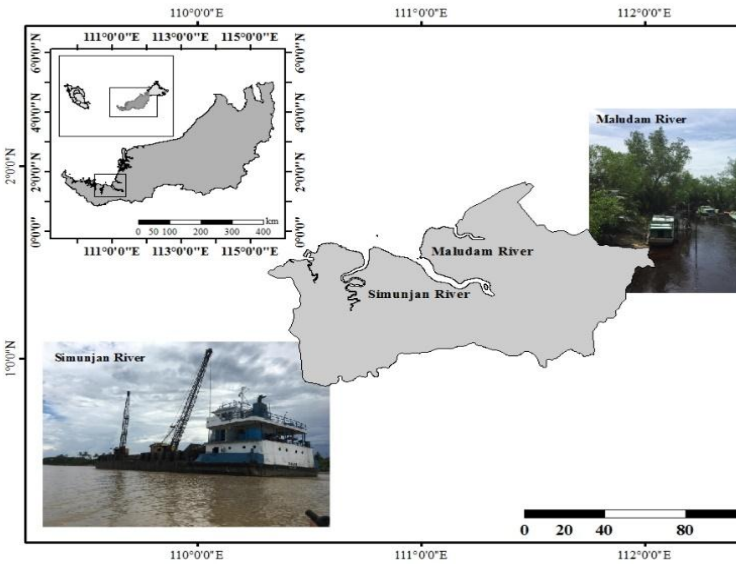


Fig. ***1***).

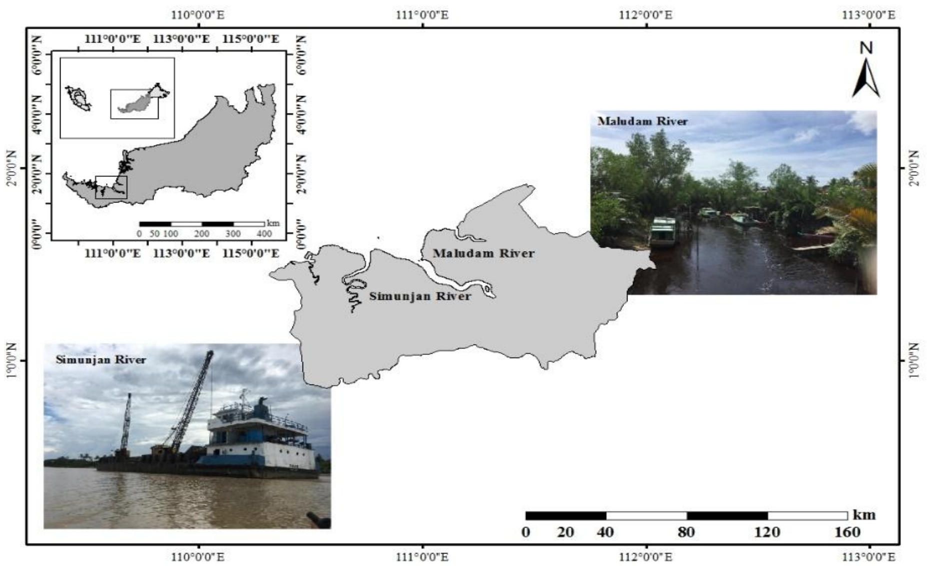
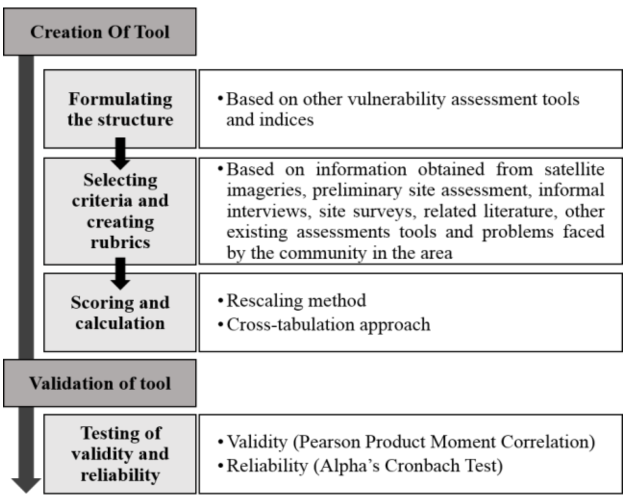


Fig. **1.** The map of Malaysia (inset) with the enlarged study area which covers Maludam River and Simunjan River

Maludam (1° 39’ 0’’ N 111° 02’ 0’’ E) is a sub-district in Betong Division in Sarawak and is situated between Batang Lupar and Batang Saribas. Located approximately 78 kilometres from the capital city of Sarawak, it is considered one of the most isolated regions in the state. Maludam is the largest peat dome in northern Borneo and the Forest Department of Sarawak recognizes that this area is subjected to various threats, hence the gazette of the peat swamp forest as a totally protected area in May 2000. The river system of 7.66 km runs through the peat of the size 43, 147 ha and houses approximately 5,000 villagers downstream of the river.



Simunjan (1° 23’ 0’’ N 110° 45’ 0’’ E) is a small district under the administration of Samarahan Division in Sarawak. It is situated around 51 kilometres of the southeast of Kuching. The district covers an area of 2,218 km^2 and has several small towns under its administration. This district holds a total population of 39,226 according to the last census conducted in 2010. The river system branches out into Simunjan Kanan and Simunjan Kiri.

2.2. Creation and Validation of Tool

Steps involved in the creation and validation of the tool are as illustrated in
Fig. *2*.

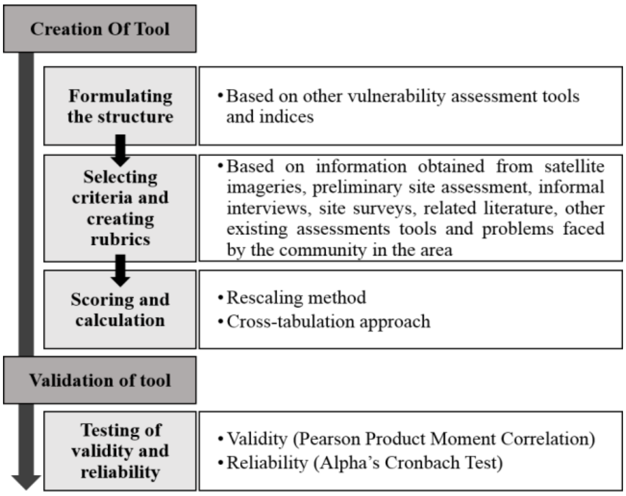


Fig. 2. Steps involved in the creation and validation of RVAT

2.2.1. Creation of tool

The tool's structure was formulated based on the structure of existing vulnerability assessment tools and indices (IPCC, 1991; Mamauag et al., 2013; MERF, 2013). Next, criteria for the tool were chosen and rubrics were created using information gathered from satellite imageries, preliminary site assessment, informal interviews and site surveys. Information was also gathered from related literature and other existing assessment tools (Abidin et al., 2017; de Groot, 2009; Khan, 2012; Lee, 2009; Peiying et al., 1999). Preliminary site assessment was conducted via Sarawak Geoportal of the Bruno Manser Fund (http://www.bmfmaps.ch/EN/composer/#maps/1001) using the filters provided on the portal to view changes in areas in terms of land cover, oil palm plantations, logging roads, deforestation and human settlements from the 1960s up to 2010 and Google Earth using the time slider feature to view the land-use changes. Site surveys were conducted by foot and car within 5-10 km radius from the town area while the boat survey was conducted along the river. Areas surveyed include areas resided by the villagers, plantations, farms, towns and rivers to observe the livelihood of communities in the study area. Necessary site information was gathered during the surveys while confirming the land-use in the target areas as viewed during preliminary site assessment. Focus group discussions were conducted between three groups of land-users (6-8 people per group) to obtain information from personal witnesses to the actual scenario on activities occurring in the surrounding area and changes in the river conditions in recent years. Feedback was collected using open-ended questions to obtain a general characteristic of the area and gain a comprehensive understanding of the issues faced by the community in response to changing land-use. All information gathered from the different sources were used to optimise the choice of criteria assessed as well as the rubrics of the tool. Next, careful examination of existing assessment tools was done to create the components for the assessment tool. The definitions for the vulnerability components (exposure, sensitivity and adaptive capacity) were created based on the base definition of vulnerability components developed by IPCC (2001) and the information gathered from both sites. The third step of creating the tool is selecting the scoring and calculation method. All information was divided into 3-tier 5-point classes that specify the quality level for the criteria in each vulnerability component. Scores for each criterion are normalised using the rescaling method. The cross-tabulation method (Samson, as cited in MERF, 2013) is employed to calculate the degree of vulnerability. This method is employed in existing coastal vulnerability assessment tools among which include Coastal Integrity Vulnerability Assessment Tool (CIVAT) and Tools for Understanding Resilience of Fisheries (TURF) (MERF, 2013).

2.2.2. Validation of tool

The tool was tested in the both Maludam River and Simunjan River with ten stations each. Stations selected represented the different land-use observed from preliminary site surveys, satellite images and interviews conducted with the community. On-site, scores for all criteria were given based on the rubrics (refer to Supplementary Information). All scores were entered into SPSS. Validity was tested using Pearson Product Moment Correlation while intraclass reliability was tested using Alpha's Cronbach Test.

3. Results

3.1. Conceptual framework of RVAT

Fig. 3 depicts the conceptual framework of the developed RVAT. This tool aims to qualitatively measure the degree of vulnerability of rivers in response to changing land-use. The conceptual framework contains the definition and relationship between the three vulnerability components along with methods for data collection. When assessed together, exposure and sensitivity can determine the potential impact of the changing land-use towards the river. Once the potential impact has been determined, it will then be assessed together with adaptive capacity to determine vulnerability.

Exposure includes all contributing factors which put rivers into a vulnerable state. The sensitivity component in this tool measures how the river system's and communities' present state respond to the exposure components. The adaptive capacity component refers to how the affected parties adjust themselves to the impacts brought upon by land-use change and include criteria which allow both the river system and communities to tackle the problems caused by changing land-use.

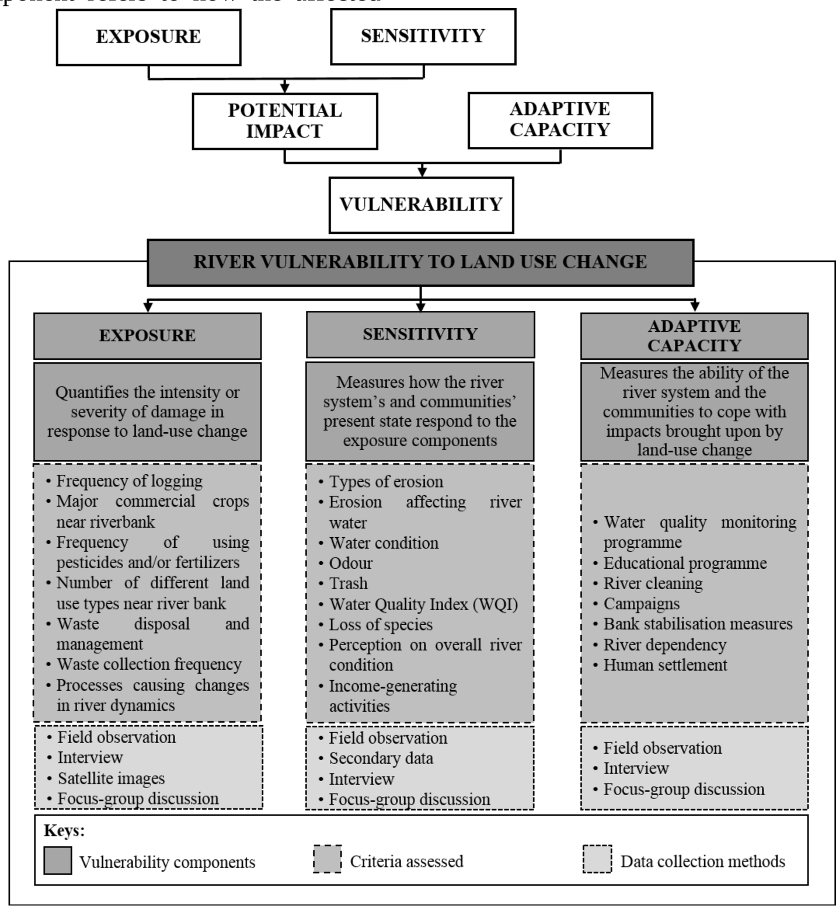


Fig. 3. The conceptual framework of RVAT

Scorings for all components are either done through field observation, satellite images, water quality assessment, or through interviews and focus-group discussion conducted with the communities.

3.2. Validity and reliability test

Results obtained from the testing of the tool's validity for the exposure (Most of the sensitivity criteria noted in this study are significantly correlated with one another showing r values ranging from 0.46 to 0.99. Erosion shows significant correlation at $p \leq 0.01$ with five other criteria reporting r values from 0.61 to 0.99. At $p<0.05$, the second criteria noted a significant correlation with r values varying between 0.68 to 0.85. Similarly, water condition criteria showed a positive significant coefficient when interpolated against the following factors with the r values up to 0.89. The weakest r values (0.46 and 0.54) were from trash correlated against odour and loss of species. Meanwhile, loss of species is positively correlated with income-generating activities (r=0.74).

Table 1), sensitivity (Table 2) and adaptive capacity (Table 3) components are as follows.

Major commercial crops near the riverbank were positively and significantly correlated ($p \leq 0.05$) with the other exposure components reporting r values varying between 0.51 to 0.82. The number of different land-use types near riverbank also shows significant correlation ($p \leq 0.01$) with the fifth and sixth exposure component with r = 0.66 and r = 0.72, respectively. Both waste-related components show a positive correlation ($p \leq 0.05$) with a value of 0.73.

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Table 1.
Correlation between the 7 exposure criteria

Criteria	1	2	3	4	5	6	7
Frequency of logging	1	-					
Major commercial crops near riverbank	-.43	1	-				
Frequency of using pesticides and/or fertilizers	.31	.51*	1	-			
Number of different land-use types near riverbank	-.23	.82**	.33	1	-		
Waste disposal and management	-.08	.61**	.46*	.66**	1	-	
Waste collection frequency	-.28	.62**	.07	.72**	.73**	1	-
Processes causing changes in river dynamics	-.03	.60**	.63**	.56*	.36	.21	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 2.
Correlation between the 9 sensitivity criteria

Criteria	1	2	3	4	5	6	7	8	9
Types of erosion	1	-							
Erosion affecting river water	.99**	1	-						
Water condition	.78**	.85**	1	-					
Odour	.66**	.71**	.84**	1	-				
Trash	.35	.30	.27	.46*	1	-			
Loss of species	.05	.00	.00	-.02	.54*	1	-		
Perception of overall river condition	.61**	.68**	.81**	.66**	.39	.29	1	-	
Income-generating activities	.43	.43	.41	.33	.41	.74**	.38	1	-
Water Quality Index (WQI)	.72**	.82**	.89**	.72**	.04	-.17	.78**	.30	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

For the adaptive capacity components, all six criteria except for water quality monitoring are positively correlated ($p \leq 0.01$) with each other. The pair of criterions which show high correlation values include river dependency and human settlement (r = 0.99), river cleaning and campaigns (r = 0.97), educational programme and human settlement (r = 0.95); and educational programme and river dependency (r = 0.94).

Table 3.
Correlation between the 7 adaptive capacity criteria

Criteria	1	2	3	4	5	6	7
Educational programme	1	-					
River cleaning	.84**	1	-				
Campaigns	.77**	.97**	1	-			
Bank stabilisation measures	.65**	.84**	.85**	1	-		
River dependency	.94**	.77**	.74**	.73**	1	-	
Human settlement	.95**	.79**	.73**	.71**	.99**	1	-
Water quality monitoring	-.40	-.65**	-.58**	-.75**	-.55*	-.58**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Results obtained from the testing of the tool's reliability are as shown in Table 4. Exposure, sensitivity and adaptive capacity components achieved intraclass reliability of 0.818, 0.880 and 0.846 respectively.

Table 4.
Cronbach's Alpha value for the final criteria for all three vulnerability components

Component	Intraclass Reliability
Exposure	0.818
Sensitivity	0.880
Adaptive capacity	0.846

4. Discussion

The River Vulnerability Assessment Tool (RVAT) created in this study was developed by acquiring vast information from various sources to identify real issues faced by the community in the pristine areas of Maludam and the anthropogenically influenced rivers of Simunjan. All information obtained to develop the tool was then established into a set of functional rubrics that can capture and represent vulnerability in the context explained beforehand.

Preliminary site assessment revealed the drastic changes in land-use and land cover over the past years in both sites. The use of satellite imageries to assess sites beforehand is both cost and time-saving. Information obtained from site surveys confirmed the characteristics of the sites obtained from the preliminary assessment. Facts and information on issues faced by the communities were obtained through focus group discussions and questionnaire surveys conducted among key informants including farmers and fishermen who were affected by the changing land-use. The questionnaire issued among respondents allows for easier summarization of the overall condition of the sites (Hague, 1993). Aside from forming a background story based on historical information to help illustrate the condition faced by the communities at the site of interest (López-Valencia. 2019), these methods allow the researcher to understand at ground level the problems occurring in the community.

Methods based on community interactions and ecological functions require an in-depth understanding of the community dynamics before a meaningful assessment of river system health is made (Pinto & Maheshwari, 2011). The development of this tool highly considers the participation of local communities. Therefore, engagement with local communities is one of the crucial points in designing this tool as they are directly affected by any changes occurring in their surrounding environment. Hence, the design of this tool enables the community to execute their own assessment. This is beneficial especially in areas where the users have restricted resources (Panthi, 2016). Involving the community in this process allows them to take part in finding their own solutions to suit the needs of their own area. The set of rubrics provided in this tool ensures fairness and reduces uncertainties during the assessment.

All information gathered from various sources were then used to confirm the characteristics of the sites and to set relevant levels for all the vulnerability component to optimise the tool. Most establishments of vulnerability indicator are done by selecting existing frameworks and methods since there are no standard methods to follow (Lee & Choi, 2019). Hence, the definition of the important vulnerability components of this tool is modified and adjusted from IPCC's definition to tailor the needs of this study. Similar to the tool's construction, data collection methods that are to be employed for the assessment require the assessor to do field observation and interviews with minimal effort. Vulnerability assessments should be feasible where data collection efforts are minimal but can capture all the important criteria required (Wamsley et al., 2015). This tool simplifies the assessment by evaluating most criteria qualitatively with results that reflect the actual problems at the site.

In this study, land-use change is driven upon the needs of the community to sustain their livelihoods, which is represented by the exposure components. These include logging, commercial cropping, use of pesticides and fertilizers which potentially cause impacts towards the current state of the river. Local conditions must be considered when choosing the exposure criteria as different sites may vary in terms of the effects due to different site characteristics (MERF, 2013). Also, it is important to note that community practices do have considerable impacts to vulnerability (Panthi, 2016).

The most important aspects captured in this study is the notable increase in the number of land-use as well as the utilisation of fertilisers and pesticides following the increasing land-use changes. The decrease in quality of land over the years contributes to lesser crop yields, hence the need to utilise fertilisers and pesticides. Burning of land contributes to soil degradation and decreases the soil's filtration ability, thus the increase in surface runoff which causes leach of nutrients from the soil surface and into rivers (Dailan, 2014). The increase in land-use change along with increasing population generates more municipal waste (Idris et al., 2004) which makes it important to assess waste disposal and management along with other exposure criteria.

For the sensitivity component, all nine criteria selected represents changes faced in response to ongoing land-use change and these changes may vary based on the scores obtained for exposure components. Types of erosion and how erosion affects river water are sensitivity criteria assessed in response to the frequency of logging and number of land-use which are exposure criteria. Clearing of land for oil palm plantations removes the vegetative cover and exposes the soil, causing it to be at risk of erosion. Erosion not only deteriorates soil and water but also causes environmental, ecologic and economic problems which highlight the need to protect both soil and water concurrently since they are interrelated (Fitzherbert et al., 2008; Pavlík et al., 2012). Sheet, rill and gully erosion (Abidin et al., 2017) will define the exposure level of the areas assessed. The inclusion of Water Quality Index (WQI) to represent the condition of the river is optional as this data is difficult to obtain from government agencies unless the assessor plans on conducting WQI on their own during the assessment on-site. The three sensitivity components assessed together (water condition, odour, trash) are direct observations made at the time of assessment. They are identifiable on-site, require minimal procedures and are not costly. These components are crucial as they are direct multi-sensory measures of the river condition, however, they are subjected to the assessor's judgment and interpretation. Visual assessments have been actively conducted since the 1990s mostly in the States. The Environmental Protection Agency (EPA) provides training and assessment manuals to conduct visual assessments for freshwater bodies including wetlands, estuaries, streams and lakes. The United States Department of Agriculture (USDA, 1998) developed the Stream Visual Assessment Protocol (SVAP) to assess the general quality of rivers and their riparian zones. These assessments are more comprehensive as they consider other contributing factors including macroinvertebrates' habitat and physicochemical water parameters. Although it is better to assess as many biological, chemical and physical water parameters, it defeats the purpose of allowing easy assessment for the communities. Testing various water parameters is time-consuming, costly and requires training. Along with the previous criteria mentioned, perception of overall river condition also has to be assessed to gauge the assessor's perspective on the state or condition of the river. Income-generating activities are significant measures of how severe land-use changes may affect the communities socioeconomically. Improper utilisation of land causes an impact on the vulnerability status of the existing socio-economic condition of the population (Sarthak et al., 2015).

For the adaptive capacity components, the criteria chosen are based on ways communities adapt to the changes and problems that arise due to changing land-use which include attention, efforts and intervention from stakeholders. In Sarawak, water quality monitoring conducted by Natural Resources and Environment Board (NREB) Sarawak through its River Water Quality Monitoring Program (RWQMP) may not cover several crucial points across the freshwater bodies. Most stations are only monitored on a quarterly basis with monitoring that was not conducted intensively. Educating the community on river and river management is crucial to expose them to more information aside from their existing indigenous knowledge on it. River cleaning or "gotong-royong" as the locals call is necessary to maintain the river cleanliness. Regular clean-ups not only give the community a sense of responsibility and ownership over their rivers but also contribute to cleaner, healthier rivers which in turn increases the quality of life. Conducting campaigns to raise awareness on current river issues are vital, although this may be costly and require actions from the authorities for more effective campaigns. Areas surrounding rivers will have higher adaptive capacity for the previous four criteria if they are conducted frequently with high participation, cooperation and willingness from both the communities and the authorities, hence showing good co-management. Bank stabilisation measures have been taken to reduce the risks of erosion and to strengthen the riverbanks. These measures consist of soft and hard stabilisation structures. Hard stabilisation structures include ripraps and retaining walls, while soft stabilisation structures are built through bioengineering (Garanaik & Sholtes, 2013). Higher adaptive capacity scores are to be given to soft stabilisation structures as they are less damaging to the river ecosystem as compared to the hard structures. River dependency is also a significant criterion to assess as this summarises to what extent the communities had to alter their livelihoods based on the changes in their rivers. Having other alternative water sources like tap water allows communities to not be strongly dependent on their rivers for daily consumption. The wide distribution of humans along the river indicate the communities' ability to adapt and adjust their current livelihoods based on the changes their rivers are facing and demonstrate high adaptive capacity. Raising of homes by adding stilts or adding piling may be costly but these are alternatives for the communities, so they do not lose their homes due to erosion and landslides. However, where safety is a major concern, shifting of settlements is the most ideal action to take as it is not worth the risk to continue settling themselves in areas that are likely to face the same hazard over and over.

All criteria presented in this tool are mutually exclusive between the components and do not equally contribute to vulnerability. When assessed together, all 23 criteria from the three components can piece together information to provide an estimation of the river vulnerability towards changing land-use. From the tests conducted on both river systems, this tool was able to give a general representation of the current state of vulnerability of the rivers. Of the ten stations in Simunjan, eight of it are highly vulnerable towards land-use changes. Sand dredging occurs very often in this area, along with oil palm plantations along the river system. Erosions are also observed in some parts of the river, which is then confirmed by the community whereby they had to be relocated due to the erosion. In Maludam, all stations had low vulnerability towards land-use changes. Although there are land-use changes in some stations, the high adaptive capacity in most stations was due to great cooperation among the small community. With a reliability of > 0.8 and a significant correlation between the criteria in the components, it thus signifies that the tool is reliable and requires little to no adjustment or calibration. The tool was able to demonstrate the different degrees of vulnerability and is generalisable to fit into other sites of interest.

However, this tool also had certain limitations. Improving the tool by assigning weightage to each criterion will increase reliability and accuracy. Some criteria may carry higher weightage compared to other criteria, e.g. frequency of logging should be assigned a higher weightage in comparison to the usage of pesticides and fertilisers. Some criteria may be mutually exclusive and do not equally contribute to vulnerability, thus requiring the tool to have a weighting factor. Future validation work must include more sites, stations and areas of clear differences in intensity of changing land-use. Further validation and development of this tool should also be done so it can increase the ability of this tool to be applied for more rivers for river management work.

5. Conclusion

This study offers a standard river vulnerability assessment tool which will function as a pioneering tool in Malaysia to assess the vulnerability of river systems in relation to land-use change. This tool is not data-intensive hence allowing it to be a base tool that can be adjusted and further improved as new discoveries are made as well as with further input from other experts in this field. Application of this tool can potentially pave ways for more assessments of river vulnerability in the country while also opening more opportunities for the application of citizen science. From these, more adaptive measures can be determined, planned and conducted to further improve river systems which are more vulnerable to the negative impacts of land-use change.

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Supplementary Information

RVAT Exposure | Assessment Form

Date : __ /__ /____
Location : Simunjan / Maludam
Assessor :

Instructions

1. Please score all variables.
2. Use the scoring criteria below to guide you during scoring.
3. Rescale all total scores into Low-Medium-High rating using the guideline provided.
4. For items 2 and 4, please refer to the guidelines attached to help in the scoring of criterion.

EXPOSURE CRITERIA	LOW (1-2)	MEDIUM (3-4)	HIGH (5)	SITE SCORES		
				1	2	3
Frequency of logging	None to occasional	Moderate to frequent	Very frequent			
Major commercial crops near riverbank	1-2 types	3-4 types	5 or more			
Frequency of using pesticides and/or fertilizers	Little to no use of pesticides and/or fertilizers	Moderate use of pesticides and/or fertilizers	Very frequent use of pesticides and/or fertilizers			
Number of different land-use types near riverbank	1-2 types	3-4 types	5 or more			
Waste disposal and management	Waste segregation/ Recycling	Composting	Landfilling/ Dumps/ Incineration			
Waste collection frequency	Waste collection conducted daily	Waste collection conducted twice weekly	Waste collection conducted weekly/ irregularly			

Processes causing changes in river dynamics	Natural events such as flood and landslides	Commercial	Residential/ Rural agricultural			

RVAT Sensitivity | Assessment Form

Date : __ /__ /____
Location : Simunjan / Maludam
Assessor :

Instructions

1. Please score all variables.
2. Use the scoring criteria below to guide you during scoring.
3. Rescale all total scores into Low-Medium-High rating using the guidelines provided.
4. For item 1, please refer to the guidelines attached to help in the scoring of criterion.

SENSITIVITY CRITERIA	LOW (1-2)	MEDIUM (3-4)	HIGH (5)	SITE SCORES		
				1	2	3
Types of erosion	Sheet erosion	Rill erosion	Gully erosion			
Erosion affecting river water	Little to no effects towards river water	Moderate to minimal effects towards river water	Severe and very visible effects towards river water			
Water condition	Clean, water is clear	Murky/silty sometimes	Murky/silty most of the time. Visible oil film on the water surface			
Odour	No detectable odour	Detectable natural odour. Smell of soil, fish and leaves	Strong and unpleasant odour. Smell of chemical, manure and sewage			
Trash	No visible trash	Visible trash which could potentially be carried away by currents	Plenty of trash, some of which could potentially be toxic trash			
Loss of species	No loss of species reported	Reported loss of species which are not economically important	Reported loss of key species and species which are economically important			
Perception of overall river condition	Excellent/ Very good	Good/ Satisfactory	Unsatisfactory			
Income-generating activities	Not affected by changing land-use	Slightly affected by changing land-use	Communities resort to other income-generating activities			
Water Quality Index (WQI)	81-100 (Clean)	60-80 (Slightly polluted)	0-59 (Polluted)			

RVAT Adaptive Capacity | Assessment Form

Date : __ /__ /____
Location : Simunjan / Maludam
Assessor :

Instructions

1. Please score all variables.
2. Use the scoring criteria below to guide you during scoring.
3. Rescale all total scores into Low-Medium-High rating using the guidelines provided.

ADAPTIVE CAPACITY CRITERIA	LOW (1-2)	MEDIUM (3-4)	HIGH (5)	SITE SCORES		
				1	2	3
Educational programme	No educational programme held	Held occasionally. Some of the community are involved	Held often. Majority of the community are involved			
River cleaning	River cleaning not held	River cleaning is held occasionally. Some of the community are involved	River cleaning is held often. Majority of the community are involved			
Campaigns	Campaigns are not held	Campaigns are held occasionally. Some of the community are involved	Regular campaigns are held by authority. Majority of the community are involved			
Bank stabilisation measures	No bank stabilisation measures	Soft or hard stabilisation structures	Riparian reserves			
River dependency	River dependency is completely altered.	Slightly affected by river changes. Some still rely on river water for necessities.	Not affected by river changes. Has access to other water sources			

	Communities now heavily reliant on other water sources					
Human settlement	Unfit for settlement. River dwellers shift their settlements due to extreme changes in riverbank and river conditions	Human settlement has shifted from eroding riverbanks and dirty rivers to town area or other areas free from erosion	Human settlement is still widely distributed along rivers			
River water quality monitoring programme	River monitoring not implemented	Implemented. Authorities conduct river monitoring occasionally	Implemented. Regular river monitoring conducted by authorities			

Guideline:

EXPOSURE

ITEM		DESCRIPTION	
4	Identify the types of crops near the riverbank:	Industrial crops ☐ Paddy ☐ Coconut ☐ Vegetable ☐ Fruits	Commercial crops ☐ Oil palm ☐ Rubber ☐ Cocoa ☐ Pepper
6	Identify the number of land-use types near the riverbank:	☐ Roads and highways ☐ Agricultural area ☐ Residential area	☐ Industrial area ☐ Town area ☐ Forest

SENSITIVITY

Identify the type of erosion based on the following photos:

Sheet erosion. The most common type of erosion.
Least damaging

Rill erosion. Moderate erosion. Soil appears to erode downwards and extends into the subsoil

Gully erosion. Most eroding process. Causes a substantial amount of soil loss