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Interface change of seawater and freshwater on *Asam – Asam* Watersheds, South Kalimantan, Indonesia

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Abstract

Temporal change of seawater and fresh water interface in the watershed area needs scientific study on dynamics of ecosystem parameters in different seasons and analysis of satellite imagery. This research aims to assess the change of interface seawater and freshwater from the temporal estuary upstream. The study used four methods: (1) Interviews with local community respondents; determined with snowball method. (2) Secondary data obtained from the Report of Environmental Monitoring Result of Power Plant Operations of *Asam – Asam* in 2014 (3) Observed parameters include pH, salinity, electrical conductivity in the dry season (August), transition (October) and rainy season (December). (4) Temporal observations with the use of satellite imagery analysis with Nipah (*Nypa fruticans* Wurmb) as indicator. According to the respondent, seawater intrusion has occurred extremely from the estuary of *Asam-Asam* river to the upstream. Secondary data shows significant differences in the intake value of DHL *Asam-Asam* power plant (546 µ mhos/cm) with upstream intake (231 µ mhos/cm) which means the intrusion of sea water is moderate to high level. Field observations show the dry season (August 2013) interface was 12.86 miles from the estuary, whereas in transitional season (October 2013) was 12.53 miles from estuary, and rainy season (December 2013) is 5.24 km from the estuary. Satellite imagery showed the interface in 1991 was 8.13 miles from the estuary and increase upstream from 0.03 to 1.86 per year. In 2014, the interface becomes 12.88 miles from the estuary. This shows that the sea water increasingly moving toward the river.

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Introduction

Along with damage in the catchment area of upstream region in South Kalimantan, potential rainfall infiltration is reduced because transformed into surface water runoff into the river flow during the rainy season. However, soil water reserves decline due to a continuous source of water that does not flow along the river flood season. As a result, intrusion of seawater reaches upstream in the dry season and the risk of fresh water overflow in the downstream area of the river during the rainy season.

Public Relation of South Kalimantan (2011) stated the damage of water catchment area. They explained that 700,000 ha from the total 3.7 million ha of South Kalimantan, is very critical (including forest as a water catchment area). It increased quite dramatically compared to the data of very critical area of 54,000 ha in 2007; means very critical area increase 161,500 ha per year. Despite the efforts, watershed management in Indonesia has been needed quite a long time to be implemented. Yet, it has not reached the desired result because of the complexity of the problems (Sudaryono, 2002).

In the viewpoint of watershed management, upstream environmental damage related to the degradation of coastal areas. Rainfall in the watershed becomes a major factor controlling the flow of rivers and estuaries, substantially affect productivity and related variables (Mallin *et al.*, 1993). Damaged catchment area increased surface water runoff, river discharge, flood, and erosion on downstream that carried sediment to the estuary. The degradation rate of coastal environment was relatively rapid and perceived impact. Arifin *et al.* (2006) found the most severe damage to coastal vegetation around the estuary of South Kalimantan. This condition is triggered by coastal areas desalination due to the increasing of freshwater abundance from upstream, thus changing habitat conditions and mangrove communities. This condition causes the degradation of coastal ecosystems become vulnerable and fragile that mangroves are not able to grow optimally and reduce wave energy (Iriadenta, 2001). This situation is exacerbated by the exploitation of mangrove areas without regard to the conservation value (Iriadenta, 2003). Priyono and Cahyono (2003) also added that the increasing number of critical watersheds in Indonesia showed inaccuracies watershed management.

Observing the phenomenon of linkage effect on upstream to downstream, it uses natural phenomena of ecosystems downstream to assess the damage of upstream ecosystems. Downstream ecosystems parameters can provide a partial and collective response on the river ecosystem changes or specific responses of environmental component changes that occur in the upper. An alternative is the natural response of the river and coastal ecosystems, such the phenomenon of seawater and freshwater meeting which has been generally known, but it has not been studied scientifically. It is necessary for the specific study on the response of coastal ecosystems include *Nypa fruticans* Wurmb vegetation habitat around the interface of seawater and freshwater. It is then associated with the changes interface of seawater and freshwater, which in turn can be represented for the assessment of watershed conditions. Assessment can be assisted by temporal satellite imagery and geographic information system (GIS) data computing as an efficient supporting device.

The purpose of this study is to obtain a change within the limits interface of seawater and fresh water from the estuary upstream temporally. Studies of this retrieval boundary changes can be used as a device for the assessment of watershed management efforts in integrated watershed areas to be effective and efficient.

Materials and methods

Data collection

Temporal data of interface change between seawater and fresh water were qualitatively and quantitatively analyzed through 4 methods: (1) interviews with local community respondents, (2) secondary data (3) field observation, (4) temporal observations of satellite imagery on the presence of Nipah (*N. fruticans* Wurmb) vegetation as an indicator.

1. Snow Ball

Respondents determined based on the Coleman snowball method (Handcock and Gole, 2011; Dragan and Maniu, 2013). Respondents were asked to identify potential subjects of other respondents who have specific characteristics, i.e. have stayed more than 10 year in the study area.

2. Secondary data

Secondary data were obtained from the Report of Environmental Monitoring Result of Power Plant Operations of Asam - Asam in 2014 (PT. PLN, 2014).

3. Field observation

Field observation carried out by measuring the parameters of pH, salinity, electrical conductivity in the dry season (August) especially at highest tide, the transition (October) when the water highest tide and lowest tide and the rainy season (December) at lowest tide. Salinity were assumed 0 to 0.5 ⁰/₀₀, DHL < 200 µ mhos/cm (Davis and Wiest, 1996).

4. Satellite Imagery on *Nipah Existence*

Existence considerations of *N. fruticans* Wurmb are:

a) naturally growing specific near the streams that supply the coastal mud,

b) the only kind that found lots in mangrove swamps and brackish water marsh in estuaries (Hyene, 1987), with river water salinity 1-10 ⁰/₀₀ (Robertson *et al.*, 1991), in brackish water habitats; the interface area between seawater with freshwater;

c) including mangrove species at ecological conditions that close to the tolerance limit of water salinity (Blasco *et al.*, 1996); found in far upstream along the tidal that influenced salinity water;

d) live throughout the year (annual crops), thus relatively insignificantly changed naturally in a long time;

e) its existence or habitat associated as interface of seawater with freshwater (Rustiyawatie *et al.*, 2009).

This approach supported by data analysis on temporal satellite imagery. The temporal values determined farthest position of Nipah from the estuary as a boundary related to the interface of seawater and freshwater in the past to the present.

Data analysis

Each observation method shows the stages on the objectives of data performance, with qualitative to quantitative verification. Observation methods of 1-3 were analyzed descriptively appropriate to data acquisition for each observation. The satellite imagery analysis used supervised methods with digitized *N. fruticans* Wurmb existence value as an associative object that characterized the interface between seawater and fresh water.

The object processed into supervised classification into homogeneous spectral object, then continued for classifying the object as the smallest unit (Schirokauer *et al.*, 2006). Landsat ETM+ was used as the basis of the corrected image transformation algorithm using NDVI (Normalized Difference Vegetation Index) (Liang *et al.*, 1989) for the value of *N. fruticans* Wurmb reflectance which aligned to the actual values in the field. Geographic information systems also used to proceed analysis and mapping.

Accuration test of the interpretation used the matrix methods of Short (1982) which is verified by actual conditions. Verified furthest location of *N. fruticans* Wurmb in upstream associated as interface of seawater and freshwater, and the distance from the estuary then measured. Overall results were analyzed descriptively.

Results

Results of interview

Recapitulation interviews with respondents are shown in Table 1. All 100% information of respondents were qualitatively corroborate the assumption that there has been a change in the influence of extreme seawater mass urge compare to the past, although the exact limit size can not be determined.

Table 1. Summary of Analysis Results per Phase / Methods.

1. Interview respondents (Source : Primary Data Analysis, 2013)			
Characteristics	**Data source**	**Info of Change**	**Location of interface**
Age 55-70 year live > 20 tahun	there are changes (100 % of respondents)	*Before* : the floodgates Asam-Asam power plant, *Now*: - More upstream - Up to settlements (more upstream) Before back in the downstream and now far upstream. It used to be still in the downstream, now reach the settlement	• In the rainy season about 3 miles upstream. In the dry season, approximately 10 km upstream (1 respondent) • not sure (7 respondents) • in rainy season is about 3-5 km or more, to the upstream direction. • in dry season ±10-15 km upstream (1 respondent)
2. Secondary Data: Environmental Monitoring Operations of *Asam - Asam* power plant 2014			
Station	**DHL (µ mhos/cm)**	**Sea Water Intrusion**	**Reference**
AS1	546	high	Davis and Wiest (1996)
AS2	231	Moderate	
3. Field observations in 2013			
Parameter		**Season**	**Interface from Estuary (km)**
pH, salinity, DHL		Dry season	12.86
		Transitional season	12.53
		Rainy season	5.24
4. Temporal analysis			
Year			**Interface from Estuary (km)**
1991			8.13
2000			10.19
2003			10.84
2006			11.52
2009			17.11
2010			12.15
2011			12.18
2012			12.39
2013			12.66
2014			12.88

Results of secondary data

Secondary data on two monitoring stations from Environmental Monitoring Operations of *Asam - Asam* power plant 2014 showed that there were significant differences in the intake water DHL value in *Asam- Asam* power plant (546 µ mhos/cm) with the upstream intake plant (231 µ mhos/cm). Refers to the classification of Davis and Wiest (1996) water station AS1 (intake plant) including high intruded, while at the station AS2 (upstream intake) are intruded by seawater.

Field observations

Observation on dry season (August 2013) salinity values tend to decrease from estuary to upstream, until it reaches the limit of interface at a distance of 12.86 miles from the estuary. The observation of the transition season (October 2013) indicates retrieval limit is 12.53 miles from the estuary. Interface farthest distance to the estuary is small compared with first observations. Observations of the rainy season (December 2013) reached a distance of 5.24 miles from the estuary.

Approach in temporal data resource utilization

Temporal approach determined the interface seawater and freshwater using *N. fruticans* Wurmb growing indicators in *Asam-Asam* watershed. The growth site of *N. fruticans* Wurmb in current field observations plotted on Landsat ETM +. It corrected and analyzed resulting in reflectance of *N. fruticans* Wurmb in *Asam – Asam* watershed by 0.476232 Watt/m^{2}µm with composite of RGB 321.

Overall accuracy of test results using the ALOS satellite image of 2010 and Landsat Satellite Image 8 OLI/TIRS of 0.93 with the amount of 91.83% Kappa coefficient meets the requirements specified level of accuracy if Kappa coefficient >85 % (Short, 1982). The results of furthest point of *N. fruticans* Wurmb from the estuary as the interface seawater and fresh water is shown in Table 1, along with the results of the study as a whole.

Discussion

Temporal interface of seawater and fresh water in *Asam – Asam* watershed is shown in Fig. 1 and Table 2. All the results showed that a change in the interface of seawater and freshwater which were calculated from the estuary, tend to increase towards the upstream than ± 20 years ago.

Table 2. Changes of interface seawater and freshwater (1991 – 2014).

Year	Distance from estuary to interface (km)	Span of time (years)	Changes Distance (km)	Mean Change Distance (km/year)
1991	8.13	-	-	-
2000	10.19	9	2.06	0.23
2003	10.84	3	0.65	0.22
2006	11.52	3	0.68	0.68
2009	17.11	3	5.59	5.59
2010	12.15	1	-4.96	-4.96
2011	12.18	1	0.03	0.03
2012	12.39	1	0.21	0.21
2013	12.66	1	0.27	0.27
2014	12.88	1	0.22	0.22
			Average	**0.28**

Based on previous observational data and data retrieval from seawater and freshwater interface during 1991 - 2014, conditions are likely to create farther distance to upstream due to the factual circumstances in *Asam - Asam* wathershed. The causes are increasing various human activities, e.g. mining, deforestation and other land use compared to the past, which can lead to worsening catchment area or diminishing its range and impact on the dynamics of the tide. Extreme changes occurred in 2009 where in the cycle of El Nino occurs every five years that have an impact on the climate conditions of South Kalimantan.

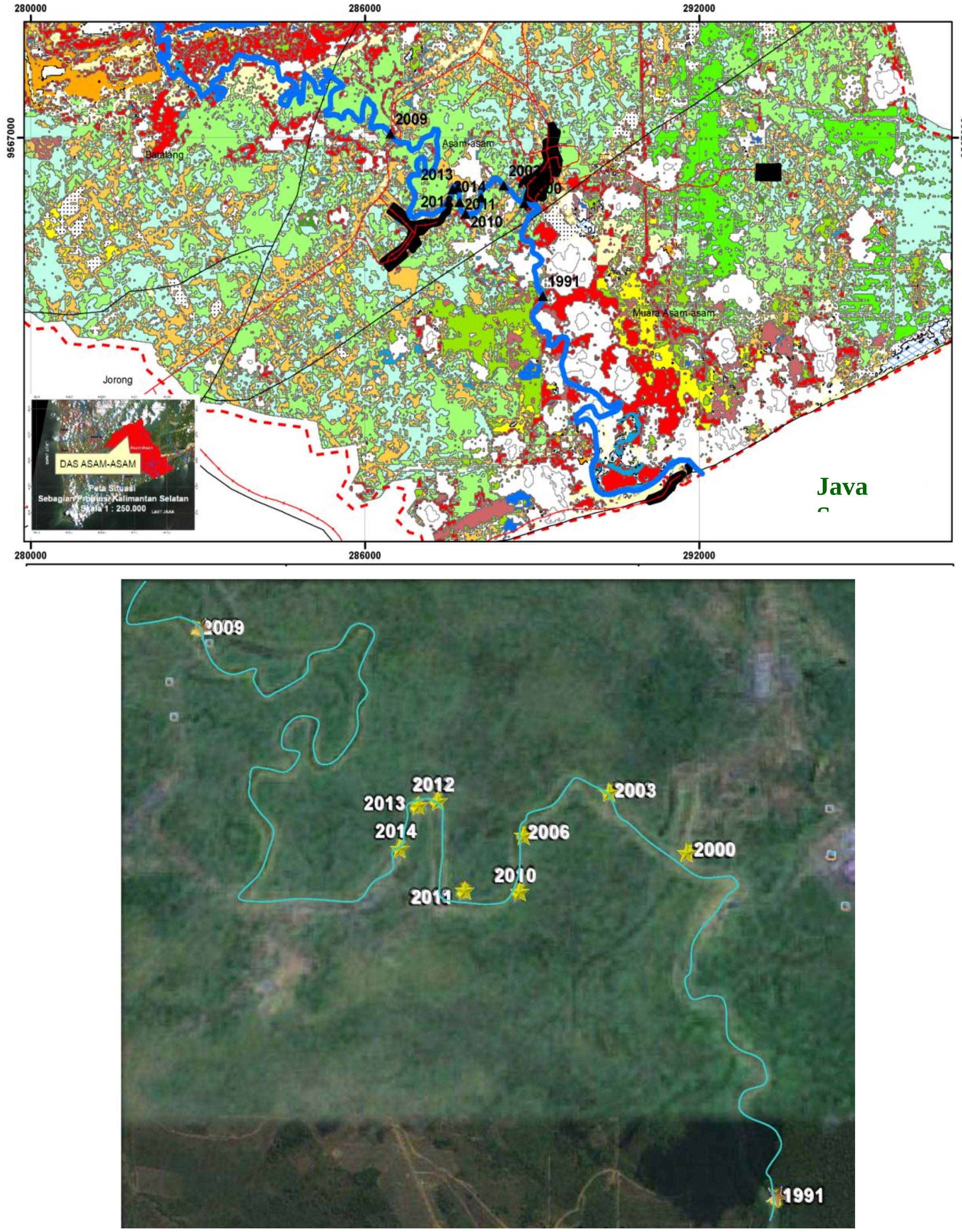

Fig. 1. Changes of Seawater - Fresh water Interface (1991-2014).

Conclusion

Based on the results of this study concluded that there was a change of seawater and freshwater interface temporarily during 1991-2014 with a tendency to change increasingly to upstream. Changes of interface of seawater and freshwater indicates that distance from estuary to upstream tends to get bigger. Based on the research results, it suggest to do an assessment on the changes of seawater and freshwater interface to land cover changes on the watershed.

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