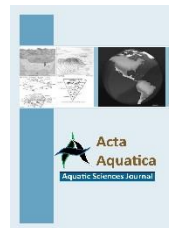




# Acta Aquatica

## Aquatic Sciences Journal



### Water salinity evaluation suitability for settlement after ten year tsunami in Banda Aceh, Indonesia

### Evaluasi kesesuaian salinitas air untuk pemukiman setelah sepuluh tahun tsunami di Banda Aceh, Indonesia

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#### Abstract

Banda Aceh is a residential area that is most severely impacted by the earthquake and tsunami on December 26, 2004. Recently, ten years after the incident, many settlements were rebuilt. As a disaster-prone areas, Banda Aceh would need to be evaluated against the settlement area base on water salinity. The focus of the study centered on the application of geographic information systems in handling spatial data bearing capacity of the land into the concept of the FAO land suitability. To ensure the application works, it requires geospatial analysis compiled based on the salinity of the water variables that can be observed and measured for the residential requirements. The results showed that 86 percent (ordo S) suitable for residential areas and 14 percent (ordo N) is not suitable.

**Keywords:** GIS; Water salinity; Land suitability, Residential

#### Abstrak

Banda Aceh adalah daerah pemukiman yang paling parah terkena dampak gempa dan tsunami pada 26 Desember 2004. Baru-baru ini, sepuluh tahun setelah kejadian tersebut banyak pemukiman yang dibangun kembali. Sebagai daerah rawan bencana, evaluasi terhadap kadar salinitas pada basis kawasan pemukiman di Banda Aceh perlu dievaluasi. Fokus dari penelitian ini berpusat pada aplikasi sistem informasi geografis dalam penanganan data spasial terhadap dukung data tanah sesuai dengan konsep kesesuaian lahan FAO. Untuk memastikan aplikasi tersebut sesuai, analisis geospasial disusun berdasarkan variabel salinitas air yang diamati dan diukur sebagai persyaratan pembangunan pemukiman. Hasil penelitian menunjukkan bahwa 86 persen (ordo S) cocok untuk daerah pemukiman dan 14 persen (ordo N) adalah tidak cocok.

**Kata kunci:** SIG; Salinitas air; Kesesuaian lahan; Tempat tinggal

#### 1. Introduction

On December 26, 2004, an earthquake of 9.0 on the Richter scale occurred on the west coast of northern Sumatra, Indonesia. Global Seismic Network stated that the point of the quake was at a depth of 10 km in the ocean Hindi. Based on a review of geography, it is located at position 95.85 N 3:32 E, which is approximately 149 km south-west of Meulaboh, Aceh western (Shofiyati, Dimiyati & Kristijono, 2005). The Settlements in Banda Aceh was destroyed in the earthquake and tsunami. Settlement is part of the cultivated area and is outside the protected area. Settlement area serves as the residence of the environment and activities that support community life (UU-RI,

2011). Rebuilding the settlements in the region has been hit by disaster is associated with comfort and a sense of community anxious to disasters that could happen again. In addition, the housing itself fostered by residents often do not pay attention to the physical condition of the land and the environment. According to, (Chiara & Koppelman, 1997) housing design has several requirements: a) attractive building foundation, appropriate and economical, b) provides safety, comfort and functional, c) balancing the nature with foundation of the structure. Therefore it is necessary to evaluate the suitability of land settlement with the current environmental conditions. Therefore it is necessary to evaluate the suitability of land settlement with the current environmental conditions. Land suitability evaluation is an approach or a way to determine the potential of land resources (Hardjowigeno & Widiatmaka, 2007). Niekerk (2010) said that land evaluation is also integral part of land use planning for continuous land management. Land use for

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settlement should go inline with environment supporting ability (Masri, 2012). Therefore, it is essential to measure whether building structure on the soil will affect soil bearing capacity or no. Further Woro (2014) stated that salinity is one of the factors in the carrying capacity of the land for settlement. Results of the study McLeod et al. (2010) which states that the effect of salinity on land affected by the tsunami.

The use of GIS (Geographic Information System) in the land evaluation suitability for settlement will ease and speed up the process of data analysis (Setyowati, 2007). GIS technology has advantages for input, editing and analysis of data, both geographic data and attribute data in an appropriate manner at the time of rapid.

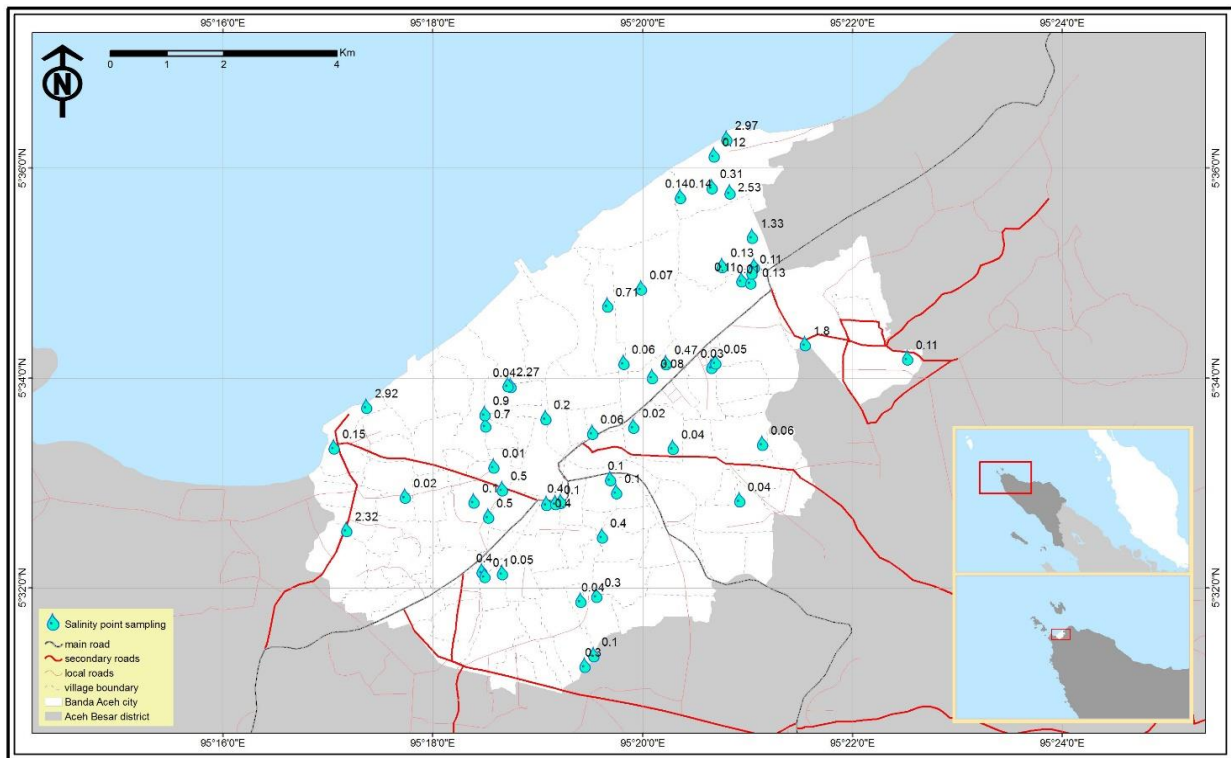
## 2. Material and method

Direct field testing to determine the water salinity with Salt Meter (Cahyadi et al., 2013) and positioning using GPS receiver (Abidin, 2007). The work mostly concentrated on spatial analysis of salinity values and land suitability evaluation model of FAO (FAO, 1976, 1985, 1990, 2007) adjusted for settlements. GIS is used in managing spatial data and presenting visual classification results.

Zhang, 2001; Kalogirou, 2002) distribution of salinity measurement results can be seen in Figure 1.

**Table 1**  
Salinity measurement results in Banda Aceh.

No.	Salinity	Unit	No.	Salinity	Unit	No.	Salinity	Unit
1	1.33	%	19	0.5	%	37	0.04	%
2	2.53	%	20	0.5	%	38	0.02	%
3	0.11	%	21	0.7	%	39	0.07	%
4	0.06	%	22	0.3	%	40	0.71	%
5	0.04	%	23	0.3	%	41	0.06	%
6	0.02	%	24	1.8	%	42	0.08	%
7	2.32	%	25	0.1	%	43	0.47	%
8	2.92	%	26	0.1	%	44	0.11	%
9	0.15	%	27	0.2	%	45	0.13	%
10	0.06	%	28	0.1	%	46	0.01	%
11	0.01	%	29	0.1	%	47	0.11	%
12	0.05	%	30	0.1	%	48	0.13	%
13	0.04	%	31	0.4	%	49	0.12	%
14	2.27	%	32	0.1	%	50	0.31	%
15	0.04	%	33	0.9	%	51	2.97	%
16	0.14	%	34	0.12	%	52	0.05	%
17	0.4	%	35	0.14	%	53	0.4	%
18	0.4	%	36	0.03	%	54	0.4	%



**Figure 1.** Spatial distribution from water salinity measurement results.

## 3. Result and discussion

### 3.1. Water salinity

Salinity is the saltiness or salinity levels dissolved in water (Effendi, 2003). Water is one resource that has an important role in human life. One example of its use is to provide a source of clean water for residential area. It is necessary to plan for sustainable settlements. The results of measurements of salinity in Banda Aceh is presented in Table 1. By using GIS (Dai, Lee &

### 3.2. Analysis spatial of water salinity

Results analysis of water salinity like Fig 1 still comes in point. To predict the overall land surface, GIS is used with interpolation concept. Spatial classification based on field salinity value is used in applying this function (Prahasta, 2009; ESRI, 2013). In summary interpolation is the process of changing the data points into the area. Inverse distance weighted, natural neighbor, spline, and kriging trend are rules used interpolation. Further more Booth and Mitchell (2001), Gorr and Kurland (2008) and Pramono (2008) confirms that Kriging rules has the

advantages of unbiased properties, minimum variance, and it is a linear combination rather than observation. Kriging interpolation results from data analysis of water salinity in Banda Aceh, is presented in Figure 2 as follows.

this matching, then the interpolated maps based on criteria reclassify suitability classes.

Suitability classes salinity distribution maps provide preliminary information regarding the carrying capacity of land in general. Based on the broad suitability of salinity in Banda Aceh, are presented in Table 2, while the percentage can be seen in Figure 3. Results reclassify into residential land suitability map

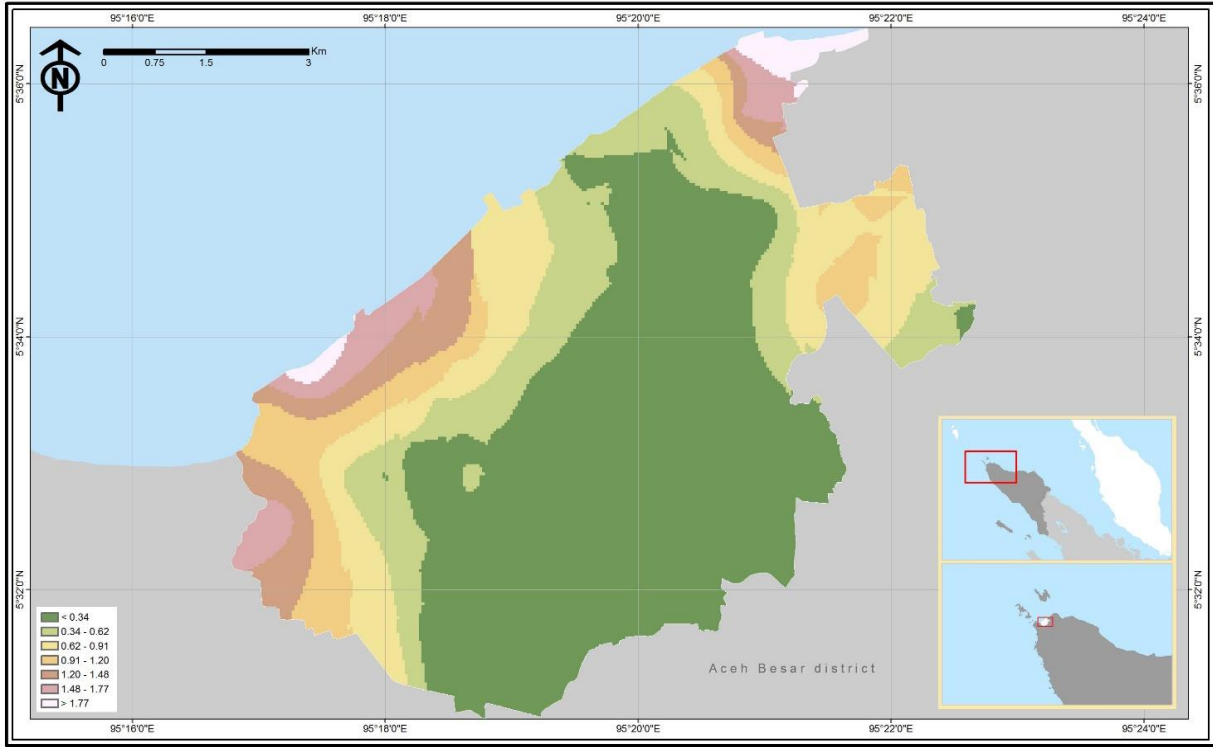


Figure 2. Map of kriging interpolation results from water salinity.

3.3. Land evaluation suitability base on water salinity for settlement

Based on the modification of Fandeli (1988), PP RI (2001) and Effendi (2003) distribution of salinity level class table can be incorporated into the FAO land suitability classes, as shown in Table 2. The relationship between salinity to land suitability is comparable where the higher the salinity, the greater obstacle for suitability classes (settlement/residential).

Table 2

Salinity level class.	
Class	Salinity (%)
S1	0
S2	0.1 - 0.5
S3	0.6 - 1.0
N1	1.1 - 1.5
N2	>1.6

Land suitability evaluation system adopted the FAO. Suitability categories used order to class. Order S corresponds with class S1 (highly suitable), S2 (moderately suitable) and S3 (marginally suitable). Order N to not comply with Class, N1 (currently not suitable) and N2 (permanently not suitable). Salinity class into thematic criteria land suitability requirements settlements based analysis literature review (FAO, 1976; Sugiyanta, 2003; Setyowati, 2007). Adoption of the concept of

based on salinity, as shown in Figure 4.

Table 3

Area of salinity suitability for settlement.

Class	Hectare
S1	686
S2	2,975
S3	1,614
N1	888
Total	6.136

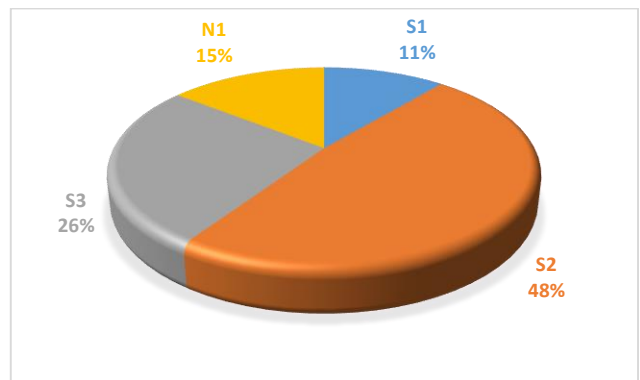


Figure 3. Graph the percentage of salinity suitability for settlement.

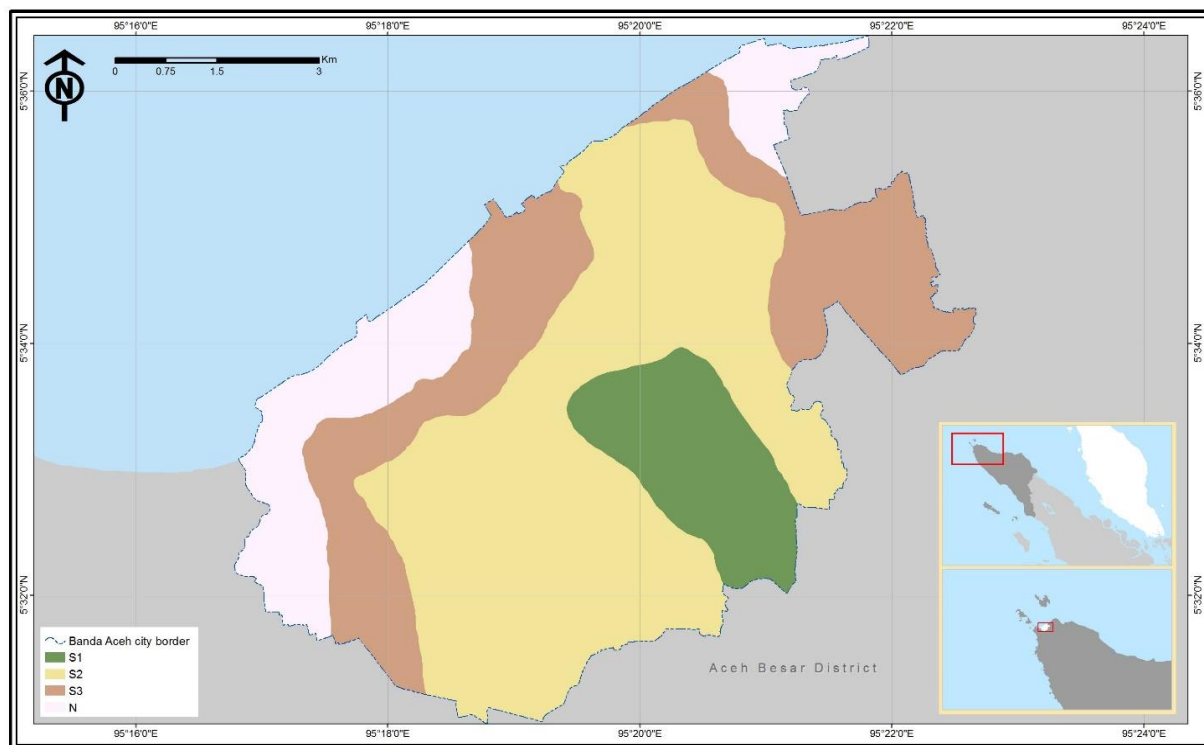


Figure 4. Map salinity suitability class for settlement.

#### 4. Conclusion

The results of this study showed that the salinity suitability for settlements in Banda Aceh, 86 percent are in the order of S (suitable) and 14 percent of the order N (not suitable). The detailed extent of the percentage of suitability classes; S1 (highly suitable) covering 686 ha or 11%, S2 (moderately suitable) covering 2,975 ha or 48% and S3 (marginally suitable) covering 1,614 ha or 26%. While the details for order N; N1 (currently not suitable) covering 888 ha or 15%.

#### Bibliography

- Abidin, H. Z., 2007. Penentuan Posisi dengan GPS dan aplikasinya. Jakarta: PT Pradnya Paramita.
- Booth, B., Mitchell, A., 2001. *Getting started with ARCGIS*. Redlands, California, USA: (ESRI) Environmental System Research Institute, Inc.
- Cahyadi, A., Marfai, M. A., Tivianto, T. A., Hidayat, W., 2013. Analisis Distribusi Spasial Salinitas Airtanah di Pulau Pramuka, Kepulauan Seribu, DKI Jakarta.
- Chiara, D. J., Koppelman, L. E., 1997. *Standar Perencanaan Tapak (terjemahan dari Site Planning Standards)*. Jakarta: Erlangga.
- Dai, F., Lee, C., Zhang, X., 2001. GIS-based geo-environmental evaluation for urban land-use planning: a case study. *Engineering geology*, 61(4), 257-271.
- Effendi, H., 2003. *Telaah kualitas air, bagi pengelolaan sumber daya dan lingkungan perairan*: Kanisius.
- ESRI, 2013. *Understanding GIS: An ArcGIS Project Workbook*. Retrieved Regular, 2013, from <http://resources.arcgis.com/en/communities/understanding-gis/>
- Fandeli, C., 1988. *Pengelolaan Sumberdaya dan Lingkungan Hidup*. Yogyakarta, Indonesia: Yayasan Pembina Fakultas Kehutanan Universitas Gajah Mada (UGM).
- FAO, 1976. *A Framework for Land Evaluation* FAO. Rome, Italy: FAO (Food and Agriculture Organization).
- FAO, 1985. *Guidelines: land evaluation for irrigated agriculture-FAO soils bulletin 55*. Rome, Italy: FAO (Food and Agriculture Organization).
- FAO, 1990. *Land evaluation for development*. Rome, Italy: FAO (Food and Agriculture Organization).
- FAO, 2007. *Land evaluation Towards a revised framework*. Rome, Italy: FAO (Food and Agriculture Organization).
- Gorr, W. L., Kurland, K. S., 2008. *GIS Tutorial*. Redlands, California, USA: Environmental System Research Institute (ESRI) Press.
- Hardjowigeno, S., Widiatmaka., 2007. *Evaluasi Kesesuaian Lahan dan Perencanaan Tataguna Lahan*. Yogyakarta. Indonesia: Penerbit Universitas Gajah Mada (UGM Press).
- Kalogirou, S., 2002. Expert systems and GIS: an application of land suitability evaluation. *Computers, Environment and Urban Systems*, 26(2), 89-112.
- Masri, R. M., 2012. Analisis Keruangan Kesesuaian Lahan untuk Permukiman di Kabupaten Bandung dan Bandung Barat. *Forum Geografi*, Vol. 26, No. 2(Desember 2012), 190 - 201.
- McLeod, M. K., Slavich, P. G., Irhas, Y., Moore, N., Rachman, A., Ali, N., ... Caniogo, C., 2010. Soil salinity in Aceh after the December 2004 Indian Ocean tsunami. *Agricultural Water Management*, 97(5), 605-613. doi: <http://dx.doi.org/10.1016/j.agwat.2009.10.014>
- Niekerk, A. V., 2010. A comparison of land unit delineation techniques for land evaluation in the Western Cape, South Africa. *Land Use Policy*, 27(3), 937-945. doi: <http://dx.doi.org/10.1016/j.landusepol.2009.12.007>

- PP-RI, 2001. *Peraturan Pemerintah Republik Indonesia (PP RI) No. 82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air*. Jakarta, Indonesia: Presiden Republik Indonesia.
- Prahasta, E., 2009. *Sistem Informasi Geografis : Konsep-konsep Dasar (Perspektif Geodesi dan Geomatika)*. Bandung, Indonesia: Informatika.
- Pramono, G. H., 2008. Akurasi Metode Idw dan Kriging Untuk Interpolasi Sebaran Sedimen Tersuspensi. *Jurnal Forum Geografi, Vol. 22, No. 1, 2008*(Fakultas Geografi Universitas Muhammadiyah, Surakarta), 97-110.
- Setyowati, D. L., 2007. Kajian Evaluasi Kesesuaian Lahan Permukiman dengan Teknik Sistem Informasi Geografis (SIG). *Jurnal Geografi UNNES, Volume 4 No. 1 Januari 2007*((UNNES) Universitas Negeri Semarang), 44-54.
- Shofiyati, R., Dimiyati, R. D., & Kristijono, A., 2005. Tsunami Effect In Nanggroe Aceh Darussalam And North Sumatra Provinces, Indonesia. *Asian Journal of Geoinformatics,, Vol. 5, No. 3*.
- Sugiyanta, I., 2003. *Kajian Kesesuaian Lahan untuk Pembangunan Perumahan di Kota Wates Kabupaten Kulon Progo*. (Tesis), Universitas Diponegoro (UNDIP), Semarang, Indonesia.
- UU-RI., 2011. *Undang-Undang Republik Indonesia (UU RI) No. 1 Tahun 2011, tentang Perumahan dan Kawasan Permukiman*. Jakarta, Indonesia: Presiden Republik Indonesia.
- Woro, S., 2014. Perencanaan Permukiman (Materi Kuliah). Retrieved 20 September 2014, 2014