Assessing the Optic and Non-optic Remote Sensing Data; A Validation of Soil Wetness Approach.

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Abstract: Remote sensing data have been used in multiple circumstances to collect and monitor changes in surface soil wetness (SW). However, the models between optical and spectral bands combination are still subject to major uncertainties, whether empirically or physically based. This article aims to compare and calibrate synergistic methods of Sentinel multi spectral and Landsat 8 data to assist the monitoring of soil wetness and its relation to agriculture or flooding subject. The NDWI method was used to assess the SW and the proposed approach was evaluated against the ancillary data of the history of flooding against a classical method on across seasons of optical data. A sample of West Java area was used for the analysis and the result indicated the synergetic method of optic remote sensing data are in line with the ancillary information of the SW variables, but the curacy is varying among the land cover type.

I. INTRODUCTION

Soil wetness (SW) is one of the important variables in studying the dynamics of land surfaces such as the agricultural cycle and environmental monitoring. Aside from being important to monitor the agricultural cycle, environmental problems such as floods are also one of the factors that can be predicted by using this SW study. SW may relate to the history of frequent flooding. This issue can be potentially estimated by using remote sensing data (Amazirh et al, 2018). However, the models between optical and spectral bands combination are still subject to major uncertainties, whether empirically or physically based. Several studies have generally assessed that microwave technique is better to determine the SW (Mehrez and 42 Dechambre, 2003). The better polarization for SW studies is also varied among scientists. Indeed, which optical spectral band combined need to be more explored in certain method for determining the digital processing of the SW model. This article aims to compare and calibrate synergistic methods of Sentinel multi spectral and Landsat 8 data to assist the monitoring of soil wetness and its relation to agriculture or flooding subject. The NDWI (Normalized Difference Water Index) with certain band combination will be used to determine water content in soils. A validation to ancillary information of the SW is also needed to be employed for describing the accuracy and the relation of SW to the history of frequent flooding or sustainable agriculture.

The study site is located in the highland of Bandung (Figure 1). The selection of study area based on eagerness to learn the trace of frequent flooding through remote sensing data. Therefore, the SW in the event of not flooding or dry season and the occurrence of flooding or rainy season is important will be applied for deriving the model of SW for frequent flooding.

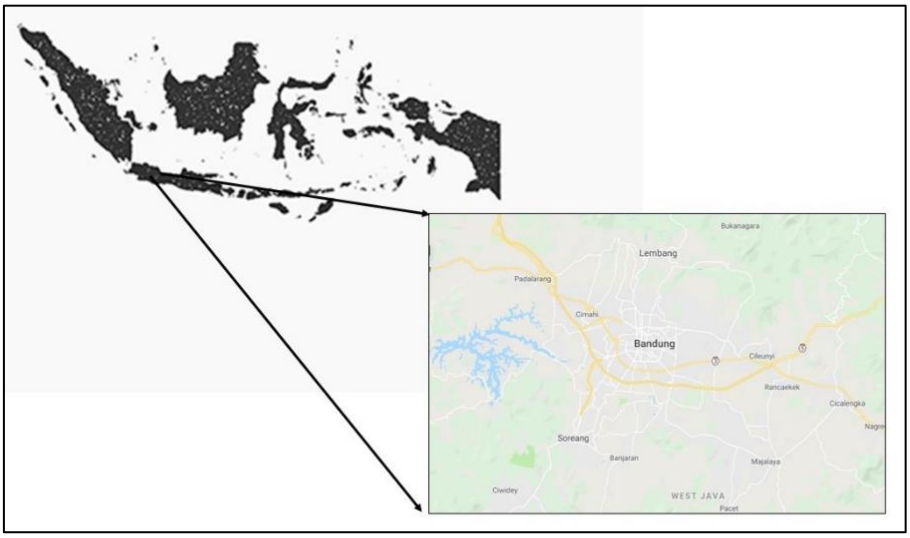


Fig. 1. Bandung area, The location of Assessment

II. METHOD

The method applied in this paper relies on the use of SW which in its algorithm uses the data obtained from satellite sensors. Two different satellite scenes were downloaded from Earth Explorer USGS web application, there is Landsat 8 Oli obtained at July, 6th 2018 and Sentinel 2B obtained on December 6th 2017. The Landsat 8 Oli image represents the dry season, the Sentinel 2B image represents the rainy season in a different year to indicate the multi-year variation of SW. The Sentinel 1A on the occurrence of big flooding on October 28th 2016, topography and the history of Bandung flooding map was used for accuracy testing.

The algorithm that applies to the calculation of SW function is based on the utilization of the NDWI which are calculated each pixel of the Landsat 8 Oli and Sentinel 2B imageries. Because its sensitivity to water differs, the relationships among different water absorption spectral bands were applied to derive the SW. Landsat 8 Oli has 11 spectral bands with specific uses of mapping (Table-1). Related to water, Landsat 8 Oli has spectral bands of band-2 visible blue, band-6 SWIR-1, band-7 SWIR-2, band-10 TIRS-1 and band-11 TIRS-2 that can give information on the earth water’s conditions, either on water bodies or soil and vegetation moisture content. Therefore, the algorithm developed in this article was combined the water-related spectral bands, there are the NIR and the

SWIR band of Landsat 8 Oli. Band 5 – NIR , the wavelength at 0.64-0.88 is able to emphasize biomass content and shorelines. So, it is able to discriminate land and water clearly. Meanwhile, Band 7 – shortwave infared/ SWIR 2 at 2.11- 2.29 is able to improve the moisture content of the soil. So, the algorithm of NDWI can be described as:

$$NDWI_{Ls} = \frac{NIR-SWIR}{NIR+SWIR} \quad \ldots\ldots(1)$$

Table -1. Spectral bands of Landsat 8 Oli Characteristic for mapping (USGS)

Band	wavelength	Useful for mapping
Band 1-coastal aerosol	0.43 – 0.45	Coastal and aerosol studies
Band 2 - blue	0.45 – 0.51	Bathymetry mapping, distinguishing soil from vegetation and deciduous form coniferous vegetation
Band 3 - green	0.53 – 0.59	Emphasizes peak vegetation which is useful for plant vigor
Band 4 - red	0/64 – 0.67	Discriminate vegetation slopes
Band 5- NIR	0.85 – 0.88	Emphasize biomass content and shorelines
Band 6 - SWIR1	1.57 – 1.65	Discriminate moisture content of soil and vegetation, penetrate thin cloud
Band 7 – SWIR 2	2.11 – 2.29	Improve moisture content of soil and vegetation and thin cloud penetration
Band 8 – Panchromatic	50 - 68	15 m resolution, sharper image definition
Band 9 – Cirrus	1.36 – 1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.5 – 12.51	100 meter resolution, thermal mapping and estimated soil moisture

Meanwhile, Sentinel 2B has 12 spectral bands, that has spectral bands of band-2 blue, band-9 water vapor, band-10 cirrus, band-11 SWIR and band-12 SWIR that can also give spatial information related to waters. For sentinel 2B, the NDWI algorithm was developed by following Mcfeeters (1996) *in* Wiweka, et al. (2014) which develop the NDWI algorithm using green (Vb) and near infrared (NIR) bands, as:

$$NDWI_{sen} = \frac{V_g-NIR}{V_g+NIR} \quad \ldots\ldots\ldots..(2)$$

A secondary data of Sentinel 1C on the big flood event on October 28th 2016 and the map of flooding were also used for validating the risk area of multi-temporal and multi sensor image processing data (Landsat 8 Oli and sentinel 2B) by using the logical area test method. The logical test followed the condition:

"IF (Something is True, then do something, otherwise do something else)"

and could be formulated as;

$if\,(x,y)_1 = (x,y)_n \quad then\ (x,y)_1\ is\ true$ ....(3)

and

$if\ (x,y)_1 \neq (x,y)_n\ then\ (x,y)_1\ is\ false$ ....(4)

However, since the SW may include agriculture land, water bodies, vegetation moisture and soil moisture, the matrix evaluation was used to evaluate the accuracy of both SW images linked to frequent flooding. The historical flood map of Bandung has become the reference for this evaluation. The formula for this evaluation is:

$(x_1y_1)_{n1} \dots (x_ny_n)_{ni} = (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 1 = t$ ....(5)

$(x_1y_1)_{n1} \dots (x_ny_n)_{ni} \neq (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 0 = f$ .....(6)

then

$Ev = \frac{\sum t_1 + t_n}{\sum (t+f)_{ref}}\ x\ 100\ \%$ ......(7)

Whereas *Ev* is the result of evaluation (%) based on *t*, *t* is the value of true features, *f* is the value of false features, *1..n* the kernel of imageries, *ref* is the value of reference data with 100 % true.

Result and Discussion

Satellite technology development offers a strong technique for tracking regional SW's spatial-temporal variation and offers quantitative estimation. The development of Landsat 8 and sentinel 1 and 2 which have a more diverse number of bands causes more detailed information to be examined through specific combinations of bands to estimate SW. The availability of SW information is very important to study the agriculture and flood risk areas to find the best solution for sustainable spatial planning. Before determining the best combination of spectral bands for SW mapping, the combination of scattergram plot of both band-5(x_1) and band-6 SWIR-1 (y_1) and band-5 and band-7 SWIR-2 (y_2) has been analyzed. This because both of these spectral bands can be applied for determining the water contents of the soil and the water bodies. From both of the scattergram, the spectral value was distributed to y^2 axis rather than to y_1 (Fig 2). It is meant that the spectral band combination of band 5-NIR and band 7-SWIR2 can be more utilized to map SW because of its ability to record the water contents characteristics.

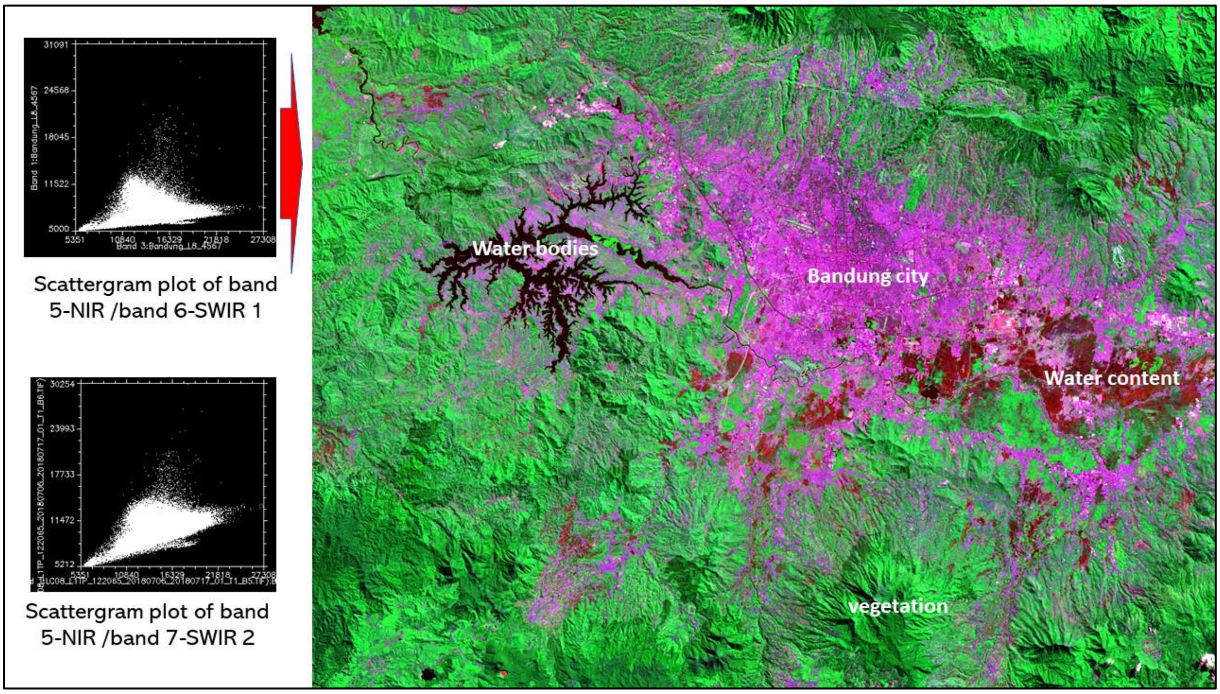


Fig 2. The scattergram plot of B5-NIR/B6-SWIR1 and the composite image of Landsat 8 Oli-July, 6^{th} 2018

By combining the spectral band of band-2 blue, band-5 NIR and band -6 SWIR-1 for composite image color with linear contrast enhancement and the NDWI algorithm for Landsat 8 oli images, the soil wetness can be properly mapped, indicating the yellow color in NDWI images. (Fig 3).

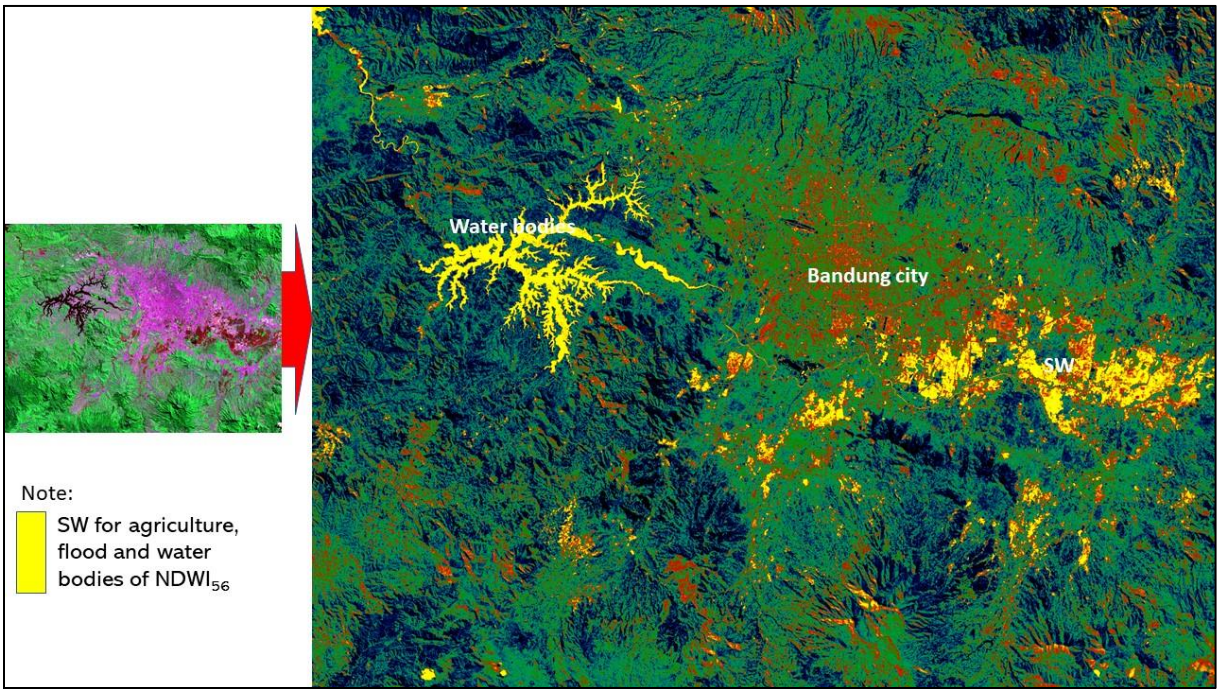


Fig 3. NDWI of Landsat 8 Oli to illustrate SW

Generally, each SWIR band reacts differently to soil moisture and leaf water content. A study using Modis image to calculate SW show that the NDWI of water absorption - sensitive band and insensitive band is able to enhance the sensitivity to leaf water content (Wang et al, 2007). Indeed, Burapol and Nagasawa (2016) proved that the normalized difference water index (NDWI) from the NIR and short-wave infrared (SWIR) band reflects changes in both water content and spongy mesophyll in vegetation canopies, making this index possible to be related to soil moisture owing to its effect on vegetation water stress. The result of the algorithm shows the soil wetness caused of both agriculture and flooding.

A survey of Sentinel 2B NDWI representing the rainy season and the flooding event was also evaluated to study the SW across the monsoon. Wiweka (2014) states that based on the calculation results, all variables of NDWI, either NDWI (Gao), NDWI (Mc Feeters), MNDWI (Xu) or NWI (Haibo) have good abilities in detecting inundation. The findings are however different in terms of image data or combination of spectral bands. Franzpc (2019) states that the composite of band 8,11 and 4 is able to discriminate land and water, but in this assessment the result of NDWI using these spectral band combination shows less profound result of SW. A scattergram plot evaluation attempts to discover the closely related of spectral bands with water content that can be seen by using band 3-green and band 8-NIR instead. The NDWI of these spectral bands' combination of these spectral bands can distinguish the content of water from any other element in the features (Fig.4). A variable has a strong capacity to detect objects if they have a distance normalization > 1, which can be accomplished by using this combination of spectral bands. Wiweka, et al. (2014) also developed the NDWI formula using these green and near infrared (NIR) bands. Within a vegetated region, an rise in the reflectance value of visible spectral bands and a decrease in Infrared spectral bands (NIR, SWIR, MIR) will occur if there is a flood. In the meantime, the visible and infrared spectral bands will be decreased for open land (barlelad) (Wiweka, 2014).

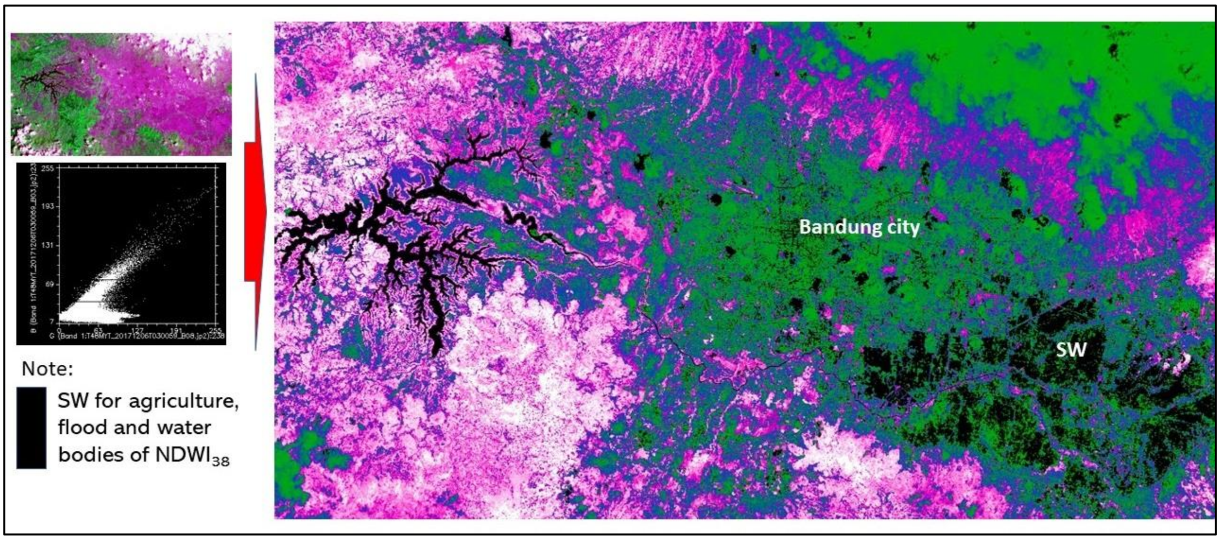
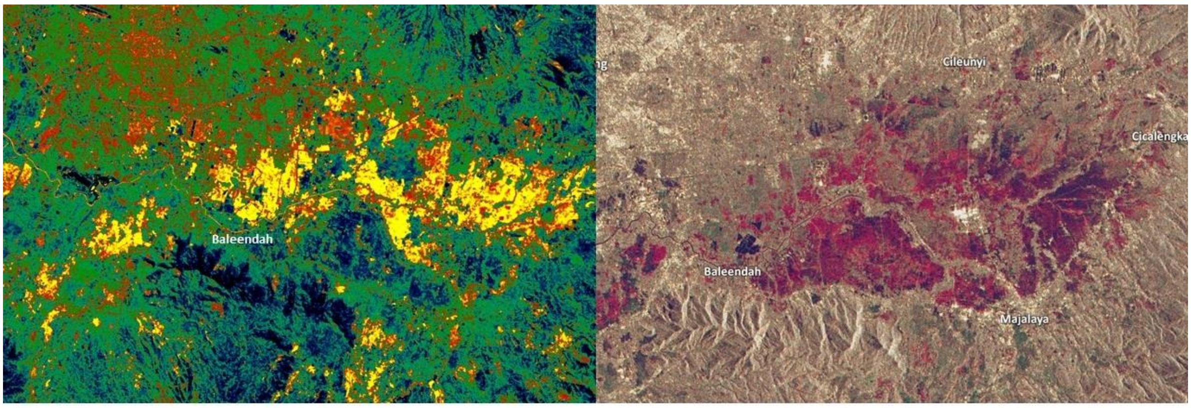


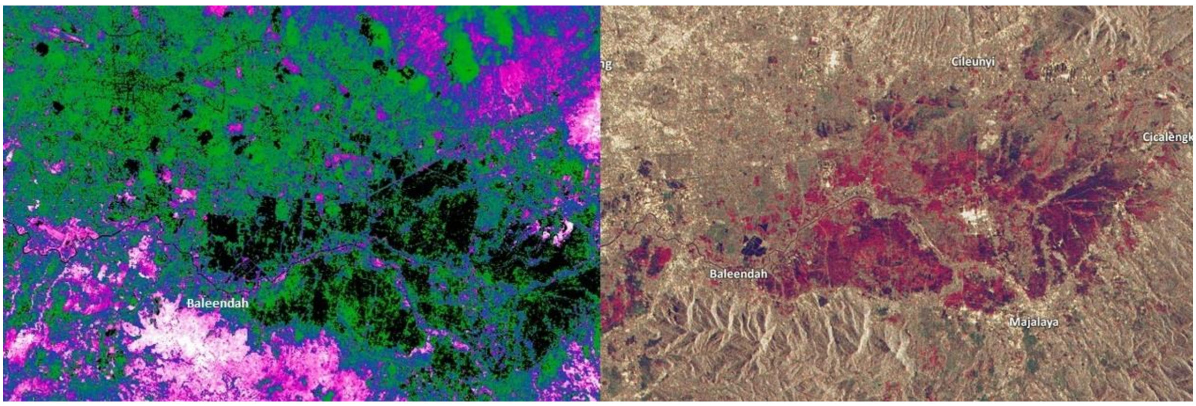
Fig 4. NDWI of Sentinel 2B - December 6th 2017

A sentinel 1A with VH polarization during the major flooding on 28 October 2016 (Kushardono, 2016) was used as reference for validation of both NDWI outcomes (Fig 5). On the rainy seasons' image, the spreading of water features is closed to the water features of reference images when the major flooding takes place. Whereas in the dry season, some of the water features are not link to the reference image of major flooding. Nevertheless, even both of these NDWI images can inform SW over seasons, either the rainy or dry seasons, but it cannot distinguish the SW related to the water bodies, flooding and agriculture. An assessment of the history of flooding must be evaluated using other ancillary data.

A study of the Bandung flood map showed that Bale endah, pameungpeuk, Ranjaengkek, Majalaya, cikandung, Cicalengka, even Bandung city has a lengthy frequent flooding history (Fig. 6). The map shows that the flooded regions (orange / orange colored) in Bandung Regency are located within the watershed of Citarum. Indeed, on Bandung Regency's topographic map, it can be seen that the flooded area are located at low topography compared to the surrounding region. These areas therefore have a lengthy history of flooding.



(a) $NDWI_{Ls}$ of dry season vs high flooding incident image on October 28th 2016



(b) $NDWI_{sen}$ of rainy season vs high flooding incident image on October 28th 2016

Figure 5. the Evaluation of NDWI images of dry season (a) and rainy season (b) with the occurrence of high flooding obtained by sentinel 1A on October 28th 2016 (Kushardono, 2016).

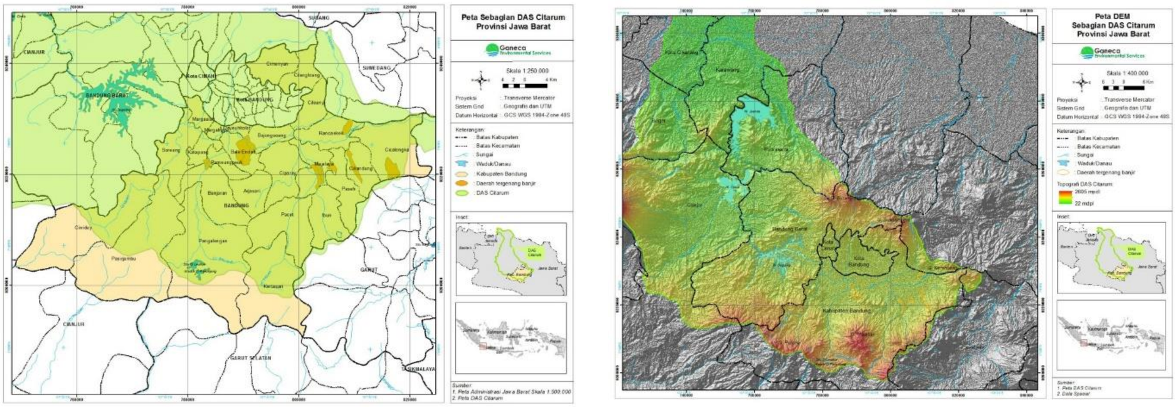


Fig 6. The map of Citarum watershed and flooding are (a), Topography map of Bandung (b) (Ganeca environmental services, 2017)

To evaluate how far the NDWI-based SW of particular spectral bands can be used to predict the flooding area, an evaluation matrix of flooded and not flooded area, excluding agriculture lands, was being assessed (Fig.7). The findings show that the SWs accuracy for $NDWI_{ls}$ are 75 % within the Pemeungpek, 26% for Bale endah area, 5 % within Majalaya, 32 % Cikadung and 45 Ranca engkek; and for $NDWI_{sen}$ are 2 % accuracy within the area of Pameungpuk, 5 % for Bale endah, 70 % for a Majalaya, 50 %for Cikadung and 91 % for Ranca engkek.

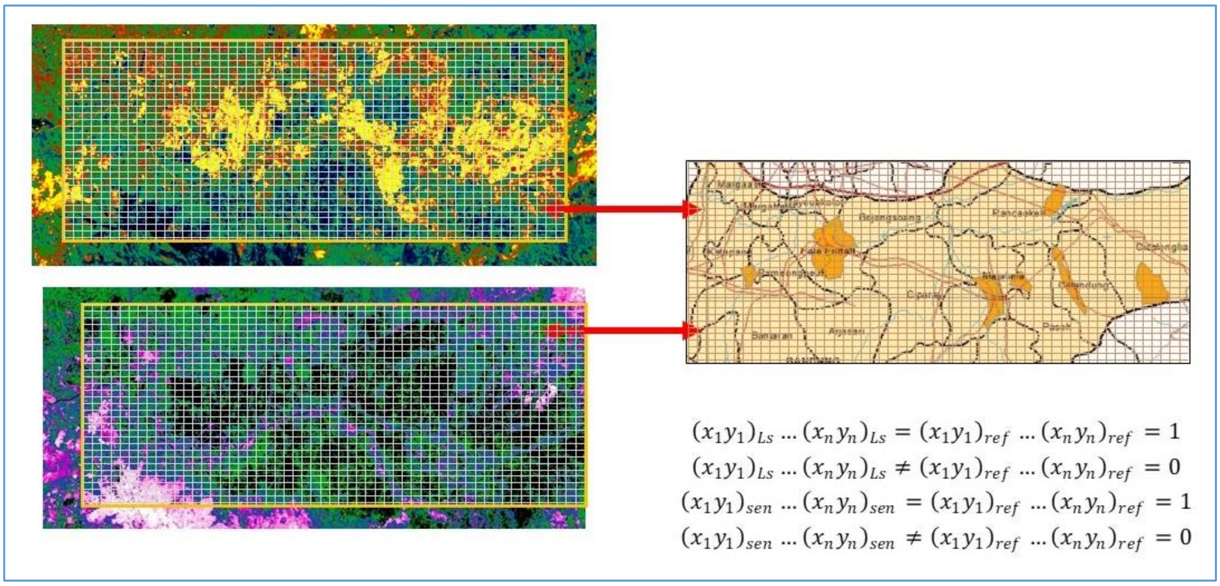


Fig. 7. evaluation matrix analysis Of NDWI derived images for accuracy assessment of SW to reference map of Flooding historical

Based on the evaluation, it can be said that SW derived from the NDWI algorithm can be used for SW mapping, but the relation with flooding needs to be investigated more specifically for seasonal analysis. In some area the flooding area are related to agriculture land, open area and vegetation covers, so it can be easy to identify the SW. But it some part such as build up area, the existence of building will decrease the ability to assess the SW. Therefore, within the built-up area, the flooding assessment based on SW only can be identified within the occurrence of flooding The traces of flooding are sometime disappeared with the dry season, living only a small part of traces that is not easily identify by using remote sensing data. However, both of the NDWI algorithms and spectral bands combination are able to map the SW. Although the findings are not as expected, there is a flood trace that can be identified by remote sensing analysis, the SW at least can be mapped with NDWI method and the spectral band combination developed in this study. Furthermore, the role of microwaves image in identifying the SW associated with flooding need to be further researched.

Conclusion

NDWI of SWIR and NIR of Landsat 8 Oli are able to map the Soil wetness of agriculture lands and some part of flooding area, and so, did the NDWI of NIR and visible green of Sentinel 2B. The prediction of SW for assessing the history of flooding only can be able to the frequent flood of sparse settlements, agriculture land and vegetations' cover area. It is unlikely to map for built-up area. Further study needs to be more explore to assess the trace of history of flooding based on satellite data imageries

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$$(x_1y_1)_{Ls} \dots (x_ny_n)_{Ls} = (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 1$$

$$(x_1y_1)_{Ls} \dots (x_ny_n)_{Ls} \neq (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 0$$

$$(x_1y_1)_{sen} \dots (x_ny_n)_{sen} = (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 1$$

$$(x_1y_1)_{sen} \dots (x_ny_n)_{sen} \neq (x_1y_1)_{ref} \dots (x_ny_n)_{ref} = 0$$