Detecting Tidal Flood Pattern with Landsat TM Remote Sensing Data in South Sumatra Coastal Area

Perkiraan Pola Pasang dengan Menggunakan Data Inderaja di Pesisir Sumatera Selatan

K. Nugroho[1], U.S. Wiradisastra[2], S. Arsyad[2], H. Pawitan[2], and Sudarsono[2]

ABSTRACT

Detecting the availability of sufficient water in tidal land management is important for agriculture. Tidal flood pattern provides an information of area where has tidal flood as well as drought by time and places. The objectives of this research are 1) to study the tidal flood spatial pattern by using real time data and digital data image processing, 2) to determine a tidal flood classification based on ground water level on a specific location and time, and 3) to study the hydrological factors affecting the flood. The tidal flood pattern can be classified within a block by their ground water fluctuation. The visual analysis with four image of different time, gives a clear differences between tidal flood pattern change and tidal fluctuation. The classification on the moist Landsat TM image after a Tesseled Cap transformation can produce classified image with similar flooded condition with the same range of ground water level. After the test, the tidal flooded pattern was found similar with the classification results. The tidal flood pattern is also recognized having a specific relationship with land use or land utilization type. The land use and land management affect the pattern. The application of geographical information system, especially remote sensing digital image data analysis, will help in determining tidal flood pattern as well as the ground water spatial pattern.

Keywords : *Tidal flood classification, Hydrological aspect, Image analysis*

ABSTRAK

Perkiraan kecukupan air tersedia pada pengelolaan lahan pasang surut sangat penting untuk pertanian. Pola pasang memberikan informasi daerah yang mempunyai pasang, baik menurut waktu maupun menurut tempat. Tujuan penelitian ini adalah 1) mempelajari pola spasial luapan dengan data lapangan dan pengolahan data inderaja digital, 2) menentukan klasifikasi luapan pada tempat dan waktu tertentu, dan 3) mempelajari faktor hidrologi yang mempengaruhi luapan. Pola pasang dapat diklasifikasikan dalam suatu blok dengan mempelajari turun naiknya air tanah. Analisis citra dari empat waktu memberikan perubahan pola dan turun naiknya tinggi pasang surut. Klasifikasi terhadap citra LANDSAT TM berdasarkan algoritma "*moist*" dengan transformasi "*Tesseled Cap Classification*" mampu menghasilkan citra terklasifikasi yang sama dengan kondisi pasang berdasarkan pengamatan di lapangan. Sesudah pengujian, pola pasang ternyata mirip dengan hasil klasifikasi data yang diamati. Pola pasang dikenali juga memiliki hubungan yang erat dengan penggunaan lahan dan pola pemanfaatan lahan. Penggunaan dan pengelolaan lahan menentukan pola tersebut. Penggunaan aplikasi sistem informasi geografi terutama analisis data digital citra dapat membantu menentukan pola luapan juga kondisi air tanah di lapangan.

Kata Kunci : *Klasifikasi luapan, Aspek hidrologi, Analisis citra*

INTRODUCTION

Background

Water condition in tidal land should be classified according to their tidal flood characteristics, both in term of spatial and time. There are several tidal (flood) land classifications (Direktorat Rawa, 1984; Widjaja-Adhi *et al*. (1992); and Noorsyamsi *et al*. (1984). Many researchers (Segeren *et al*., 1998; van den Bosch *et al*., 1998; Suryadi, 1995; Mudjiadi *et al*., 1998; Napitupulu *et al*., 1998) proposed the classification. Unfortunately, the tidal classification is not quantitative performing tidal flood spatial information. The recent tidal flood classification has not been informing tidal flood spatial pattern and water height. Widjaja-Adhi *et al*. (1992) classification were qualitatively and point oriented, without notifying flood occupation or reachability and flooding sequences (Table 1).

The classification can be improved by using the classification that related to the tidal height and the flood or ground water height according to geographical position, and actual ground water level. Therefore, the tidal flood pattern is needed to identify directly in the field at each point and in a real time, to create spatial information. The difficulties to obtain such data is that should be conduct in rigid observation scheme, with very high

1. Researcher from Indonesian Center for Agricultural Land Resources Research and Development, Bogor
2. Professors in Bogor Agricultural University, Bogor

Table 1. Swamp land classifications based on flood

Tidal flood type	Description		
	High tide	Daily high tide	Ground water level
A	Always flooded	Always flooded	Above near surface
B	Always flooded	Not flooded	Above near surface
C	Not flooded	Not flooded	< 50 cm from soil surface
D	Not flooded	Not flooded	> 50 cm from soil surface

(Widjaja-Adhi *et al.*, 1992)

cost, can be solved by using a spatial model and remote sensing analysis. The field performance can be proved identified the hydrological parameters. The remote sensing is clearly give a spatial performance, which can be proved related to the hydrological parameters.

Therefore, a study is needed to prove the relationship by using available real time digital satellite data. The hydrological aspect is studied in adjacent to the type of tidal flood pattern that also identified in the classified remote sensing data. The study performed two ways approaches. The remote sensing data analysis and the field point data spatial interpolation represent the tidal flood classification (in class pattern). Performance in two dimensional such as in a map, depend on coordinate positions in certain piece of land (Davis, 1973). A map is meant to provide a spatial distribution of water status in a piece of land. Then, water level in the field can be performed in three dimensional features. Tide reachability or tidal flood in certain field is performed as a map or geographical information.

The objectives of this research are 1) to study the spatial pattern of tidal flood using real time data and digital data image processing, 2) to determine tidal flood classification based on ground water level on a specific location and time, and 3) to study hydrological factors affecting the flood. The hypotheses are that the tidal flood spatial patterns performed by an image digital data analysis results and has a similarity with tidal flood patterns based on field measured interpolation data.

MATERIALS AND METHODS

Materials and tools

The research materials are images data Landsat TM 62/122, 15 June 1997, 5 January 1998, 7 May 2000, and 13 July 2001 of Telang Area, South Sumatra as real time image data. All coordinates were confirmed by terrestrial measurement using theodolite based on field map (Suratman, 1997) scale 1:40,000, topographical and soil maps scale 1:50,000. A Global Positioning System (GPS) data from a GPS type Garmin 45 help to fix the observation points. The statistics were counted by SPSS, whereas image processing used Idrisi Windows 2.0, Erdas-Imagine, ILWIS 2.2 and Arc-View 2.1 (ESRI). For geostatistics used Surfer Version 7.0 (Golden Software Inc.),

Water level observation data, at the point and time (real time) of each point stated as observation points.

Methods

Determination of tidal flood pattern

The water level is mapped using interpolation technique. There are main points which have been recorded their geographical positions. The coordinates are used to make an interpolation maps. The interpolation maps are considered as the actual data.

Tidal flood from image data analysis

Prerequisite Image Data. Optimum Index Factor (OIF) is used for recognizing the natural conditions compared to classification results. Cropping (of image) was meant to simplify the used of memory in computer. Image data were geo-referenced and rectification. The Landsat Image data were transformed. The transformation is executed to create a relationship between generated value and field conditions. The transformation included Maximum Likelihood, Principle Component Analysis (PCA), and Tesseled Cap (all in IDRISI version Window 2.0 from Eastman, 1997). The Tesseled Cap transformation (Crist and Cicone, 1984) stated that the humidity of earth surface is one of the results from the transformation moist. The other results such as greenness and brightness were not analysed. Image data classification was conducted with the transformed data.

Tidal flood pattern versus image classification

The results of image data classification were verified with point data interpolation.

RESULTS AND DISCUSSION

Tidal flood pattern in Telang

The interpolation, which make an isoline of area with the same water level, then can figure out the area where water is concentrated. It was shown in Figure 1. The isoline and delineation of water concentration from the field observation at 13th July 2001 approximately 11.00 local time, is a result from interpolation method used in this particular calculation, which are kriging, inverse distance, and neighbourhood (Figure 1). The result from the three interpolations show that the kriging method has a more realistic from the other two methods. The interpolation of the field data of 13th July 2001, shows that the southern part of the research area or western part of the J4 is drier than the rest of the research areas.

The interpolation result from different day (10 July 2001), three days before the Landsat data were taken; 13 July 2001 or the day when the Landsat TM data were taken; and 16 July 2001 or three days after the Landsat TM data were taken), shows the changing of water concentration in the field (Figure 1).

The first data interpolation (10 July 2001) shows that the whole area was generally wet. The water concentration at the time when the image data were taken at 13th July 2001 (about 11:00 local time) there is an area which is drier in the middle, that more pronounced at 16th July 2001. The whole areas at that time have deeper water table.

The research result agrees upon the above mentioned statement. Four times of observation indicated a similar condition. During the research execution (March 2001 up to February 2002), the rice field area was very limited in dry season, and covers a larger area during rainy season. During March, the area indicated as rice field but have been harvested twice larger of the planted area.

Tidal flood from remote sensing image data

From four Landsat data with the same row and path but of different time (7 May 1997, 10 January 1998, 23 June 2000, and 13 July 2001), they were performed in image composition Band 5, Band 4, and Band 3 (Figures 2, 3, 4, and 5). The composition is taken after an analysis, which considered Optimum Index Factor or OIF (Jensen, 1996).

In 1998, the largest OIF value is a combination of Band 541, but when it was performed, the combination Band 543 with rather smaller OIF is give the OIF Band 541 is not clear. In Figure 2, 3, 4, and 5, the three Band compositions are performed using three color palettes Red Green Blue (or RGB). The figures indicated that three locations which strong features of tidal can be recognized easily by changing in “wet area”. The specific vegetation (mangrove) indicated the tidal influence.

Figure 2 is a Landsat TM image data that consist of composite image of Band 5, Band 4, and Band 3 at 7 May 1997. It has been performed in RGB

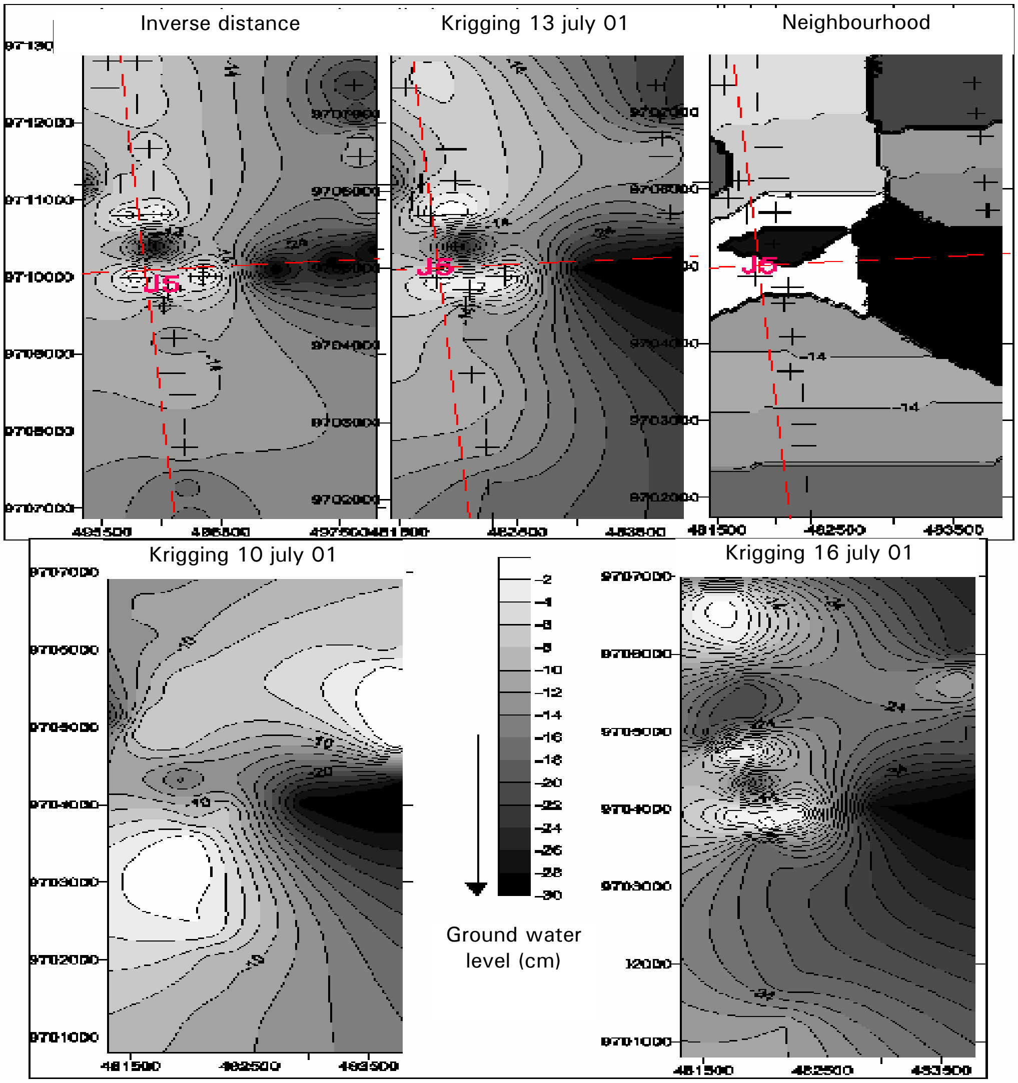

Figure 1. The interpolation maps of ground water level as generated by three different techniques in Telang

color, showing a natural color of dry season. The daily tide is close to the maximum. The seasonally tidal flood is considered as neap tide. Figure 3 is a Landsat TM image data consist of composite image of Band 5, Band 4, and Band 3 at 18 January 1998. It has been performed in RGB color, showing a natural color of the peak of rainy season. The daily tide is closed to the maximum. The seasonally tidal flood is considered as neap tide.

Figure 4 shows a Landsat TM image data consist of composite image of Band 5, Band 4, and Band 3 at 10 June 2000. It has been performed in RGB color, showing a natural color of the beginning of dry season. The daily tide is closed to the maximum. The seasonally tidal flood is considered as high tide (full moon tide). Figure 5 is a Landsat TM image data consist of composite image of Band 5, Band 4, and Band 3 at 13 July 2001. The figures are performed in RGB color, which are showing a natural color of the peak of dry season. The daily tide is passed the maximum. The seasonally tidal flood is considered as low tide (dead moon tide).

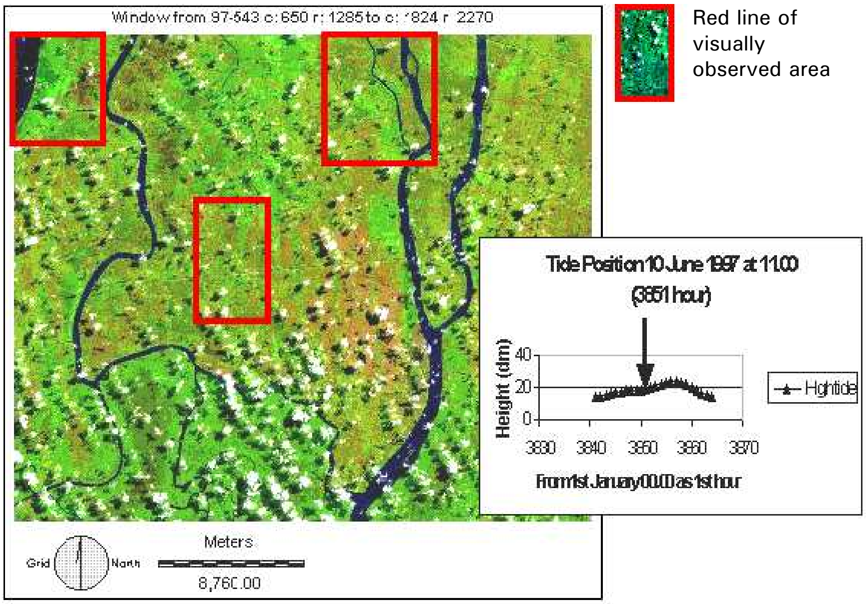

Figure 2. Composite Landsat TM band 543 of Telang in 7 May 1997

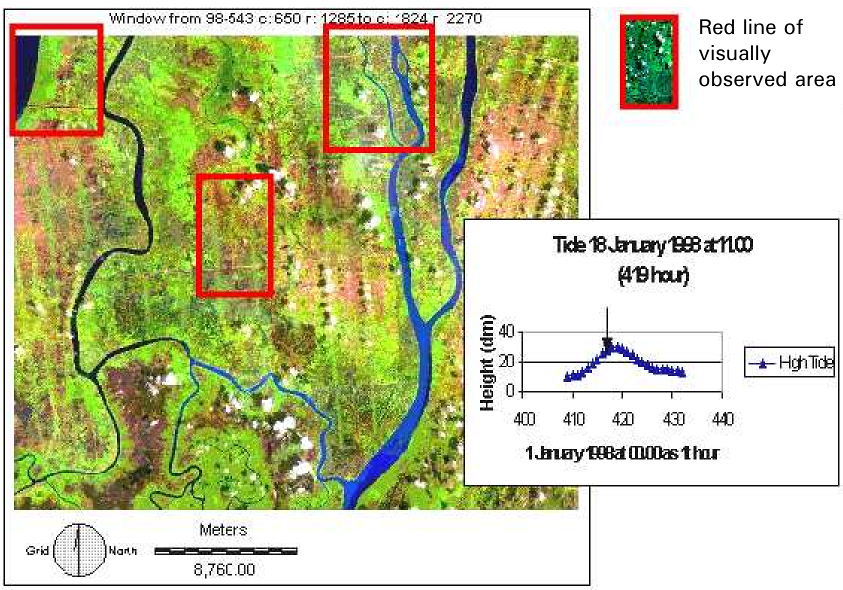

Figure 3. Composite Landsat TM band 543 of Telang in 18 January 1998

The use of single band to see the value reflected the water conditions is executed by testing at the points (pixel cluster) around the piezometer. It gives information that Band 1 has a significant relationship with water level (Table 2). Transformation Tesseled Cap differentiated pixels as their wetness (moist), greenness, and brightness in three data files (Crist and Cicone, 1984). The transformation results of Tesseled Cap transformation in their "wetness" or moist can be shown in numerical histogram.

Table 2. Correlation between field measurement and spectral value

	Water level	Tesseled Cap	BAND 1
BAND 1	-0.667*	-0.656*	1.000
Tesseled Cap	0.713*	1.000	-0.656*
Component 1 PCA	-0.121	-0.525*	0.556*
Component 2 PCA	0.128	0.292	-0.393
Component 3 PCA	0.006	-0.101	0.182

* Correlation significant at level 0.01

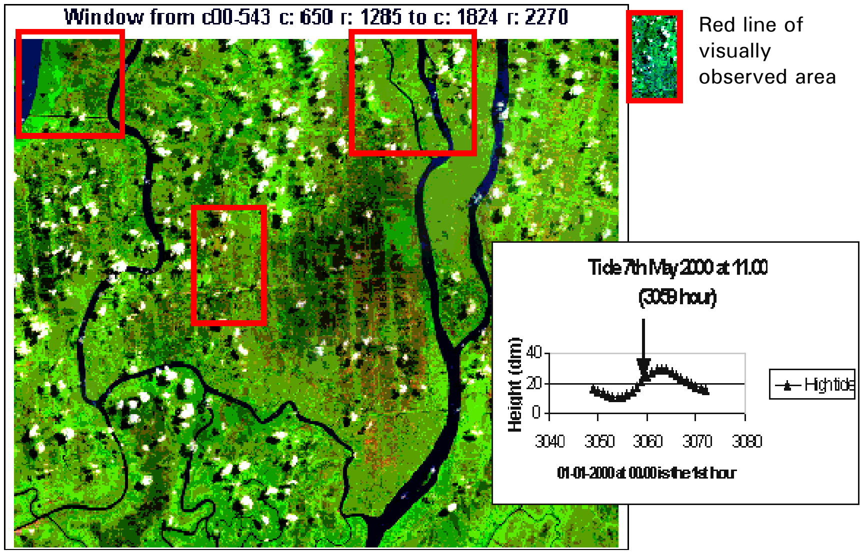

Figure 4. Composite Landsat TM band 543 of Telang in 10 June 2000

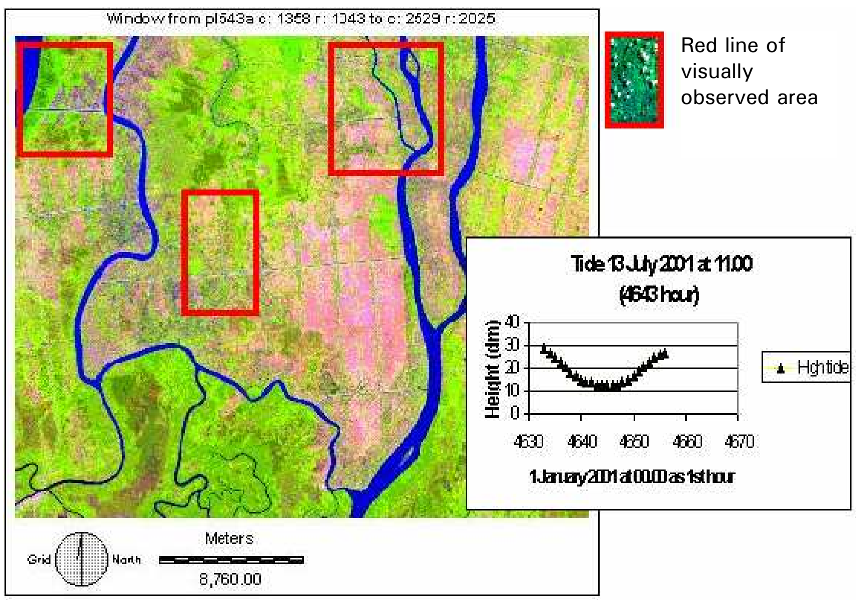

Figure 5. Composite Landsat TM band 543 of Telang in 13 July 2001

Figure 6 shows the relationship between spectral value, as the result from Tesseled Cap transformation (Landsat TM 13 July 2001) digital image data, and water level.

Classification result from digital Landsat TM image data after a Tesseled Cap transformation from 1997, 1998, 2000, and 2001, is shown having a variation. Figures 7 and 8 are overlaying between image data classification of July 2001 and field, which shows a test that proved there is a relationship between the image and field data. Field measurements were made from interpolation technique (krigging) and having a spatial pattern that shows, in some respect, an area where water accumulated (having a specific flood pattern).

The differences between the image data classification and the field data interpolation pattern are shown in those two figures. Figure 8 is oversized of Figure 7. In Figure 8 the water level pattern in three different days were shown. The first figure is three days before the observation day (when the image data captures from Landsat is coincide with the day and time of water level observed in the field).

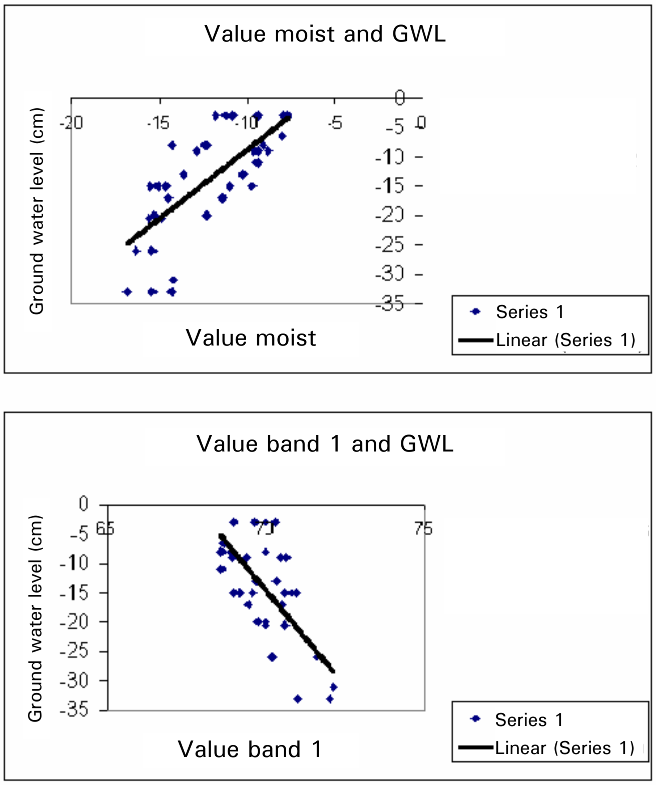

Figure 6. Linear regression value and actual ground water

The third figure is three days after the observation day. A former research result shows that the tidal flood condition can be traced from the changing of land use pattern. From the visual interpretation of two season observations, Suryanto *et al*. (2000) and Deri *et al*. (2000) found the tidal land rice field were vary according the tidal land classification (Widjaja-Adhi *et al*.,1992) which are classified as A, B, or C. Tidal land classified as A was used as rice field with two planting time (two harvest times). Tidal land classified as B was used as rice field with one planting time (one harvest time). When the land is not an A or B type of tidal land classification, then the land was not categorized as rice field.

Interpretation with different season image data is also indicated that the growing season of the area, has related to the wetness or moisture conditions of the area. The use of TC transformation is helpful to inform the area that had been capable to support sufficient water during the dry season to grow rice. The planting date for each step of rice field cultivation can be arranged or rearranged using the information. The considered variation is also can be predicted from the seasonal/ temporal image data analysis.

The tidal reachability is determined by the canalization. The conditions are shown by the image data analysis. A test that approved the image data can be used for tidal flood analysis by superimposing the image data and available vector data. Almost all the canal network data were available in vector data (Ananto *et al*., 1998). The image data is reinforcing the performance by strengthening the line with more impassive tone differences group of raster.

The most impressive image data performance comes from composite image data and single band image data. From single band Landsat TM, the most impressive is Bands 1 and 3. The composite image is from Band 543 with Red Green Blue coloring.

The overlaying image data and vector data gives us more reluctance about the tertiary and secondary canal conditions. The changing in condition can be monitored from the temporal data. The result of overlaying can give us the data of damage canal locations. As the drainage canals broken or disturbed, the area then submerged creating closed basin or submerged area. The Landsat TM (composite Band 5, Band 4, Band 3) shows those phenomenon (Figures 2-5). The damage in canalization is also recognized by field survey (Ananto *et al*., 1998).

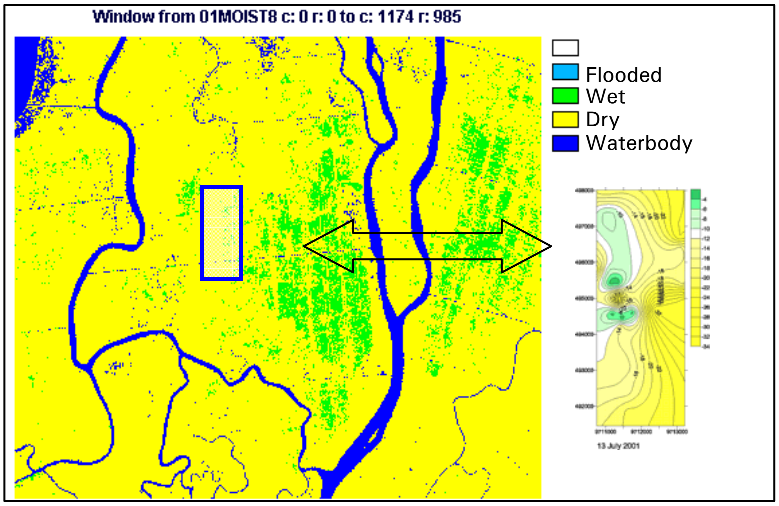

Figure 7. Image verification with water level interpolation at 13 July 2001

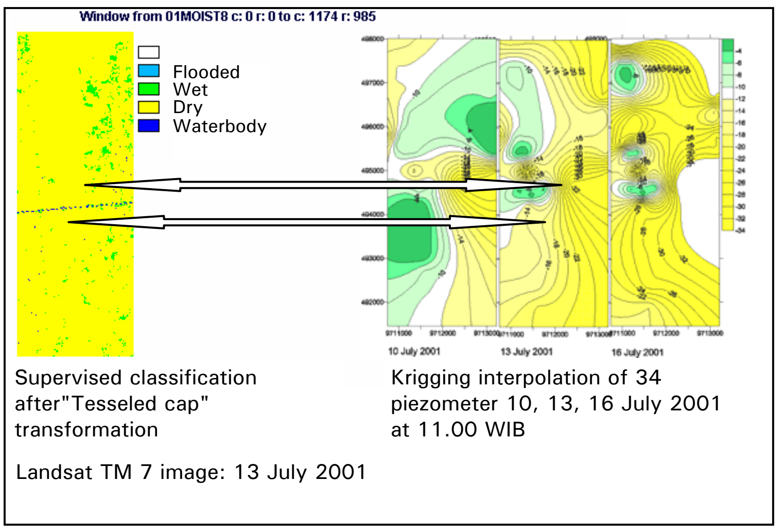

Figure 8. Detailed figure of ground water level verification

The use of overlaying technique (GIS) between the vector and image data (Landsat TM) as a facility from IDRISI (Eastman, 1997), in fact was strengthened the view and features of submerged area. By a comprehensive monitoring with a systematic procedures (using the coordinates and the benchmark), then the data is supported each other. Hydro-topographical Performance of Landsat Image data vector field tertiary and canals hydro-topography Landsat TM image data Single Band 1, 2 or 3, image data from Tesseled Cap transformation as "moist". The hydro-topography from image tone can considered as clue to the changing of hydro-topography. Overlaying vector (contour) gives information of the area of depression and the raised bed. Elevation changing as mentioned by Suryadi (1995) shows hydro-topography conditions clearly in the field (from terrestrial). There are varieties in hydro-topography, due to the *surjan* reclamation of the area, improvement in dyke and canals, and the changing of land-use. The sloping starts from Jembatan 2 as shown in Landsat TM 13 July 2001 is drier. The other condition of hydro-topography is ground water level.

The availability of water is determined by the tidal flood, that were affected by tidal reachability (tide height) and also the length of tide at one places and at one consecutive time. The effect of hydrological factors on tidal flood is clearly observed from water flow phenomenon in a hydrological model. The tidal flood is also depend on the geographical positions and hydro-topographical situation. The effect is observed from tidal flood fluctuation variation. The former tidal land classification can not give any information concerning the length and height of tidal flood, unless it is calculated or observed as in Telang. There is no relationship between the tidal land classification and the tidal flood classification and the height of tidal flood. Indication of the height is only pronounced from the water level calculation/ measurement, not from one time one spot observation. The variability of soil conditions, land use or land cover, and water management is usually becoming source of an error in extrapolating a point calculation result to a spatial performance. Therefore, a choice of using the model extrapolation/ interpolation program should be notify.

The 13th July 2001 Landsat image data have a good enough resolution (Landsat TM 7). To anticipate the difference performance of image data from different season/time, a temporal data should be used instead. This research used single time LANDSAT image data (13 July 2001) as a real time data, with three more data that related to the other part of the years. From the main data performance (extreme dry seasons), the water level is proven well recognized by using Tesseled Cap transformation (from IDRISI) and Supervised classification. A raised water level as an affect of the tide (from tidal data) conformed with wet or flooded area in Landsat data (composite from Band 5, 4, and 3 in RGB color) interpretation, were shown in many part of the research area (Figures 2, 3, 4, and 5). Then, to perform the difference of tidal flood height in two different time, at least two image data should be provided.

The result from image data processing by a transformation procedures (Tesseled Cap transformation IDRISI), which were recognized as ”moist”, is classified into four classes. The classes are water body (including sea, river, and lakes), flooded or submerged land, moist or wet land, and dry land.

Land cover and cropping pattern in the field is conformed with the water level or tidal flood classes.

Hydro-topographical factors are crucial in performing flood area quantitatively (as the water can make a benchmark or standard of elevation). The deeper part observed meant it has lower surface level.

Reclamation (excess drained) or land management would change the flood pattern. The water management zone should recognized the impact. The water availability in certain area should be recalculated by inputing the land cover effect. The land use performed in the end of rainy season (image 13 January 1998) is quite different from the land use performed in dry season (image 14 July 2001). The flood area delineation correction should be made upon the Landsat image data processing interpretation results.

CONCLUSION

1. Flood type in a specific location based on time of direct observed ground water level for each day or each season, in Telang South Sumatra has a large variation, that specified by time and location.
2. The use of prediction model and digital image data processing can make the tidal flood type classification easier. The image data processing using Tesseled Cap transformation shows good spatial performance of tidal flooded area.
3. To assure water availability in a water management scheme, tidal flood type should be determined by height of water in the land

affected by tidal reachability and length of flood. Hydrological factors such as canalization, climate, soil physical properties, geographical position to inlet, and hydro-topography affect the height and time of flood.

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