Remote Sensing for Disaster Projection Model

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Abstract: Natural disasters are natural phenomena that cannot be avoided by humans, but human beings are able to mitigate its impact for the humanitarian aspects. Therefore, monitoring, predicting and managing natural phenomenon in the earth is one of the methods to mitigate disaster - one of them by using remote sensing technology. Integrated of imageries from near real-time remote sensing satellite system to the higher resolution with the support of the ancillary data may develop spatial information for any mitigation purposes. Therefore, the aim of the study is to assess rapid information of the prone area and the possibility of developing a projection model with the remote sensing approach. The steps included the assessment of prone area by implemented the integrated method of NDVI, fuzzy and high pass and the overview of the projection model using remote sensing approach. The disasters associated with landslides may be used for example, because this disaster often struck the Asian region. The result of the assessment indicated the integration of NDVI, fuzzy and high pass method can give faster information of the landslides hazards that is needed for disaster and humanitarian institutions. Meanwhile, to develop a projection model for the hazards cannot be developed only on remote sensing technique, but better support by GIS technique and other in situ ancillary information.

Keywords: Disaster, remote sensing, projection, Landslide, Banjarnegara

1. Introduction
Natural disasters often occur in some part of the world and may affect a large number of vulnerable communities. Disaster mitigation is one of the solutions that can be implemented to overcome the humanitarian problems caused by the disaster. Monitoring, predicting and managing natural phenomenon in the earth is one of the methods to mitigate the disaster. For these purposes, spatial information or mapping the impacts area is an important part of disaster management purposes and indeed a good tool for humanitarian action to plan any emergency responses or other humanitarian activities.

Satellite remote sensing is the ideal tool for disaster management since it offers information over large areas, and a short time interval [20]. Just-in-time analysis of disaster and crisis areas using optical and radar satellite data dedicated to supporting humanitarian decision making and ground operations by increasing situational awareness called as UNOSAT humanitarian rapid mapping [21] has been acknowledged for years. This humanitarian purpose is possible to be accomplished either by employing remote sensing or other terrestrial or ancillary information.

Therefore, considering Indonesia as one country that has annual historical experiences of disasters, the continuous spatial information of disaster risk area is urgently needed. A projection model needs to be developed for answering this issue. Integrated the near real-time remote sensing data, either active or passive, added by local knowledge is one of the science-based tools that provides a practical rapid
mapping technique for decision makers and end-users. By considering landslide as the major disaster that quite often occurred in Asian countries, such as Indonesia, the prone area of Banjarnegara regency – central Java, Indonesia - which has been attacked by landslide couple of times will be used as the study area. [11] supports the study of landslide disaster and it is associated flood because these disasters have been accounted for the largest number of natural disasters and affect more people than any other type of disasters. Indeed, in the national history of landslides, Banjarnegara is one of central java district that has a long history of landslides, especially during the rainy seasons. More than 90 % of the area is undulating, hilly and steep slopes with the high saturation type of soils [22]. The hilly area with less of trees on the top, type of soils and rocks and so does the soil saturation may trigger the landslide in some steep part of the area.

The aim of the study is to assess rapid information of the prone area and the possibility of developing a projection model with the remote sensing approach. The steps to obtain including the assessment of prone area by implemented the faster-integrated method of digital image processing and the overview of the projection model using remote sensing approach. It is hoped that with the implementation of this study, the rapid method of disaster spatial information by using remote sensing, along with its forecasting items can be developed and able to decrease the number of humanitarian issues caused by a disaster.

2. Method
Remote sensing techniques represent a powerful tool for landslide investigation [18]. For this project, applications are divided into two main steps although this subdivision has some limitations. The first step is to develop the techniques for faster landslide spatial information. The second step is an overview of landslide forecasting using remote sensing approach. The explanation of the method is as follow;

2.1. Remote Sensing Technique for Rapid Information of The Prone Area
When a disaster occurs, one thing that the related institution needs is the rapid information with regard to the location and environmental conditions surrounding the disaster area, whereas this issue can be met by using remote sensing technique. The right alternative to get this information is by using visual analysis or by using digital image processing method that can provide a fast result, among others by using NDVI, enhancement and fusion method

This study examines to use the integration of NDVI, linear stretch, Brovey transforms and high pass and method which implemented by using Landsat 8 Oli and Sentinel 1 at the study area of Banjarnegara district (Figure 1).

![Figure 1. The Study Area in Banjarnegara district, central java – Indonesia](image)

The analytical process is as follows

2.1.1 NDVI Analysis. Satellite remote sensing for quickly responding to disasters still faces a certain challenge in real-time data collection [23]. Therefore, the near-real-time remote sensing data become the best alternative to provide information for disasters area. [23] define the time of near-real-time approximately the first 72 hours after an event.
In this case, analysis of the medium temporal resolution satellite image such as Landsat 8 Oli is the prior possible analysis to be employed, since this imagery can be freely downloaded. The fastest method is by simply identified the prone area after the images have been quickly rectified using an international/national standard such as SRGI 2013 (Indonesian Geospatial References System 2013).

NDVI method used to identify the prone area. [12] believe that the implementation of NDVI method to assess the environmental change and disasters provides simple and rapid information.

The automated formula of NDVI was developed to assess this prone area

\[ P_A = \frac{I_{NIR} - I_R}{I_{NIR} + I_R} \]  

\[ P_B = \frac{I_g - I_b}{I_g + I_b} \]

So \[ P = P_A + P_B \]

Whereas \( P \) = prone area, \( P_A \) is the prone area using the NDVI method of A \((I_{NIR} \text{ and } I_R)\), \( P_B \) is the prone area using the method of B \((I_g \text{ and } I_b)\). \( I_{NIR} \) = near infrared, \( I_R \) = visible red, \( I_g \) = visible green, \( I_b \) = visible blue.

Besides that, an automated Linear contrast stretch is a good method to identify the nearby area, residential, infrastructure and other linear information to make the visualization of the image enhance [1], [4],[5], [13]. The formulation of the analysis was described as follow;

\[ g(x,y) = \frac{(f(x,y) - \text{min})}{(\text{max} - \text{min})} \times 255 \]  

Where \( g(x,y) \) = output image, \( f(x,y) \) = input image, \( \text{min} \) = minimum intensity value in the current image and \( \text{max} \) is the maximum intensity value.

2.1.2 Image Fusion. Pan-sharpening is the process to fuse a low-resolution multispectral (MS) image with a high-resolution panchromatic (Pan) image to construct high spatial and spectral resolution MS image [10]. In this case, the prone area Landsat 8 Oli derived map were fused with Sentinel 1 image. This Sentinel data was also previously geo-corr ected with SRGI 2013. The process to obtain a new pan-sharpening image was using a simple Brovey transform [8] combine with the high pass filter.

The formula of Brovey transform can be explained as following

\[ R_{new} = \frac{R}{(R + G + B)} x \text{PAN} \]  

\[ G_{new} = \frac{G}{(R + G + B)} x \text{PAN} \]  

\[ B_{new} = \frac{RB}{(R + G + B)} x \text{PAN} \]

Meanwhile automated high pass file using [5x 5] kernel was implemented over the fused image. High pass filtering is the best solution to map the infrastructure or other feature that is not available in the previous optical images. This method merges the high frequencies of panchromatic to multispectral images data to obtain higher multispectral resolution image.

2.2. Assessment of Landslide Projection Model

Modeling disaster forecasting is a very useful tool for mitigating the impact of disasters, both physically and humanely. Relating to the research that has been conducted related to disaster projection, especially landslide disaster, the qualitative assessment approach by utilizing an overview from some research to
assess the criteria of projection model was being employed. Thus, what can be done with remote sensing technology can be inventoried for future research implementation.

3. Discussion

3.1. Analyzing The Prone Area

Example of the result of rapid information for the prone area of landslide within the Banjarnegara region can be seen in Figure 2 as follow:

![Figure 2](image)

**Figure 2.** The result of integrated analysis of NDVI, Brovey transform and highpass method

It clearly proved that the prone area can be fully identified by using the integrated method of NDVI, Brovey transform and High Pass filter. However, the results of the analysis with Landsat 8 Oli data by using NDVI method cannot describe the detailed information of the prone area due to the spatial resolution of the Landsat and the extent of the prone area (Figure 2-a, 2-b, 2-c). This condition indicates in Figure 2-d which illustrated the need for more detailed information related to the impact/prone areas of landslide disaster.

For the small impact area of a natural disaster such as landslide in Banjarnegara, seems the utilization of the near-real-time remote sensing and mid-spatial resolution data such as Landsat 8 Oli data need to be more assessed by using another high-resolution remote sensing data. The highest temporal resolution of
a remote sensing data is contradicted with the lowest spatial information, in which the highest temporal resolution is urgently needed to indicate the prone area for further management and humanitarian aspect, especially for providing early warning information of a disaster, no matter how small the extend prone area is.

Multi-temporal and multi-sensor remote sensing data can be used for selecting the best data to indicate the faster information of Landslide disasters. NOAA AVHRR, Modis, Feng Yun or Terra Aqua is the best rough scale remote sensing imageries that can prior indicate disasters. Other more detail remote sensing data such as Landsat 8 and Pleiades and so does Formosat is the second layer that can give more detail information on the landslide (see Fig.3).

These multi-sensor data was used to see lots of information regarding the changes before and after the landslides. Besides that, the multi-sensor imageries can be used to indicate the landslide, the trend and the option of post-disaster and pre-disaster management.

![Landsat 8 Oli, Modis, Pleiades](image)

**Figure 3.** multi-sensor image for Banjarnegara Area (courtesy of Lapan)

Nevertheless, the results of NDVI analysis on Landsat 8 Oli indicates that this imagery is able to indicate the location and the environment condition around the prone area which is very necessary for post-disaster management and the humanitarian aspects. [2] support this result that the NDVI can be used for the situation of unfortunate natural disasters to provide humanitarian aid, damage assessment and furthermore to device new protection strategies. The accuracy assessed on the basis of independent data on natural disasters was high -76% correct for the NDVI-based map [17]. Even though, by using the higher spatial resolution, the more detailed information of the prone area will be obtained.

Meanwhile, the result of image fusion using the Brovey transform method can give more detailed information rather than the single NDVI derived image (Figure 2-d). [14] support this method that accordingly SAR data complemented Landsat 8 data which had enriched spectral information and enhanced geologic information. The SAR classification depicted landslides along the ridges and lineaments, important information lacking in the Landsat 8 image classification, whereas the success of landslide identification and classification was attributed to the enhanced geologic features by spectral, textural and roughness properties [14]. The importance of image fusion methods between optical and radar data to quickly and clearly identify the prone area can quickly be obtained by employing the simple method of NVI, liner stretch, Brovey transforms and high pass filtering, which was needed by decision makers of disaster and humanitarian institutions. It is meant this method can be further employed for the projection model of a natural disaster.

### 3.2. Assessment of Projection Model

For the prone area model that can be quickly assigned to decision makers, the integrity of the three formulas in a model is reliable. However, to develop it into a projection model requires further analysis, taking into consideration the various criteria that enable landslide disaster. In general, the factors which influence whether a landslide will occur typically include soil, slope angle, climate, weathering, water content, vegetation, overloading, geology, and slope stability [3],[6],[7],[9],[19]. The role of remote Sensing to landslide disaster consists in deriving various parameters related to landslide predisposing and triggering factors. For those criteria, slope, climate-related to rain, water content and vegetation cover can be obtained from remote sensing data processing. There is (a) the slope issues can be derived from a digital elevation model (DEM) of remote sensing data, (b) climate, especially the raining projection, can be obtained by using Hiwari, Terra aqua or other near real-time remote sensing data, (c) water content
can be obtained by using ratioing method, (d) vegetation cover can be obtained either by using NDVI or supervised/unsupervised classification method, (d) overloading related to settlement/agricultural activities or infrastructure can be obtained from remote sensing data by using NDVI or supervised/unsupervised classification method. However, for soil, geology, weathering and slope stability the ancillary data need to be obtained from techniques other than remote sensing.

Another projection model with remote sensing approach has also been implemented such as by [15] who use the SMOPRH model for projecting the prone area. This method used to project the prone area based on slope aspect only, by using Aster GDEM [15]. But the real utilization of this model in the field cannot be ascertained, because the landslide problem is not analyzed by using only one element such as slopes. For example, by assuming the landslide as the hydrological disaster only, at least other aspects such as land use, soil moisture/soil water content must also be taken into account in arranging the projection model of a landslide. Disaster-prone projection with hydrological approach can use the NDVI method to determine vulnerable areas of land use, where open areas can be categorized as vulnerable; soil water contents can be assessed by the ratioing method, where areas with soil moisture or high soil water content can be categorized as prone area; and combined with a steep slope that may derived from the DEM image data. All can become input to determine landslide-prone areas. Integration of the four methods as mention before is a highly recommended input to forecast landslide-prone areas

[18] states that the projection of Landslide should depend on geomorphology, topography, geology, land cover and hydrology. An effective approach to landslide forecasting should go through the integration of RS techniques into spatial sensors networks [18] and which are able to gather various kinds of information from contact sensors, geotechnical sensors, and multi-platform RS techniques. Other authors followed this approach such as [16] that proposed an integrated approach to landslide research based on remote sensing and sensor networks. This approach is composed of three important parts: (i) landslide susceptibility mapping using remote-sensing techniques for susceptible determination of landslide spots; (ii) scaled-down landslide simulation experiments for validation of sensor network for landslide monitoring, and (iii) in situ sensor network deployment for intensified landslide monitoring

Taking into account the rapid model of identifying the prone area as described in section 3.1, the inventory of the prone areas can be assessed. Based on the results of this inventory, the criteria of each prone area can be analyzed in which this analysis is related to the key interpretation of the remote sensing data. Thus, disaster-prone areas can be mapped and with the input of satellite remote sensing rain data, the precursor to disaster events can be assessed.

All those methods need to be integrated to develop a landslide projection model based on remote sensing. By overlapping the result of prone area forecasting from a projection model and the near real-time prone area model, as explained in subchapter 3.1, the accuracy of the projection model can be further assessed and the real prone area can be determined for real to the decision makers.

However, still, it can be stated to obtain the accurate projection model of landslide disaster cannot be developed only on the remote sensing technique. Other techniques by using a geographical information system that may consist in situ data and other ancillary data can be used to develop the model. The multi-temporal and multi-sensor remote sensing data are should better be used to obtain the accuracy of the spatial information model of landslide disaster.

4. Conclusion
Rapid identification of disaster area can be done by using integration of NDVI linear stretch, Brovey transform, and high pass method. However, to develop it into a predictive model based on a remote sensing technique requires another approach, whether using a complex approach or by using a simple approach, such as a hydrological approach. Completeness of supporting data such as slopes, vegetation, soil moisture/soil water content, overloading can be obtained by using the integration of the above method and equipped with rainfall data derived from remote sensing analysis. This method of course still has weaknesses.

Another solution is to create disaster-prone maps based on previous disaster events inventory, which then each of these disaster areas are characterized by a remote sensing key interpretive approach. So that it can be specified parameters and remote sensing data needed. Still, this method has some limitations. Therefore, to get this projection model required another technique besides remote sensing or a combination of both. Hybrid methods that incorporate remote sensing techniques, GIS, ancillary data
from field survey techniques is the best alternative that needs to be further studied in order to obtain more precise landslide projection model.

References

[1] Al Amri, Saleh Salem, N.V. Kalyankar and S.D. Khamitkar. 2010. Linier and Non-linier Contrast Enhancement Image. International Journal of Computer Sciences and Network Security, Vol. 10 No.2, pp 139-143

[2] Bhandari, A.K, A. Kumar and G.K. Singh. 2012. Feature Extraction using Normalized Difference Vegetation Index (NDVI): A Case Study of Jabalpur City. Procedia Technology, Volume 6, 2012; pp 612-621. doi.org/10.1016/j.protcy.2012.10.074

[3] Brunsden, D. 1973. The application of system theory to the study of mass movement, Geologia Applicata e Idrogeologia, 8, Part 1, Nat. slopes stability conserve., proc. IRPI(CNR) conf (1973), pp. 185–207

[4] Campbell, James B and Randolph, H. Wynne. 2011. Introduction to Remote Sensing. 5th edition. Guilford Press. USA

[5] Chen, Biao., Shahram Latifi and Junichi Kanai. 1999. Edge Enhancement of Remote Sensing Image Data in the DCT Domain. Image and Vision Computing. Vo.17, issue 12, pp 913-921

[6] Cho, K., Misono, T., Shimoda, H., 2007. Study on extracting sea ice area from MODIS data for the Okhotsk Sea. Proc. of the 22nd International Symposium on Okhotsk Sea & Sea Ice, The Okhotsk Sea and Ocean Research Association, C-3, pp.42-45

[7] Dinata, I wayan Hewik Indra. 2013. Pemetaan Daerah Rawan Bencana Longsor di Kecamatan Sukasada Kabupaten Buleleng (Mapping the susceptible Landslide in Sukasada District, Buleleng Regency). Jurnal Jurusan Pendidikan Geografi, Vol.3 No1, pp1-10

[8] Earth Resource Mapping Pty Ltd. 1990." The Brovey Transform explained", EMU Forum. vol. 2(11). Available in www.ermapper.com/forum/new/emuf211.htm#articale 5

[9] Efendi, Ahmad Danil. 2008. Identifikasi Kejadian Longsor dan Penentuan Faktor faktor Utama Penyebabnya di Kecamatan Babakan Madang Kabupaten Bogor (Identification of Landslide Case and Determination Main Cause of Landslide Case in Babakan Madang Sub District, Bogor District). Skripsi/Essay, IPB, Bogor

[10] Helmy, A.K and Gh.S El-Tawel. 2015. An integrated scheme to improve pan-sharpening visual quality of satellite images. Egyptian Informatics Journal, Volume 16, Issue 1, March 2015, pp121-13. doi.org/10.1016/j.eij.2015.02.003

[11] Hong, Yang., Roberts F.Adler, Andrew Negri, George J. Huffman. 2007. Flood and Landslide Applications of Near Real-time Satellite Rainfall Product. Natural Hazard, Vol 43, issue2, pp 285-294

[12] Liu, Yongqiang, John Stanturf and S. Goodrick. 2010. Wildfire Potential Evaluation During A Drought Event With a Regional Climate Model and NDVI. Ecological Informatics. Vol 5/5, pp 418-428

[13] Liu, Jian Guo and Phillippa J.Mason. 2013. Essnetila Image Processing and GIS for Remote Sensing. Wiley-Blackwell. A John Wiley &sons, Ltd., Publication

[14] Mwaniki, D.N.,Kuri, M.K.Boitt, T.G.Ngigi. 2017. Image enhancements of Landsat 8 (OLI) and SAR data for preliminary landslide identification and mapping applied to the central region of Kenya. Geomorphology, Volume 282(1):162-175. Geomorphology. Doi: doi.org/10.1016/j.geomorph.2017.01.015

[15] Putra, Erwin Hardika. 2014. Identifikasi Daerah Rawan Longsor Menggunakan Metode Smorph Slope Morphology Di Kota Manado (Landslide Hazard Area Identification Using Smorph Slope Morphology Method In Manado City). Jurnal Wasian Vol.1 No.1 Tahun 2014, pp1-7

[16] Qiao, G, Lu, P.; Scaiioni, M., Xu, S.,Tong, S., Feng, T.,Wu, H., Chen, W., Tian, Y., and Wang, W. 2013. Landslide investigation with remote sensing and sensor network: From susceptibility mapping and scaled-down simulation towards in situ sensor network design. Remote Sens. 2013, 5, 4319–4346

[17] Reginster, F.Lupo and E.F.Lambin. 2010. Monitoring land-cover Change in West Africa with SPOT Vegetation: Impact of Natural Disaster in 1988-1999, International Journal Of Remote Sensing, Vol22, 2001: issue 13, pp 2622-2639
[18] Scaioni, Marco, Laura Longoni, Valentina Melillo and Monica Papini. 2014. Remote Sensing for Landslide Investigations: An Overview of Recent Achievements and Perspectives. Remote Sens. 2014, 6, 1-x manuscripts, pp1-53. doi:10.3390/rs60x000

[19] Sudibyo dan semesta. 2016. Longsor Klampar banjarnegara. eliptika.wordpress.com

[20] Van Westen, Cees. 2000. Remote Sensing for Natural Disaster Management. International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000, pp 1609 - 1617

[21] Wiesman, A. U.Wegmuller, Y.Haeberlin; A. Retiere, O. Senegas, T.Strozzi and C.Werner. 2004. SAR Based Product for The Implementation of Humanitarian Aid and Development Assistance Project Within UNOSAT Project. Proceedings of 2004 IEEE International Geoscience and Remote Sensing Symposium: Science for Society: Exploring and Managing A Changing Planet, 20-24 September 2004. Anchorage Alaska

[22] Wikipedia, 2017. Kabupaten Banjarnegara. Wikipedia.org

[23] Zhang, Y. and N. Kerle. 2008. Satellite Remote Sensing for Near-real time data collection. Geospatial Information Technology for Emergency Response. Taylor and Francis Group

[15] Mwaniki, D.N.Kuri, M.K.Boitt, T.G.Ngigi. 2017. Image enhancements of Landsat 8 (OLI) and SAR data for preliminary landslide identification and mapping applied to the central region of Kenya. Geomorphology, Volume 282(1):162-175. Geomorphology. Doi: doi.org/10.1016/j.geomorph.2017.01.015

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