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MORALITY BEFORE KNOWLEDGE

Drought zone monitoring with remote sensing technology in Metro City, Indonesia

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ABSTRACT

Background: Lampung Province, Indonesia, is prone to drought, with 232 villages experiencing drought in recent years according to data from the Central Statistics Agency (BPS). Metro City, a region within Lampung Province, is particularly susceptible to drought, as evidenced by a decrease in agricultural production due to drought conditions observed during a three-month period (December 2021–February 2022). Despite the agricultural sector being a crucial economic driver in the region, drought poses significant challenges. Remote Sensing and Geographic Information Systems (GIS) technologies offer efficient methods for identifying drought-prone areas with precision and accuracy. **Methods:** This research employs digital image processing techniques, specifically image transformation using various vegetation index algorithms such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Drought Index (NDDI). Landsat 8 OLI satellite imagery is utilized for data analysis, with Quantum GIS serving as the primary application for image processing. **Findings:** The research findings reveal the distribution of drought-prone zones on agricultural land in Metro City. **Conclusion:** The Central Metro District exhibits the lowest severity of drought classification, with an agricultural land area of 68.88 hectares classified as experiencing very severe drought. Conversely, the North Metro District is identified as having the most severe drought conditions, encompassing an area of 537.69 hectares.

KEYWORDS: drought; gis; monitoring; remote sensing

1. Introduction

Spatial planning is one of a the essential as a subjects studied by twelfth-grade Social Sciences students. A profound understanding of this subject is a crucial to the a help students comprehend how geographic spaces are optimally utilized and managed. Geographic is a spaces encompass areas serving various functions such as settlements, agriculture, industries, and conservation areas. Spatial planning aims to regulate and manage the utilization of these geographic spaces to provide maximum benefits for humans and the environment.

Classroom learning of spatial planning often lacks engagement and proves challenging for students to grasp easily. This situation can impede the learning process and hinder students' understanding of spatial planning concepts. Hence, there is a need for innovative

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and effective learning media to enhance students' comprehension of spatial planning. Spatial planning involves numerous abstract concepts and principles, leading many students to struggle with understanding them.

One of the problems in the Metro City, Lampung Province, is drought. Drought is a condition where there is a lack of water supply in a certain area so that it unable to meet the needs of life (Fathony et al., 2022). Based on data from the Central Statistics Agency (BPS) of Indonesia, it is known that several villages/neighborhoods have experienced drought in the past few years. Detailed data on the number of villages experiencing drought, see Table 1.

Table 1. Number of Villages According to Drought Disasters in Recent Years

No	Year	Number of Villages
1	2014	95
2	2018	232
3	2021	30

(Source: BPS, 2022)

According to the analysis of the three-month precipitation index, from December 2021 to February 2022, Metro City is also include one of the regions in Lampung Province that undergo a drought disaster. Some of these facts can be the basis for information that one of the issues in Metro City that needs to be solved is the potential for drought. Of course, this needs to be the concern for the local government because drought disasters can give many negative impacts on the local community.

One of the sectors most affected by drought disasters is agriculture sector. This is in accordance with the data released by BPS (2022), which indicates a decline in agricultural production from 2016 to 2020, see Table 2. Agricultural products output in Metro City were initially considered sufficient to meet the needs of the existing local community. However, along with time, there is a propencity of decreasing agricultural output in Metro City. Whereas Metro City still relies on the agricultural sector as its leading commodity.

Table 2. Agricultural Production Results in Metro City 2016-2020

Year	Production Result (Kw)
2016	64. 268, 26
2017	51. 445, 80
2018	58. 333, 35
2019	54. 520, 61
2020	35. 144, 97

(Source: BPS, 2022)

The phenomenon of drought in Metro City needs to be promptly addressed to prevent the impact from spreading and becoming more extensive and complex. Additionally, if the drought phenomenon is not promptly addressed, it will have longer-term effects (Nuarsa et al., 2015). Although it is challenging to avoid drought disasters, however we can minimize losses by monitoring the agricultural land that has the potential susceptible to drought (Sukmono et al., 2018).

Drought is a phenomenon that is closely related to the supply of water for the benefit of society and the balance between needs (Darfia et al., 2016). The lack of water supplies includes ground water and surface water. This condition can be caused by natural factors or environmental management by humans themselves (Fadlillah et al., 2018). The consequences of drought will undoubtedly have negative impacts on all living beings on the Earth's surface. The negative impacts of drought include land/forest fires, decline in agricultural yields, and increased of land degradation and dicertification.

One way to monitor the potential for drought in agricultural land is through the use of Remote Sensing (RS) technology and Geographic Information Systems (GIS). Krismayani et al. (2021) stated that Remote Sensing (RS) technology and Geographic Information System (GIS) are methods that can be used to map drought-prone areas. Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through data obtained by devices without contact with the object, area, or phenomenon being investigated (Lillesand et.al., 2006). There are many benefits provided by remote sensing, one of which is drought mitigation mapping (Wibowo, 2017). There are numerous advantages and reasons for using remote sensing, including lower costs, faster work processes, and less labor-intensive requirements.

GIS is a computerized information system to provide data in digital form and analysis of the earth's geographical surface (Awangga, 2019). GIS is a system that can organize software, hardware, and data; also used to store, process, and analyze data related to spatial aspects (Purwadhi, 1994). GIS technology developing to assist in processing data and generating information using overlay parameters. Additionally, the application of GIS technology or remote sensing can provide input related to early warning information in the formulation of policies for mitigating drought-prone agricultural land areas and can be monitored continuously (Utomo, 2022). The use of a GIS approach is important to overcome obstacles in mapping the distribution of drought or providing up-to-date or real time spatial drought information.

The combination of these two technologies (RS and GIS) can be used to extract information on the spatial distribution of drought-prone zones. Information related to the spatial distribution of drought-prone zones in agricultural land becomes crucial for anticipating potential impacts and assisting in more organized handling (Shofiyati, 2007). The main objective of this research is to identify the drought-prone zones in agricultural land in Metro City using RS and GIS technology. Both of these technologies enable spatial analysis through the digital images processing with image transformation methods using the vegetation index algorithm such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Drought Index (NDDI). The research will generate maps contains information regarding the distribution of drought-prones zonse on agricultural land in Metro City. With this information, it is expected that the local government can make technical policies to overcome the problem of land drought in Metro City.

2. Methods

2.1 Research Methods

The method used in this research is digital image processing in the form of image transformation. Image transformation in remote sensing is a process of changing or modeling an image from one spatial domain to another. The purpose of image transformation is to facilitate the interpretation, visualization, and analysis of image data, as well as to improve image quality by addressing geometric distortions, enhancing image quality, and altering spatial scales. Some common types of transformations used in remote sensing images include geometric transformation, radiometric transformation, and spectral transformation. In this study, spectral transformation is employed, which involves changing the spectral values in the image for extracting specific information as needed. There are three types of spectral transformations used in this research: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Drought Index (NDDI).

Normalized Difference Vegetation Index (NDVI) is a simple index with a dynamic and highly sensitive spectral range that is particularly effective in detecting changes in vegetation cover. The channel/band used in this transformation are the red and infrared in Landsat 8 imagery. These bands are chosen because they have different sensitivities to vegetation (Fadlillah et al., 2018). NDVI can be used to calculate drought indices. Drought criteria can be determined based on processing results using the red and near-infrared (NIR) band. The NDVI algorithm is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Next, the values of the NDVI calculation will be classified into 5 classes according to the, see Table 3.

Table 3. NDVI Classification

Class	NDVI	Information
1	-1 to -0,03	no vegetation land
2	-0,04 to 0,15	very low greenness
3	0,16 to 0,25	low greenness
4	0,26 to 0,35	medium greenness
5	0,36 to 1,00	high greenness

Indonesian Ministry of Forestry Regulation P.23/Menhut-II/2012

The NDVI will produce values in the form of a vegetation index, which depicts the level of greenness of a plant. The vegetation index is a mathematical combination of the red band and the Near-Infrared Radiation (NIR) band, which has long been used as an indicator of the presence and condition of vegetation (Lillesand and Kiefer, 1997). The lower the index value, the higher the vulnerability to drought, conversely, a high index value indicates that the area has a low vulnerability to drought (Prayoga, 2017).

The Normalized Difference Water Index (NDWI) is a newer satellite-derived index from the NIR and Short-Wave Infrared (SWIR) channels, reflecting differences in water content. Because NDWI is influenced by drought and wilting in vegetation canopies, it may be a more sensitive indicator than NDVI for drought monitoring. NDWI is an algorithm created by Gao (1996). This index can be used to detect vegetation experiencing drought. The NDWI algorithm is as follows:

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$$

After performing NDWI processing, the results can then be classified according to the guidelines, see Table 4.

Table 4. NDWI Classification

Class	NDWI	Information
1	$-1 < NDWI < 0$	no wetness
2	$0 < NDWI < 0.33$	moderate wetness
3	$0.33 < NDWI < 1$	high wetness

(Source: Lestari et. al., 2021)

After processing image data using the above two algorithms, further processing will be carried out using the Normalized Difference Drought Index (NDDI) algorithm. NDDI is a satellite-based index capable of indicating the geo-meteorological complexity of an environment, with the aim of monitoring and identifying drought. NDDI combines the parameters of vegetation greenness (NDVI) and vegetation wetness (NDWI) in the hope of producing a more accurate drought index. In NDDI, higher values indicate drought conditions. The following is the calculation of the NDDI algorithm to obtain the drought index for a specific region (Gu et al., 2007):

$$NDDI = \frac{NDVI - NDWI}{NDVI + NDWI}$$

The level of drought is proportional to the NDDI value in a certain region. This algorithm is relatively simple in its calculations as it is based on normalized differences (addition and subtraction) and does not depend on time series data (Gu et al., 2007). To determine the drought class, classification can be performed based on the NDDI values obtained according to the specifications, see Table 5.

Table 5. NDDI Classification for Land Drought

NDDI Value	Drought Level
-0,05 – 0,01	Normal
0,01 – 0,15	Low drought
0,15 – 0,25	Moderate drought
0,25 – 1	Severe drought
>1	Very Severe drought

(Source: Renza et. al., 2010)

2.2 Research Location

The research location is the city of Metro, located at coordinates $5^0 6'$ - $5^0 8'$ South Latitude and between $105^0 17'$– $105^0 19'$ East Longitude. The administrative region of Metro City can be observed in Fig 1.

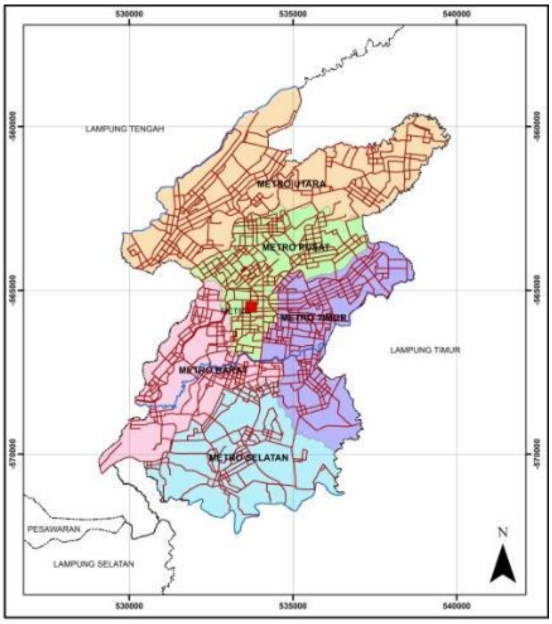

Fig 1. Administration Map of Metro City

Metro City is one of the administration areas in Lampung Province which has a tropical humid climate, with an average temperature above 18°C and doesn't have winter. The minimum temperature in Metro City is 22,9°C., while the average humidity is 80%. Soil types in Metro City are dominated by podsol and latosol. This type of soil is characterized by clay texture and dusty clay; sandy; and a granular structure. If seen from the topographic aspect, Metro City, whose landform is an alluvial plain, has a height ranging from 50 meters to 55 meters above sea level, and with a slope of 0^0 to 3^0. The landscape of Metro City is relatively flat, sloping from southwest to northeast with a height of 25 to 60 meters above sea level.

In watershed areas, rivers are generally wide and shallow with relatively sloping walls. At the bottom of the valley flow 4 rivers, in the northern part is the Way Bunut and Way Raman rivers, and the southern part is the Way Sekampung and Way Batanghari. The land use pattern in the Metro City area is dominated by agricultural areas, mainly rice fields. Metro City has potential area in the agricultural sector. Apart from wholesale and retail trade, food crop farming and livestock are contributors to economic activities. Plantation crops, livestock and fisheries grew by more than 20%. To date, 3.519 hectares of rice fields have been harvested. Average production reaches 5 tons/ha with total production reaching 17,3 thousand tons. Apart from that, another commodity that stands out is corn.

2.3 Research Stages

The research process begins with the collection of data in the form of Landsat 8 images. Subsequently, a pre-processing stage is conducted on the images to ensure that they are geometrically and radiometrically corrected. Radiometric correction aims to reduce the impact of errors or discrepancies in the brightness values of the images, which can affect a person's ability to interpret or process them quantitatively and analyze the images (Aryastana et al., 2017). Meanwhile, geometric correction aims to correct geometric distortions by placing image elements in the correct planimetric position (x and y), so that the images have an appearance that is more consistent with the actual conditions on the Earth's surface, making them suitable for use as maps.

After the pre-processing stages involving radiometric and geometric correction, the image can then be further processed. The data analysis techniques used in this research involve the use of classification and transformation of digital images. Image classification is the process of reviewing the appearance of an image based on its actual appearance on the Earth's surface. Digital image classification is carried out by distinguishing each brightness level or pixel into several classes and is done using software assistance (Hanindito et al., 2014). On the other hand, image transformation is the process of improving an image, such as making it brighter or darker, or altering the image for a specific purpose. Image transformations that can be performed include enhancing image quality, restoring images, and image compression (Kowanda, 2020). The software used is QGIS using Landsat 8 image data from the year 2023.

Digital image classification will be performed using three algorithms: NDVI, NDWI, and NDDI. The NDVI algorithm indicates the density of vegetation, the NDWI algorithm indicates the greenness level of vegetation, and the NDDI algorithm will show the vegetation drought level in a specific area. The classification of drought levels based on the NDDI algorithm is divided into 5 classes: normal, light drought, moderate drought, severe drought, and very severe drought.

Furthermore, the results of digital image classification analysis will be associated spatially and temporally. The spatial-temporal analysis process is to identify the distribution of drought levels across the entire area and monitor it gradually over several specified years (Auliyani and Rekapermana, 2020). The results of spatial-temporal analysis will provide information related to the distribution of drought levels in agricultural land within a specific region that will be studied.

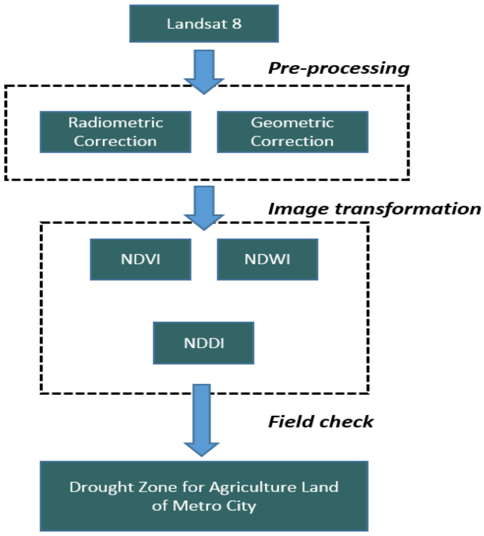

Fig 2. Research Flow Chart

3. Result and Discussion

3.1 Image Pre-Processing

The satellite imagery used in this research is Landsat 8 OLI captured in the year 2023. Landsat 8 Operational Land Imager (OLI) is a satellite sensor that is part of the Landsat program, which has been providing Earth observation data since the early 1970s. Launched on February 11, 2013, Landsat 8 is the eighth satellite in the series and carries the Operational Land Imager as its primary instrument. The OLI sensor is designed to capture high-resolution multispectral imagery of the Earth's surface. It operates in the visible, near-infrared, and shortwave infrared portions of the electromagnetic spectrum, allowing it to observe a wide range of features on the Earth's surface. The sensor has improved capabilities compared to its predecessor, Landsat 7, including better signal-to-noise ratios, higher radiometric resolution, and a wider dynamic range.

Landsat 8 OLI is valuable for various applications, including land cover monitoring, agriculture, forestry, geology, environmental monitoring, and urban planning. Its consistent and systematic data collection over time also enables researchers and scientists to track changes in the Earth's surface and study long-term trends in land use and environmental conditions. The data provided by Landsat 8 OLI contribute to our understanding of global environmental dynamics and support decision-making in areas such as resource management and disaster response.

Prior to further processing, the images underwent initial processing, including geometric correction and radiometric correction. Geometric correction was performed to ensure that the recorded positions of objects in the images matched their actual locations in the field. Meanwhile, radiometric correction was carried out to rectify errors in the spectral reflectance values of objects caused by atmospheric interference during the image capture process.

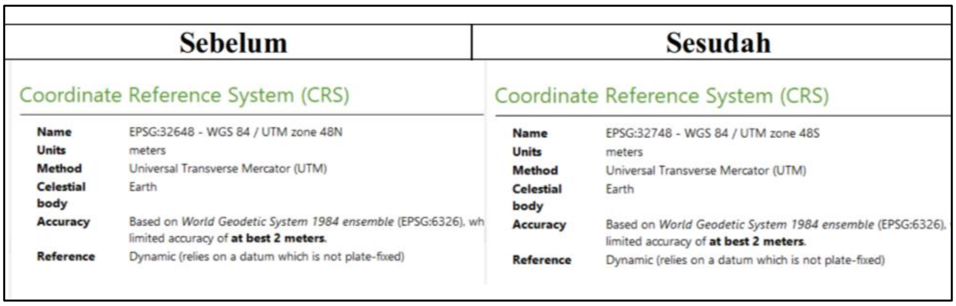

Fig 3. Geometric Correction Process

Fig 3. indicated that before geometric correction is performed, the coordinate system of the image is in UTM coordinates, zone 48 N, with the WGS 1984 reference system. However, the actual research location is in zone 48 S. Therefore, in this geometric correction stage, adjustments are made to transform the coordinate system to UTM coordinates, zone 48 S.

The next step is to perform radiometric correction. This stage is crucial as it can affect the results of image analysis, whether when conducting transformations such as NDVI, NDWI, or NDDI. Fig 4 denotes the difference between images before and after radiometric correction, where in the corrected image, the appearance of objects is more distinct and sharper.

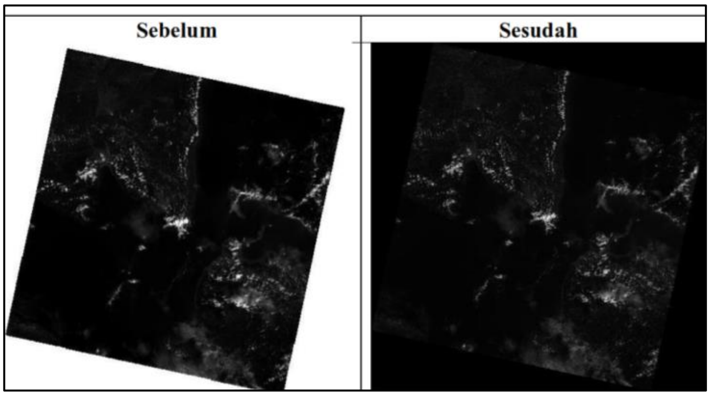

Fig 4. Radiometric Correction Process

3.2 NDVI Transformation

NDVI is one of the most commonly used indices for analyzing land drought in a particular area. The reason NDVI is widely employed for such purposes includes its sensitivity to vegetation. NDVI is responsive to changes in the amount and condition of vegetation in an area. This is a primary reason why NDVI is often used to analyze land drought. Drought typically results in a decrease in photosynthetic activity and a reduction in vegetation, which can be detected through changes in NDVI values.

NDVI is also widely used due to its ease of use. NDVI can be calculated using widely available satellite image data, including Landsat 8 imagery used in this research. Additionally, software supporting the transformation of NDVI is readily available, whether commercial or open-source, such as Quantum GIS used in this study. Furthermore, NDVI is capable of producing data of relatively good quality. This data has good spatial and temporal resolution, enabling more accurate analyses of vegetation changes over time. NDVI has an inverse relationship with drought conditions. As drought conditions worsen, NDVI values tend to decrease due to vegetation experiencing water stress. Therefore, NDVI can be used as an early indicator to monitor and identify areas vulnerable to drought.

The results of NDVI analysis indicate that, out of the total agricultural land area in Metro City, covering 2.948 hectares, it is currently dominated by non-vegetated land totaling 1.016,50 hectares and vegetation density class with very low greenness covering 1.026,62 hectares.

Table 6. NDVI Classification Result

Class	Classification	Area (Ha)
1	no vegetation land	1.016,50
2	very low greenness	1.026,62
3	low greenness	396,55
4	medium greenness	168,29
5	high greenness	340,05
	Total	2.948,00

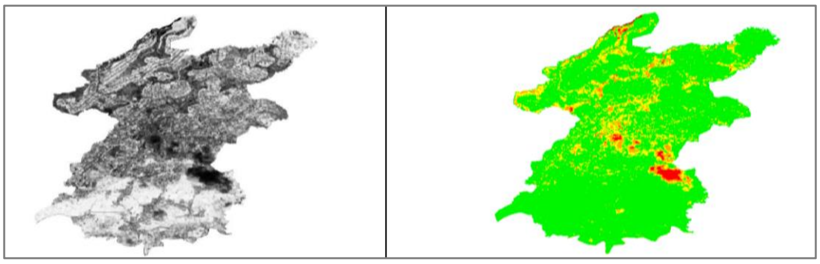

Fig 5. NDVI Transformation Result

3.3 NDWI Transformation

NDWI is an index used to measure the water content or moisture in a particular area. NDWI is widely employed for the analysis of land drought for several reasons, including its sensitivity to water. NDWI is highly responsive to water, including water contained in plants and soil. This makes it very useful for monitoring changes in soil moisture and water levels in specific regions.

Furthermore, NDWI is used in drought studies due to its ease of comparison. NDWI is an easily understood and utilized index, as it involves only the comparison between near-infrared (NIR) spectral reflectance and short-wave infrared (SWIR) in a satellite image or other remote sensing data. The higher the NDWI value, the higher the moisture in that area. NDWI can also provide additional information about soil and vegetation. When an area experiences drought, plants may undergo stress, and NDWI can help detect these changes. By monitoring NDWI over time, we can identify patterns of drought and moisture changes in specific areas. This can aid in planning and managing water resources and agriculture.

The results of the NDWI transformation conducted show that in the agricultural land in Metro City, the majority is dominated by non-water bodies (2,235, 32 Ha). This indicates that the current condition of most agricultural land is dry or lacks water content (Putra & Salahudin, 2022). This could be attributed to the Landsat 8 image being recorded during the dry season when the rainfall is very low. In general, the results of the NDWI transformation, see Table 7.

Table 7. NDWI Classification Result

Class	Classification	Area (Ha)
1	no wetness	2.235,32
2	moderate wetness	369,43
3	high wetness	343,25
	Total	2.948,00

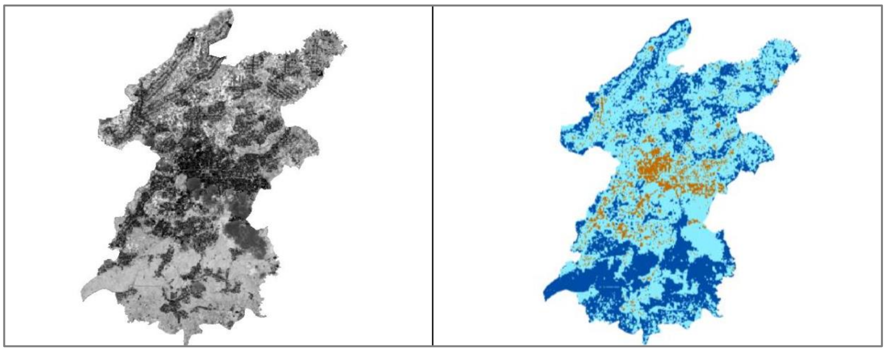

Fig 6. NDWI Transformation Result

3.4 NDDI Transformation

NDDI is a method of satellite image analysis used to monitor and measure the level of drought in specific land or areas. This method is often employed in the context of agriculture, natural resource monitoring, and environmental management. The NDDI transformation is based on the difference between vegetation index and surface temperature index, which can indicate the level of drought.

NDDI is widely used in the analysis of agricultural land drought for various reasons. One of them is that NDDI can combine two key pieces of information highly influential to agricultural land drought: vegetation condition (NDVI) and soil moisture (NDWI). These are two key factors affecting land productivity. By combining these two pieces of information, NDDI provides a more comprehensive overview of the agricultural land conditions than using only one index. The second reason is that NDDI is specifically designed to detect drought. This index is sensitive to changes in soil moisture and vegetation conditions that can occur during a drought period. Therefore, NDDI can help in early detection and more accurate monitoring of drought development.

NDDI can be used to monitor changes in real-time. By using satellite data or ground sensors, NDDI analysis can be performed continuously, allowing farmers and decision-makers to promptly respond when there are signs of developing drought. When utilized optimally and continuously, NDDI can provide valuable information for farmers and land managers. They can use this information to manage irrigation, schedule planting, and make other decisions that can help mitigate the impact of drought on crop yields. However, despite the many advantages of NDDI in monitoring and analyzing agricultural land drought, it is important to note that its use should be complemented with other data and information, as well as broader local considerations, to make effective decisions in addressing agricultural drought issues.

The results of the NDDI analysis indicate that agricultural land in Kota Metro is predominantly affected by normal-class drought (1.523,47 Ha). However, there are also areas with severe and very severe drought classes with considerable expanses. This suggests that agricultural land in Kota Metro has a high risk of drought disasters. The complete results of the NDDI transformation and the areas in each class, see Table 8.

Table 8. NDDI Classification Result

Class	Classification	Area (Ha)
1	Normal (N)	1.523,47
2	Low drought (LD)	144,72
3	Moderate drought (MD)	105,99
4	Severe drought (SD)	542,33
5	Very Severe drought (VSD)	631,49
	Total	2.948,00

Based on administrative division, the sub-districts in Metro City where severe drought is most frequently encountered are South Metro, followed by North Metro, East Metro, West Metro, and Central Metro. Meanwhile, in terms of severe drought, the most dominant sub-district is North Metro, followed by South Metro, East Metro, West Metro, and Central Metro. The complete distribution of the extent of drought levels in each administrative region, see Table 9.

Table 9. Drought Area Extent in Agricultural Land per District in Metro City

No	District	Area (Ha)				
		N	LD	MD	SD	VSD
1	West Metro	276,23	22,82	10,85	59,97	104,08
2	North Metro	486,11	70,29	55,62	244,17	167,61
3	East Metro	152,14	13,58	10,79	77,72	136,78
4	South Metro	392,53	34,47	25,59	140,15	179,62
5	Central Metro	218,02	2,55	2,42	19,43	44,48
		1.525,03	143,70	105,27	541,43	632,56

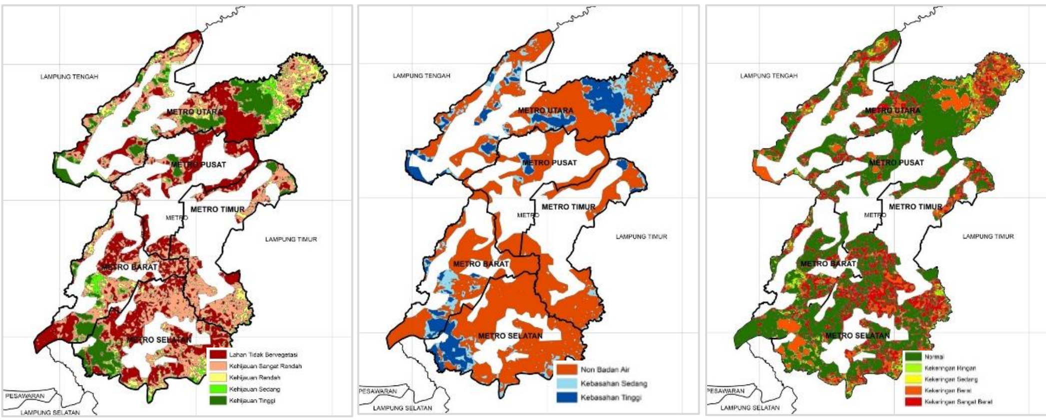

Fig 7. The results of NDVI, NDWI, and NDDI Transformation

4. Conclusion

Landsat 8 OLI's combination of spectral bands, spatial and temporal resolution, radiometric calibration, long-term data record, open access, and multi-spectral capability make it well-suited for NDDI transformation and monitoring drought conditions. The transformation of NDDI can be used for drought mapping, especially in agricultural land. In general, Metro City has classes of very severe land drought covering an area of 631,49 Ha, severe drought covering 542,33 Ha, moderate drought covering 105,99 Ha, low land drought covering 144,72 Ha, and normal (non-prone) area covering 1.523,47 Ha. Districts with the highest risk of land drought in agricultural areas are North Metro and South Metro.

The results of mapping agricultural land drought are strongly influenced by the time of satellite image recording. Therefore, further research is a needed to compare NDDI transformations during the dry season and the rainy season for more accurate analysis.

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References

Aryastana, P., Ardantha, I. M., & Agustini, N. K. A. (2017). Analisis Perubahan Garis Pantai Dan Laju Erosi Di Kota Denpasar Dan Kabupaten Badung Dengan Citra Satelit Spot. Jurnal Fondasi, 6(2). http://dx.doi.org/10.36055/jft.v6i2.2634

Auliyani, D., & Rekapermana, M. (2020). Analisis Spasial Potensi Kekeringan di Daerah Aliran Sungai Kapuas, Kalimantan Barat. Jurnal Pembangunan Wilayah dan Kota, 16(1), 61-70. https://doi.org/10.14710/pwk.v16i1.21979

Awangga, R. M. (2019). Pengantar Sistem Informasi Geografis: Sejarah, Definisi Dan Konsep Dasar. Kreatif Industri Nusantara: Bandung. https://books.google.co.id/books/about/Pengantar_sistem_informasi_geografis.html?id=4OiLDwAAQBAJ&redir_esc=y

BPS. (2022). Kota Metro dalam Angka 2022. BPS Kota Metro, Provinsi Lampung. https://metrokota.bps.go.id/publication/2022/02/25/13d3d0191c257e0855e63579/kota-metro-dalam-angka-2022.html

Darfia, N. E., Kusuma, M. S. B., & Kuntoro, A. A. (2016). Analisis Indeks Kekeringan di DAS Rokan Provinsi Riau Menggunakan Data CFSR. Racic: Rab Construction Research, 1(02), 120-134. https://jurnal.univrab.ac.id/index.php/racic/article/view/166

Fadlillah, M. F., Hadiani, R., & Solichin. (2018). Analisis Kekeringan Hidrologi Berdasarkan Metode Normalized Difference Vegetation Index (NDVI) Di Daerah Aliran Sungai Alang Kabupaten Wonogiri. Jurnal Riset Rekayasa Sipil, 2(1), 34–44. https://doi.org/10.20961/jrrs.v2i1.24324

Fathony, A., Somantri, L., & Sugito, N. T. (2022). Analisis Potensi Kekeringan Pertanian di Kabupaten Bandung. Jurnal Geografi: Media Informasi Pengembangan dan Profesi Kegeografian, 19(1), 29-37. https://doi.org/10.15294/jg.v19i1.33724

Gao, O. C. (1996). NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space, Remote Sensing of Environment, Volume 58, Issue 3, Pages 257-266, http://dx.doi.org/10.1016/S0034-4257(96)00067-3

Gu, Y., Brown, J., Verdin, J. dan Wardlow, B. (2007). A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. Geophysical Research Letters. Vol. 34. Issue 6. https://doi.org/10.1029/2006GL029127

Hanindito, G. A., Sediyono, E., & Setiawan, A. (2014). Analisis Pantauan Dan Klasifikasi Citra Digital Pengindraan Jauh Dengan Data Satelit Landasat Tm Melalui Teknik Supervised Classification (Studi Kasus Kabupaten Minahasa Tenggara, Provinsi Sulawesi Utara). Prosiding KOMMIT. https://ejournal.gunadarma.ac.id/index.php/kommit/article/view/1038

Kowanda, A. (2020). Transformasi Citra. https://informatika.stei.itb.ac.id/~rinaldi.munir/Citra/2019-2020/12-Transformasi-Citra.pdf

Krismayani, N. P. A., Nuarsa, I. W., dan Suyarto, R. (2021). Pemetaan Tingkat Kekeringan Lahan pada Fenomena El Nino 2002, 2009, dan 2015 di Provinsi Bali dengan Teknologi Penginderaan Jauh dan Sistem Informasi Geografis. Jurnal Agroekoteknologi Tropika ISSN, 2301, 6515. https://jurnal.harianregional.com/jat/id-75529

Lillesand, T.M., Kiefer, R.W. and Chipman, J.W. (2006) Remote Sensing and Image Interpretation. 6th Edition, John Wiley & Sons Inc., New York. https://www.geokniga.org/bookfiles/geokniga-remote-sensing-and-image-interpretation.pdf

Lillesand, T.M., dan kiefer, R.W., (1997). Penginderaan Jauh dan Interpretasi Citra (Terjemahan), Yogyakarta : Gadjah Mada University Press. https://opac.perpusnas.go.id/DetailOpac.aspx?id=152403

Lestari, M., Mira, M., Prasetyo, S. Y. J., & Fibriani, C. (2021). Analisis Daerah Rawan Banjir Pada Daerah Aliran Sungai Tuntang Menggunakan Skoring dan Inverse Distance Weighted. Indonesian Journal of Computing and Modeling, 4(1), 1-9. https://doi.org/10.24246/icm.v4i1.4615

Nuarsa, I. W., Adnyana, I., & As-syakur, A. (2015). Pemetaan Daerah Rawan Kekeringan Di Bali-Nusa Tenggara Dan Hubungannya Dengan Enso Menggunakan Aplikasi Data Penginderaan Jauh. Bumi Lestari, 15(1), 20-30. https://www.researchgate.net/publication/311729609_Pemetaan_Daerah_Rawan_Kekeringan_di_Bali-Nusatenggara_dan_Hubungannya_dengan_ENSO_Menggunakan_Aplikasi_Data_Penginderaan_Jauh

Prayoga, M. P. (2017). Analisis Spasial Tingkat Kekeringan Wilayah Berbasis Penginderaan Jauh dan Sistem Informasi Geografis (Doctoral dissertation, Institut Teknologi Sepuluh Nopember). Purwadhi, F.S.H. 1994. Interpretasi Citra Digital. PT. Grasindo. Jakarta. https://repository.its.ac.id/44527/1/3513100067-Undergraduate_Theses.pdf

Purwadhi, F. (1994). Dayaguna spot dan landsat untuk pemetaan penggunaan lahan pertanian di Bekasi dan sekitarnya dengan skala 1: 100.000 (Doctoral dissertation, Universitas Gadjah Mada). https://etd.repository.ugm.ac.id/home/detail_pencarian/12835

Renza, D., Martinez, E., Arquero, A., and Sanchez, J. (2010). Drought estimation maps by means of multidate landsat fused images. Proceedings of the 30th EARSeL Symposium (pp. 775-782). http://www.earsel.org/symposia/2010-symposium-Paris/Proceedings/EARSeL-Symposium-2010_17-03.pdf

Republik Indonesia. 2012. Peraturan Menteri Kehutanan Republik Indonesia Nomor : P.12/Menhut-II/2012 tentang Perubahan Kedua Atas Peraturan Pemerintah Menteri Kehutanan Nomor P.32/Menhut-II/2009 Tentang Tata Cara Penyusunan Rencana Teknik Rehabilitasi Hutan dan Lahan Daerah Aliran Sungai (Rtk RHLDAS). Sekretariat Negara. Jakarta. https://jdih.menlhk.go.id/new/uploads/files/P.12%20(5).pdf

Shofiyati, R., dan Kuncoro, D. (2007). Inderaja untuk mengkaji kekeringan di lahan pertanian. Jurnal informatika pertanian volume 16 no. 1, Juli 2007. https://adoc.pub/inderaja-untuk-mengkaji-kekeringan-di-lahan-pertanian.html

Sukmono, A., Rahman, F., & Yuwono, B. D. (2018). Pemanfaatan Teknologi Penginderaan Jauh untuk Deteksi Kekeringan Pertanian Menggunakan Metode Normalized Difference Drought Index di Kabupaten Kendal. Jurnal Geografi: Media Informasi Pengembangan dan Profesi Kegeografian, 14(2), 57-65. https://doi.org/10.15294/jg.v14i2.11521

Utomo, A. S., Hadi, M. P., & Nurjani, E. (2022). Analisis spasial temporal zona rawan kekeringan lahan pertanian berbasis remote sensing. Jurnal Teknosains, 11(2), 112-127. https://doi.org/10.22146/teknosains.67932

Wibowo, D. (2017). Pemanfaatan Penginderaan Jauh untuk Analisis Zonasi Daerah Rawan Kekeringan di Kabupaten Indramayu. Skripsi. Universitas Pendidikan Indonesia. https://repository.upi.edu/28909/

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