TECHNICAL SCIENCES

SENTINEL-2 APPLICATION IN THE URBAN SURFACE WATER DRAINAGE ANALYSIS IN BIEN HOA CITY, VIETNAM

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Abstract

The study shows the effective application of sentinel-2 images in analyzing the current state of urban surface water drainage in Bien Hoa city. The extraction of each component of water, vegetation and impervious surface based on NDVI, MNDWI and NDBI indexes has contributed very effectively in the formation of the composite cover map. Overall classification accuracy T = 0.92, Kappa coefficient = 0.87. Asymptotic analysis with the QGIS tool was used to determine the minimum distance from any point in the urban area to the natural permeable surface. The isolation of urban cover surface helps to determine the ratio of impervious surface and natural permeable surface within Bien Hoa city wards. The results of asymptotic analysis have shown that the central wards of Bien Hoa have 3-5 times higher access distance to the natural permeable surface than the suburban wards, corresponding to the ratio of impervious surface area/natural permeable surface between them. The coefficient of variation according to the statistical results of asymptotic distance is an important basis for evaluating the degree of interlacing of areas with impervious surfaces with areas with natural permeable surfaces. Research results have located the spatial distribution and characteristics of areas with high potential for flooding in Bien Hoa city, those are the downtown areas with an impervious surface ratio >60% and the access distance to the naturally permeable surface >120m. This result will be very useful in sustainable urban drainage planning.

Keywords: Sustainable urban drainage; Sentinel-2; GIS; Urban planning; Drainage system.

1. Introduction

Urbanization has led to the process of concreting, which has encroached on rivers and lakes, destroyed vegetation, and narrowed and changed the flow and natural storage of water. Surfaces of artificial works (houses, roads, yards, etc.) are collectively referred to as impermeable surfaces. They have occupied the natural surface, reducing the natural drainage capacity, increasing the surface runoff and reducing the infiltration of water into the ground, reducing the ability to replenish groundwater sources in situ as well as causing monotonous landscape, heat radiation due to concreting. Its consequence is a rapid increase in urban surface water levels in a short time, causing local flooding in low-lying areas where water cannot be drained in time, especially in urban areas located in coastal plains and in tropical monsoon regions where heavy rains are frequent [1]. Statistics show that, many urban areas in Vietnam have drainage systems that are often overloaded. Inundation also frequently occurs in urban areas, for example, Ho Chi Minh City has over 100 inundated points, Hanoi has over 30 points, Bien Hoa, Da Nang, Hai Phong also have many inundated spots [2].

Types of images commonly used by researchers for surface water monitoring are Satellite Radar (SAR) images [3, 4], LiDAR [5, 6] and various spatial resolution optical satellite images ranging from low-resolution [7, 8] to very high-resolution imagery [9, 10]. Normally, surface water researchers often use Landsat 7 or Landsat-8 images and setinel-2 images, because these image sources are freely available and have good resolution (10-20 m) [11-13]. Zhou et al. (2017) compared the performance of different water indices in Landsat 7 ETM+, Landsat 8 Operational Land Imager and Sentinel-2. Zhou concluded that the surface water analysis results from Landsat 8 and Sentinel-2 image data have similar accuracy, while Landsat 7 image data gives lower analysis results [1] .

Impermeable Surfaces are known as environmental indicators for the identification of urbanization and urban growth intensity, as well as applications for sustainable urban development and natural resource planning. They are considered as baseline variables for analysis, evaluation or decision-making in particular urban problems. Many studies have investigated the use of Impermeable Faces to describe urban residential areas according to a hierarchical system [14] or incorporate urban impermeability in a land use classification scheme to determine the spatial distribution of anthropogenic sources of pollution [15]. Urban impervious surface properties are also used for non-pollution source pollution modeling for water quality monitoring and anti-pollution planning for urban environments [16].

For conventional urban drainage systems, the surface water drainage capacity is determined based on the volume and time of rainwater from the source to the receiving source [17]. But for the drainage system towards sustainability, CIRIA has stated that the urban surface water drainage capacity in a sustainable way is based on the ability to slow down the flow rate, the ability to store water and reduce the transport of pollutants through the aquatic environment [18]. Therefore, the ratio of natural permeable surface is a potential value to evaluate urban surface drainage capacity in a sustainable way. Research by Rudong Xu et al 2018, with the topic Extracting urban impermeable surfaces with high accuracy from Sentinel-2 multispectral images through linear spectral mixed analysis (MLSMA). With this method, the team extracted impervious surface maps with a resolution of up to 10m, with an accuracy of up to 93% [19]. However, the analysis results mainly focus on impervious surfaces and have not determined the distribution of natural drainage spaces in urban areas. In Vietnam, the research project Research using GIS to build flow coefficient map of Bac Kan province by Doan Thi Noi, has proposed a method to determine the flow coefficient based on surface properties, scale and slope. Since then, the author has calculated more accurately the rainfall in a typical basin of Bac Kan [20]. However, this method still requires input data maps and is difficult to regularly update the change of urban cover surface. Another typical study is the subject of the authors Le Van Trung and Nguyen Nguyen Vu. In which, the team has applied the standardized vegetation index analysis method NDVIs with Landsat satellite data to determine the percentage of impervious surface of the city Can Tho from 1997 to 2016 [21]. However, the study mainly focuses on analyzing the proportion of impervious surface, not considering the distribution of natural drainage spaces in urban areas. Obviously, the proportion of impervious surfaces and their spatial distribution are the two main factors affecting urban surface water drainage capacity.

Therefore, in order to more comprehensively assess the status and capacity of urban natural drainage in a sustainable way, it is necessary to consider the percentage of impervious surface and calculate the accessibility of surface water to the naturally permeable surface.

2. Materials And Methods

Research area: Bien Hoa city, in Dong Nai province, Vietnam, has an area of 263.2 km2, with a population density of 3030 people/km2. Bien Hoa has a very high urbanization rate, over 70%, is the third most populous city in the country with over 1 million people (after Hanoi and Ho Chi Minh City). Every year, tens of thousands of migrant workers come to Bien Hoa, causing the city's population to increase rapidly, putting pressure on infrastructure as well as housing construction problems. Bien Hoa city has a rainy season that usually starts from late May to October every year, with a large average annual rainfall of 2000-2500 mm. The drainage system of Bien Hoa city as well as a number of cities in Vietnam, mostly built on the foundation of old urban areas, is incomplete and has little maintenance, leading to the urban drainage system is often overloaded, causing flooding. According to a report by the Department of Natural Resources and Environment of Dong Nai province, the hot spots that frequently flood during the rainy season in Bien Hoa city, which take place over many years, can be mentioned as: Gate 11, Phuoc Tan Ward; Trang Dai junction, Trang Dai ward; Phat Trien junction area (National Highway 1, section through Tan Bien and Tan Hoa wards), 30-4 park, Nguyen Ai Quoc street (section through Bac Hai parish, section in Ho Nai ward)… If it rains heavily and lasts for more than 1 hour, this area is flooded with a depth of 50-70cm. Some places even flooded over 1m [22,23]. It seriously affects the traffic and people's life. Therefore, it is necessary to have a study on the current status and capacity of surface water drainage in Bien Hoa urban area, thereby serving as a basis for planning sustainable surface water drainage systems.

Materials: The Sentinel satellite image is a passive satellite image, so it is greatly influenced by cloud cover. Bien Hoa city is often cloudy in the rainy season months (from June to October), so, to get the best quality image, we have downloaded the setinel-2 image, taken on 13/3-2021 at https://scihub.copernicus.eu. The study area is located in two images L2A_T48PXT_A020979_20210313T031920_2021-03-13 and L2A_T48PYT_A020979_20210313T031920_2021-03-13 with 13% cloud coverage. The cloud cover is outside the edge of the image, does not affect the study area. After cutting along the administrative boundary of Bien Hoa city, the image of the entire study area is not clouded. Therefore, there is no need to use the cloud removal method on the image.

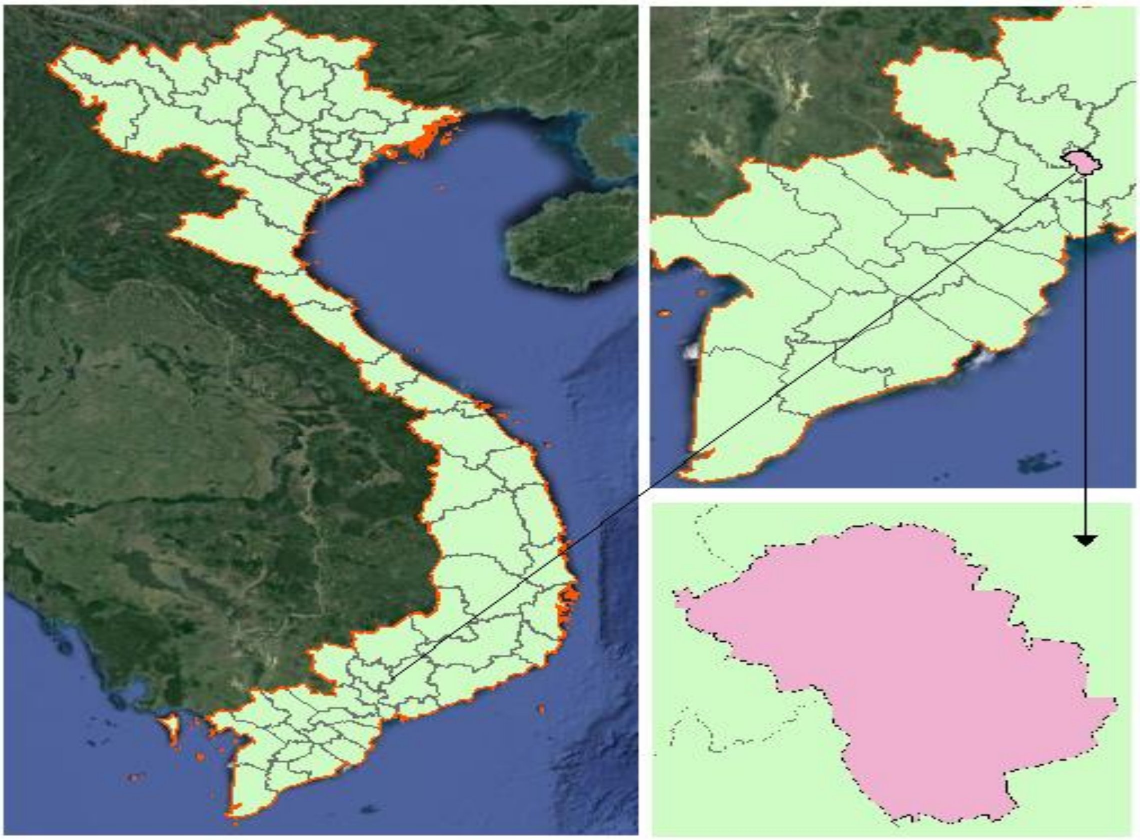

Fig 1. Location map of Bien Hoa city

Methods: To analyze the current situation of urban drainage in Bien Hoa, the overlay map was established based on NDVI, MNDWI, NDBI indexes. The combined analytical method of NDVI, NDBI and MNDWI indices was used to isolate impervious surfaces, permeable plant surfaces, natural soil and water surfaces. The Normalized Difference Vegetation index (NDVI) is determined based on the different reflectance of plants, expressed between visible red (RED) and near infrared (NIR) spectral bands, used to indicate the concentration of vegetation on the ground. The higher the difference between the reflectance of the red and NIR spectra, the more chlorophyll is found in the vegetation. The NDVI value ranges from -1 to +1. Pixels covered with vegetation will have an NDVI value close to +1, an NDVI close to 0, which means no vegetation and possibly an urban area. If the NDVI value is close to -1, the pixel is usually covered with water. Similarly, the Modified Normalized Difference Water Index (MNDWI) is based on the near-infrared (NIR) and short-wave infrared (SWIR) bands to determine the surface properties of water. and the Normalized Difference Built-up Index (NDBI) based on near-infrared (NIR) and short-wave infrared (SWIR) spectral bands, to determine the surface properties of construction soil. The formula for calculating the indexes on the Sentinel-2A image is as follows:

- Normalized difference vegetation index (NDVI)

$$NDVI= (\rho_{NIR} - \rho_{Red})/(\rho_{NIR} + \rho_{Red}) \quad (1)$$

- Modified Normalized Difference Water Index (MNDWI)

$$MNDWI= (\rho_{Green} - \rho_{NIR})/(\rho_{Green} + \rho_{NIR}) \quad (2)$$

- Normalized Difference Built-up Index (NDBI)

$$NDBI= (\rho_{SWIR} - \rho_{NIR})/(\rho_{SWIR} + \rho_{NIR}) \quad (3)$$

where ρ_{Green}, ρ_{Red}, ρ_{NIR}, and ρ_{SWIR} are the reflectances of band 3, band 4, band 8 and band 11 of Sentinel-2A imagery, respectively.

In view of SUDS [18], water space and vegetation are considered areas of natural permeable surface . Asymptotic analysis with the QGIS tool is used to determine the minimum distance from any point in the city to these spaces. Based on the raster value statistics tool of QGIS, the study can determine the statistical values of the distance approaching the area with the natural permeable surface such as: maximum value, mean, standard deviation and the coefficient of variation. The coefficient of variation helps to determine the dispersion of the data in a data series relative to the mean. In this study, a significant coefficient of variation helps to determine the difference in minimum distance to the naturally permeable surface between urban areas. The results of urban surface coverage isolation help determine the ratio of these surface types within wards or by urban drainage basin. On the other hand, the results of asymptotic analysis of areas with natural permeable surfaces in urban areas help determine the distribution characteristics between this space and spaces with impervious surfaces. The coefficient of variation according to the statistical results of asymptotic distance is an important basis for assessing the degree of interlacing of the area with natural permeable surface between urbanized areas with a high percentage of impervious surfaces. In other words, assess the porosity of urban surfaces. From there, it is possible to evaluate the applicability of sustainable surface water drainage solutions in urban areas.

Enhance image resolution: In order to increase the ability to distinguish surface water, especially small water areas in residential areas, people increase the resolution of SWIR and Green bands to calculate the MNDWI index with higher accuracy. Image blending is one of the most popular methods to enhance the resolution of remote sensing images. An image blending method that relies on the higher spatial resolution available to an image band to enhance the resolution of a lower image band by it. This method has been applied by many studies to distinguish and map surface water [26]. In this study, RGB and NIR bands of Sentinel-2 images with 10 m resolution were used as a basis to enhance the resolution for SWIR bands from 20 m to 10 m.

3. Results

The results of classification according to the NDVI index show that, with the NDVI threshold > 0.3, the vegetation is quite clear. The test results showed that the accuracy of plant classification reached 100% (15/15 points of accurate classification compared to the sample). However, the NDVI-based classification results in significant confusion between water and impervious surfaces (in particular, roads). The interpretation results show that some road sections are shaded, the main street in the city center has pixel values ranging from -0.03 - 0.3. Meanwhile, some water surface areas have pixel values from -0.3 - 0.116. This means that some interpretation areas will be confused between the road surface and the water surface in the pixel value range from -0.03 - 0.116. This is shown in detail in Figures 2 and 3.

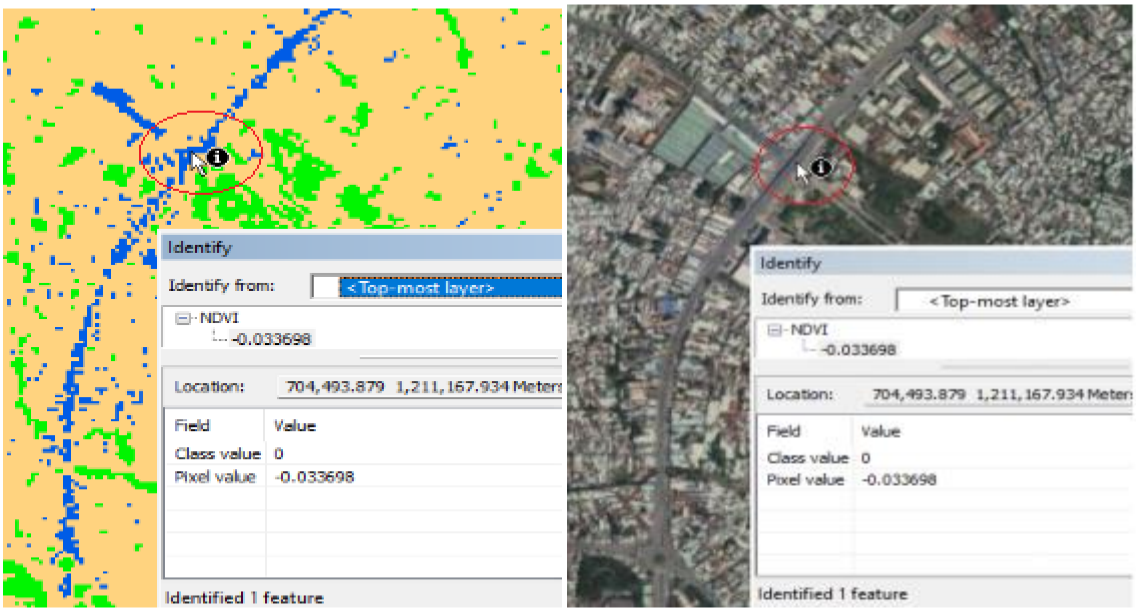

Figure 2. Pixel values on some urban road sections

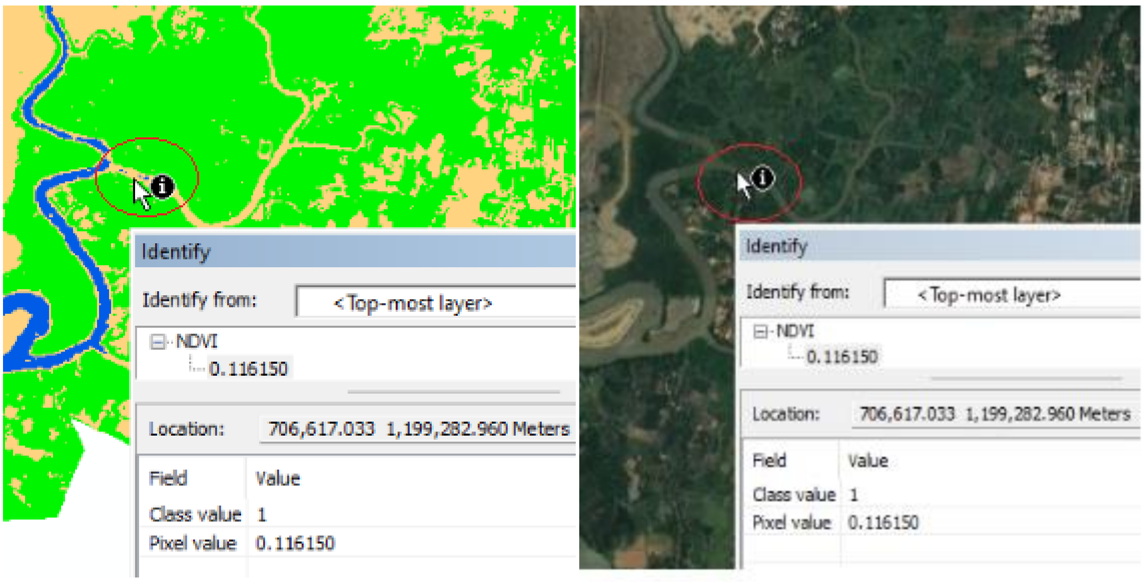

Figure 3. Pixel values on some river sections

Therefore, based on NDVI classification results alone, it is difficult to separate the water surface and impermeable surface (roads). Therefore, the interpretation results based on the NDVI index in this study are only used to separate the plant fraction. Map classified by NDVI index With threshold NDVI>0.3 shown in figure 4.

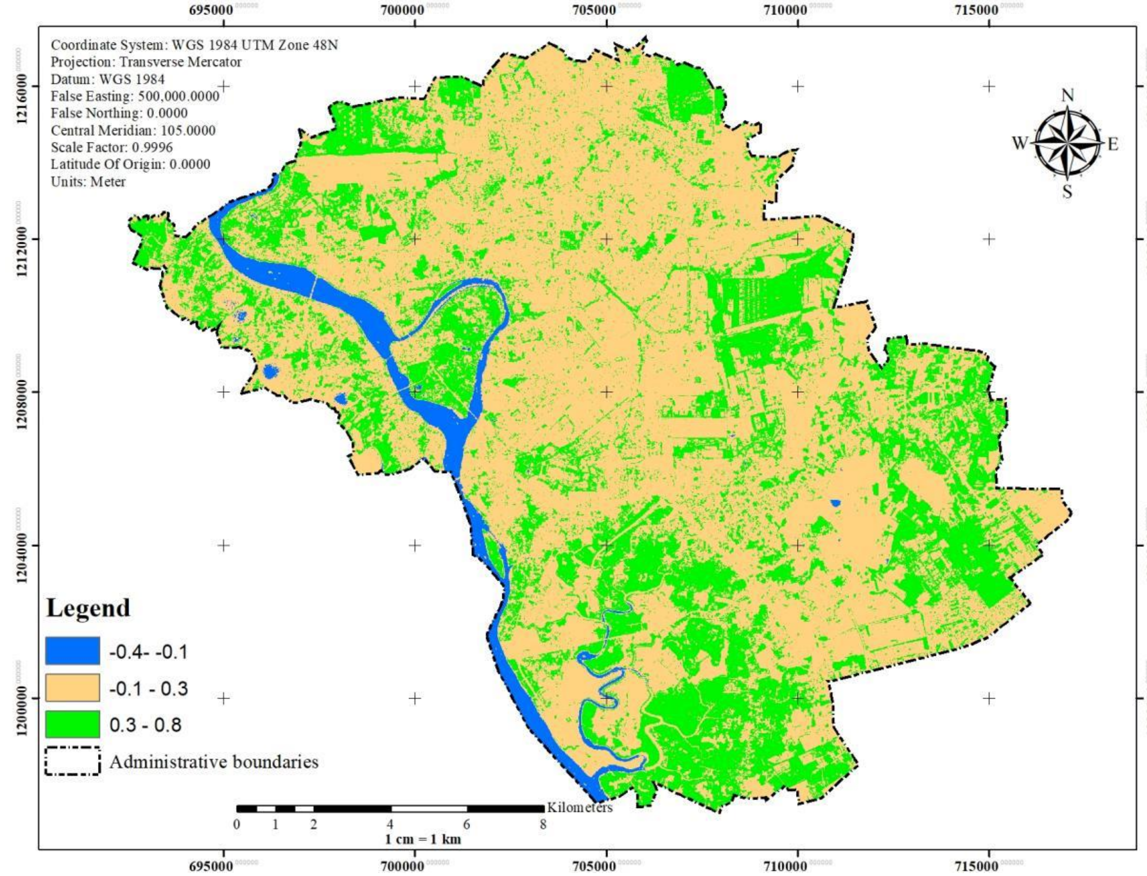

Figure 4. NDVI classification map in Bien Hoa city

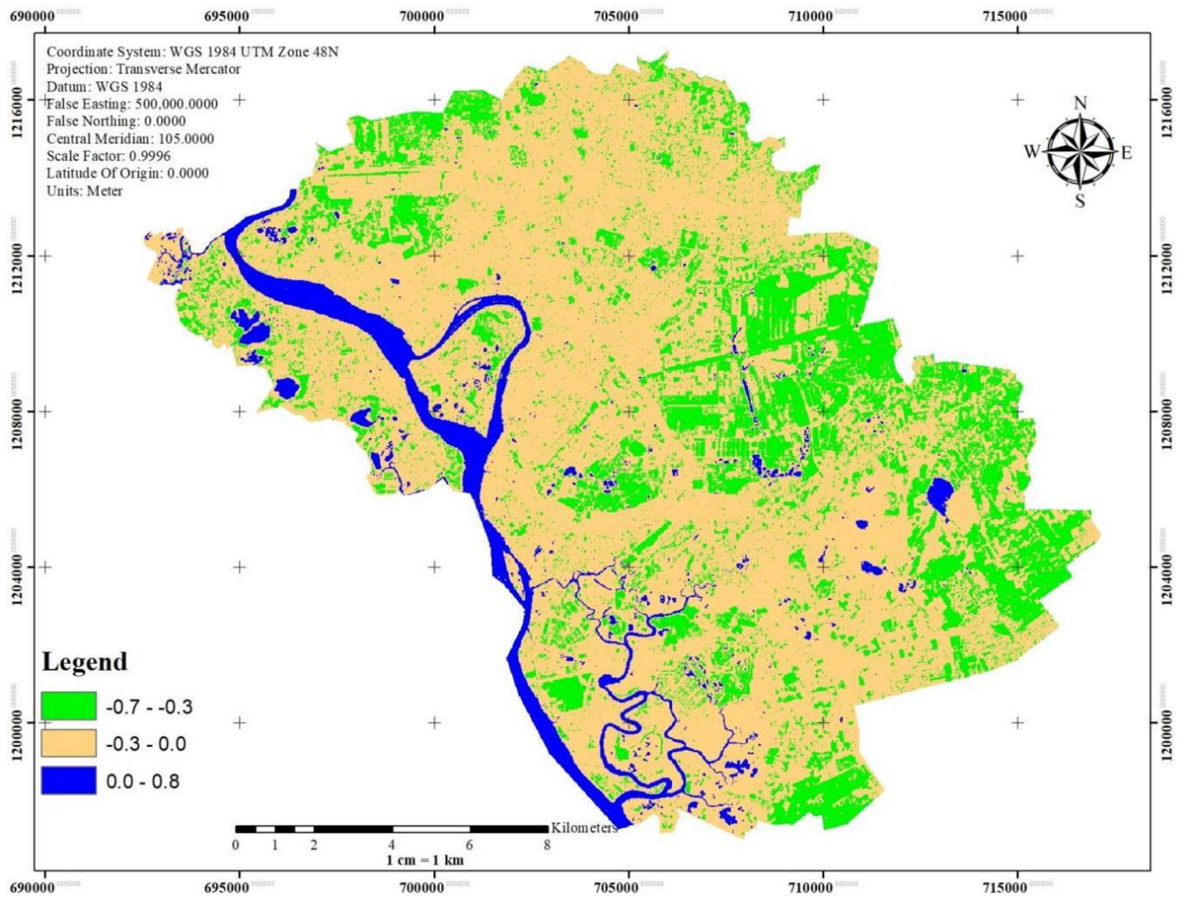

Figure 5. MNDWI classification map of Bien Hoa city, MNDWI threshold > 0

The NDVI classification map (Figure 4) shows that most of the central area has very little vegetation. Vegetation was mainly distributed in suburban wards of the city. This shows that the urbanization level of Bien Hoa city in the central area is very high. Figure 4 also shows that there is confusion in the classification between water surface and impervious surface in some streets in the city center and water surface.

The results of classification by MNDWI index in Bien Hoa city are shown in Figure 5. The surface of the water (MNDWI >0) has much more detail and clarity than in Figure 4 - in inner-city areas where there are many small canals. Although much of the confusion between road and water surface classification has been eliminated, such as the NDVI index map (shown in Figure 6). However, the results of the MNDWI classification show that there is also confusion between plants and impervious surfaces (Figure 7).

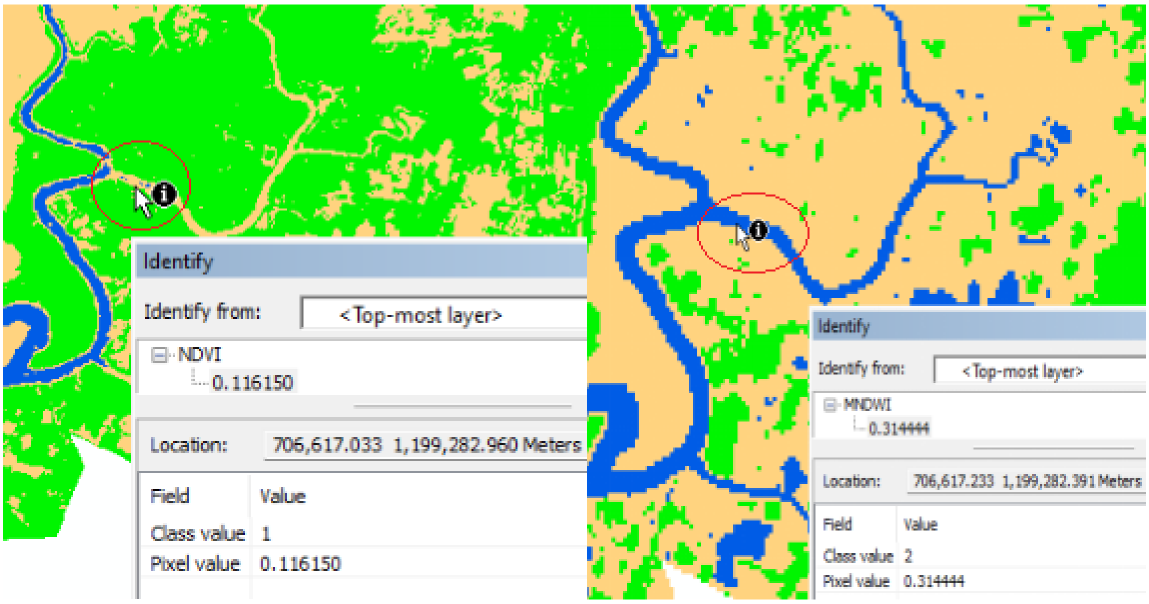

Figure 6. Comparison of results of water surface classification according to index NDVI and MNDWI

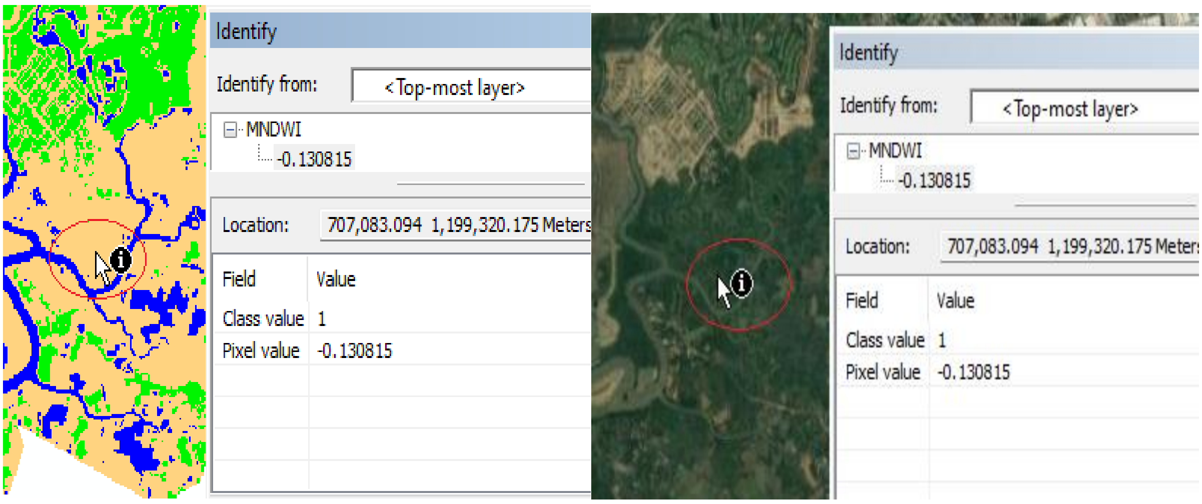

Figure 7.
Confusion between the classification of vegetation and the impervious surface according to index MNDWI .

Similarly, the NDBI index map has been constructed, shown in Figure 8. Although the impervious surface layer is shown very clearly and in detail, there is still a misclassification between water surface and vegetation (Figure 9).

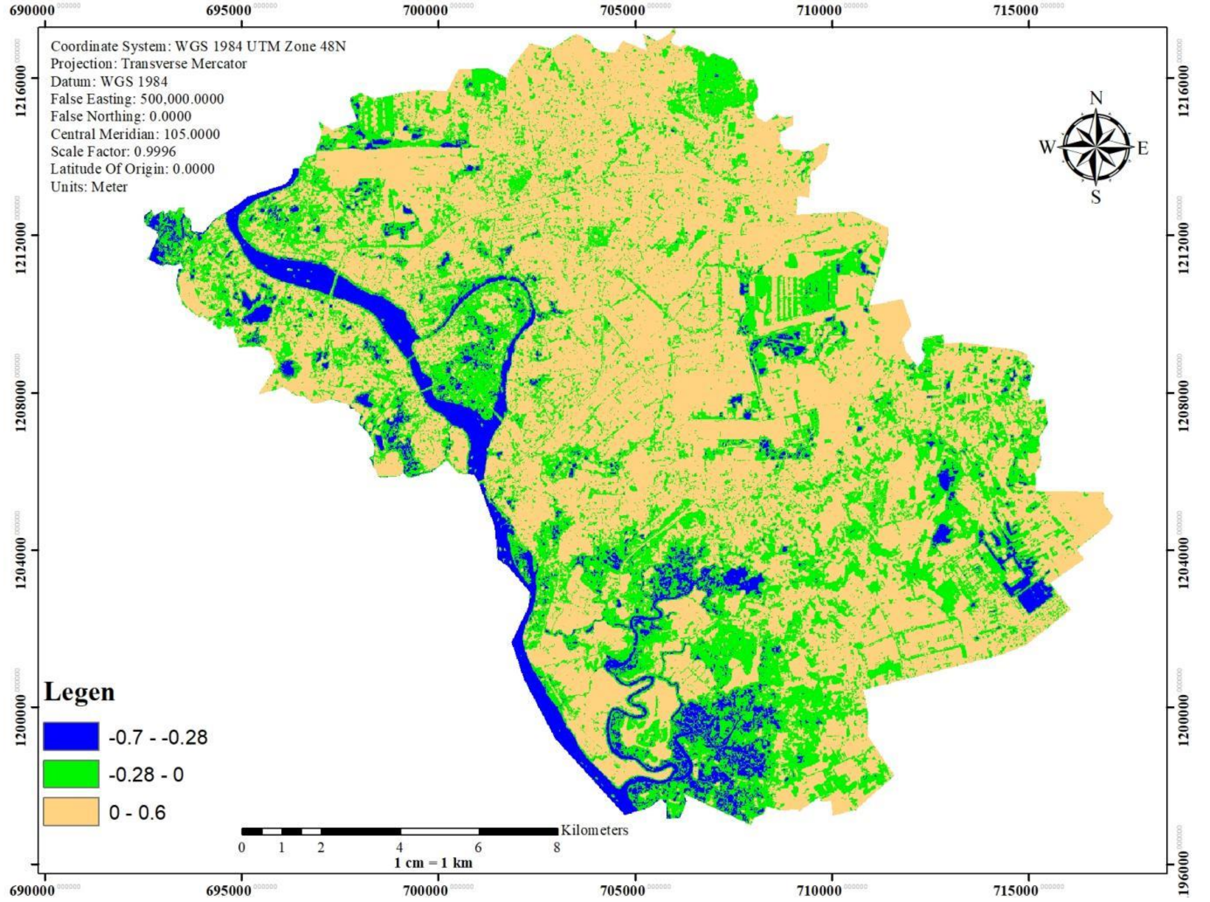

Figure 8. NDBI classification map in Bien Hoa city, NDBI threshold > 0

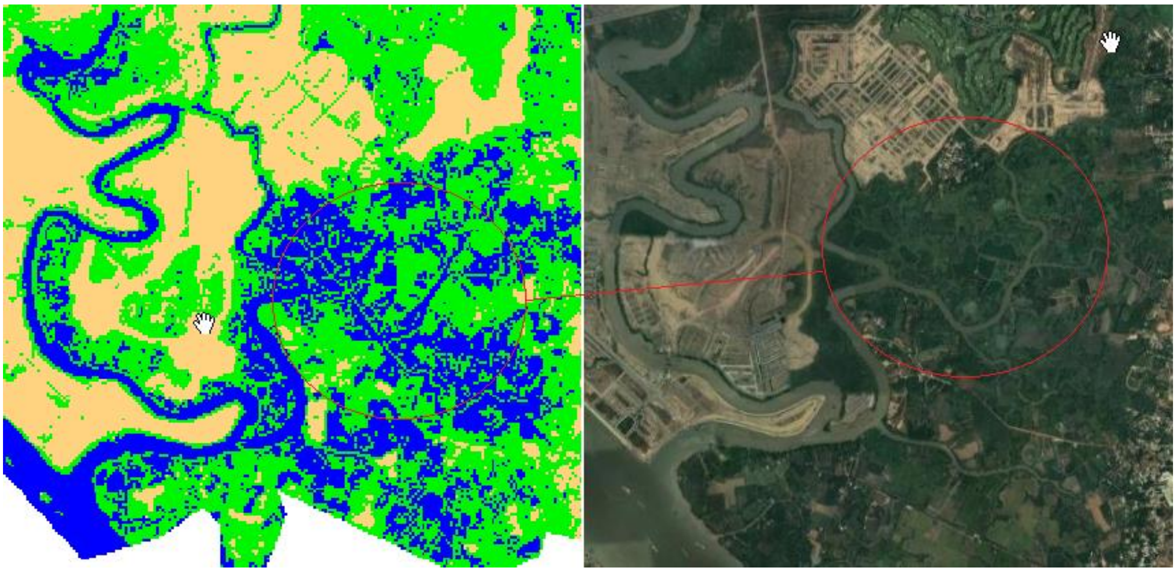

Figure 9. Misclassification between water surface and vegetation

Figures 4-9 show that the classification results for each of the different index types usually best reflect the one type of object related to it. Therefore, the synthetic overlay classification map was established based on the combination of NDVI, MNDWI and NDBI indices. After separating the water surface from the MNDWI classification map and separating the vegetation from the NDVI map, the water surface and vegetation were superimposed to form a natural permeable map. The synthetic cover map is formed from the overlapping of the impervious surface and the natural permeable map (Figure 10).

A total of 60 field samples were collected to check thesynthetic overlay classification map accuracy after overlapping. The results of the accuracy assessment are shown in detail in the classification accuracy test matrix in table 1.

Table 1.

Classification accuracy test matrix

Type	Vegetation	Water surface	impervious surface	Total row
Vegetation	15	0	0	15
Water surface	0	15	0	15
impervious surface	3	2	25	30
Total column	18	17	25	60

The results show that, overall accuracy T = 0.92, Kappa coefficient = 0.87. This proves that, it is very effective to create a synthetic overlay classification map based on the extraction of vegetation, water surface and impermeable surface from NDVI, MNDWI and NDBI classification maps. High classification accuracy.

After removing the water surface and vegetation from the synthetic overlay classification map, the impervious surface map is obtained, shown in Figure 11.

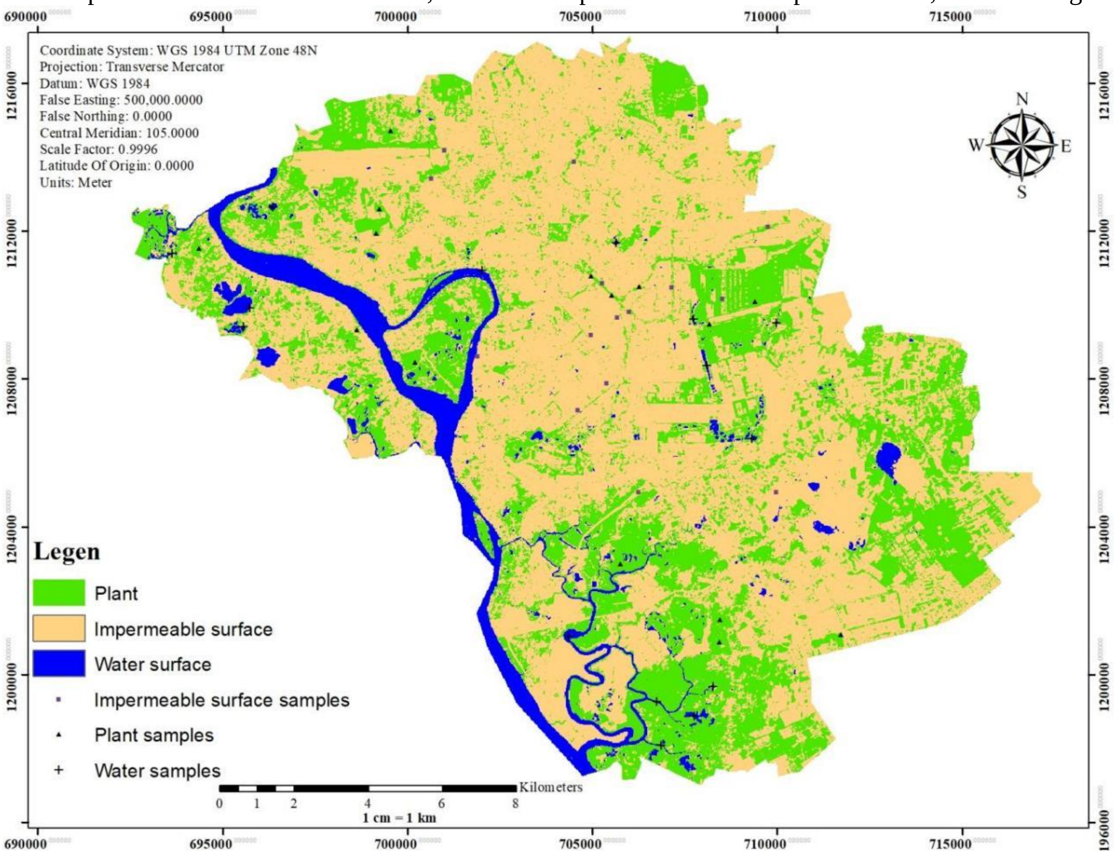

Figure 10. Synthetic overlay classification map of Bien Hoa city

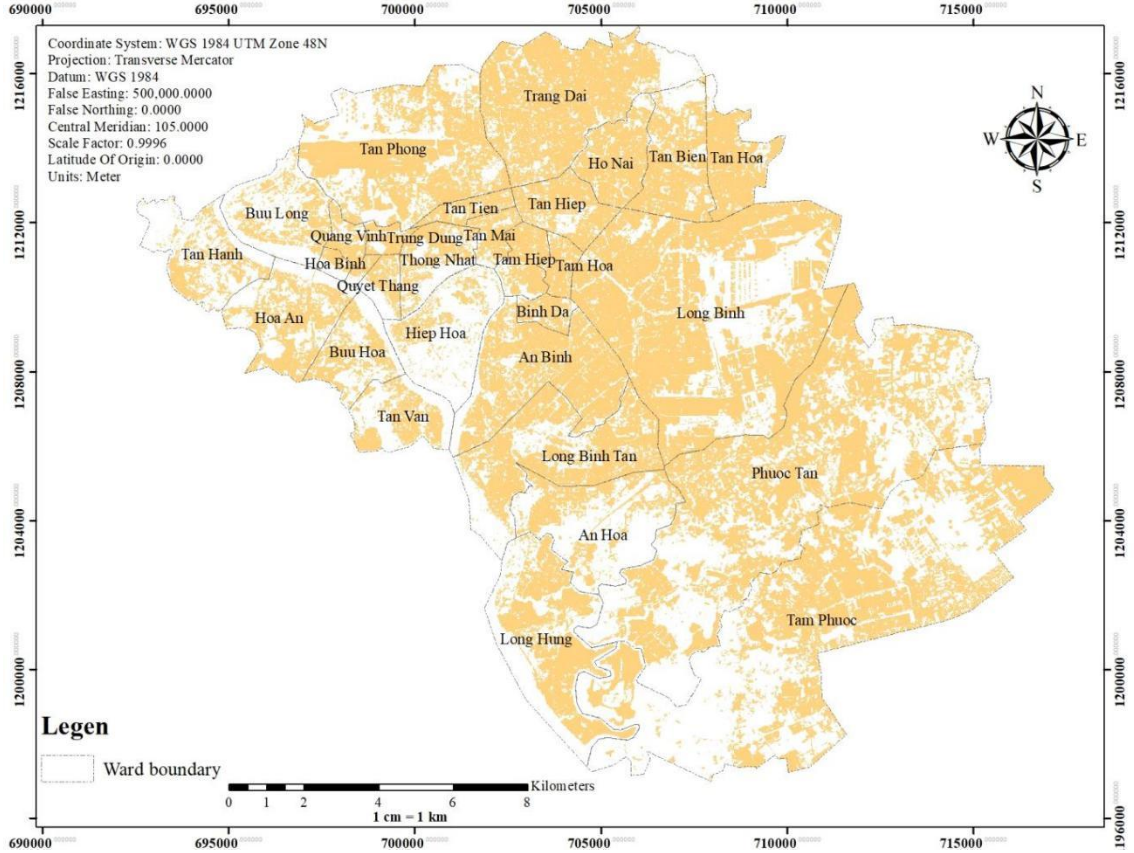

Figure 11. Map of impervious surface in Bien Hoa city

Based on the analysis tools in Qgis, the raster analysis data table is shown in Table 2. Table 2 shows that most wards in the center of Bien Hoa city and some wards in the northeast have very high rates of impervious surface area, ranging from 65-86%. In the western and southwestern wards, the ratio between the permeable surface and the impermeable surface did not differ significantly. This will obviously affect surface water drainage in these areas.

Table 2.

Analysis results by boundary of wards of Bien Hoa city

Number	Ward	Area (ha)	Percentage of surface impervious to water (%)	Average approach distance	Largest approach distance	Standard Deviation	Coefficient of Variation
1	Tan Hanh	614.76	37.62	35	160	40.43	1.16
2	Buu Long	587	39.73	28.54	165.76	38.3	1.34
3	Tan Phong	1,665.36	65.09	63.87	387.83	89.67	1.40
4	Trang Dai	1,414.28	81.18	127.6	378.32	192.53	1.51
5	Ho Nai	395.96	82.75	150.73	365.87	196.87	1.31
6	Tan Bien	594.48	73.48	120.32	287.54	157.87	1.31
7	Tan Hoa	400.48	86.61	132.65	379.42	216.54	1.63
8	Tan Hiep	350.08	80.28	109.65	332.83	210.34	1.92
9	Tan Tien	129.08	78.77	87.83	337.87	174.65	1.99
10	Tan Mai	139.88	72.32	65.43	247.65	75.34	1.15
11	Tam Hiep	218.32	79.09	57.83	216.87	76.43	1.32
12	Tam Hoa	124.16	85.79	134.83	342.76	154.87	1.15
13	Thong Nhat	340	53.16	43.23	267.43	45.76	1.06
14	Trung Dung	86.56	73.71	56.43	182.7	57.43	1.02
15	Quang Vinh	108.04	71.64	65.76	231.54	87.54	1.33
16	Hoa Binh	55.48	52.49	32.76	187.89	43.76	1.34
17	Thanh Binh	35.64	59.93	54.54	205.76	68.83	1.26
18	Quyet Thang	140.16	52.25	32.87	189.94	54.34	1.65
19	Hoa An	679.28	54.26	36.87	140.76	39.76	1.08
20	Buu Hoa	421.16	51.09	31.98	134.75	38.92	1.22
21	Hiep Hoa	694.68	25.65	20.23	117.83	32.76	1.62
22	Tan Van	437.44	47	47.87	165.98	67.87	1.42

23	An Binh	1,045.60	76.67	132.74	379.54	165.76	1.25
24	Long BInh Tan	1,150.76	68.23	62.65	287.32	88.43	1.41
25	Binh Da	127.64	72.61	67.94	189.65	98.45	1.45
26	Long Binh	3,479.16	74.39	98.45	376.87	138.92	1.41
27	An Hoa	942.8	39.99	28.77	65.87	30.54	1.06
28	Phuoc Tan	4,289.12	58.43	45.34	377.54	98.45	2.17
29	Tam Phuoc	4,486.88	51.18	57.54	276.99	76.43	1.33
30	Long Hung	1,165.76	55.26	45.55	265.67	66.45	1.46
31	TP Bien Hoa	26,320	61.08	69.19	387.83	137.54	1.99

The natural permeable map is a combination of the water surface and the vegetation. Because individual green spaces or bare land surfaces and small discrete ponds (<500 m2) are less able to absorb or regulate rainfall. So these areas have been removed from the natural permeable surface map. The analysis map of the minimum approach distance from the impervious area to the naturally permeable surface shows a significant difference in this value in Bien Hoa city (Figure 12). The dark red areas have a natural permeable surface approach distance of up to 387 m. These areas are concentrated in existing urban areas such as Tan Bien, Ho Nai, Tan Hoa, Tan Hiep, Tan Tien ...The average access distance to areas with natural permeable surfaces in central wards is 3 to 5 times higher than in suburban wards. Corresponds to the difference in the ratio of impervious surface area / naturally permeable surface area in these wards. The standard deviation is used to evaluate the dispersion of the statistics compared to the mean. It is shown in Table 2 that the wards with the highest percentage of impervious surfaces and the greatest access distance have a greater degree of data dispersion than in the rest of the areas. Wards such as Trang Dai, Tan Bien, Ho Nai, Tan Hoa, Tan Hiep, Tan Tien, Tam Hoa all have the largest access distances, ranging from 287-387 m, corresponding to it is a large standard deviation ranging from 157-210m. Meanwhile, some suburban wards (Buu Hoa, Loc Hoa, Long Binh ...), where the rate of natural permeable surface is high, and the access distance is low, the standard deviation is lower. This represents a huge difference in the distribution of impervious surfaces in central wards compared to suburban wards. The coefficient of variation shows the difference between the access distance to the area with natural permeable surface in different wards. For the entire Bien Hoa city area, this coefficient is 1.99, which proves that there is a significant difference between the distribution of areas with naturally permeable surfaces in the study area.

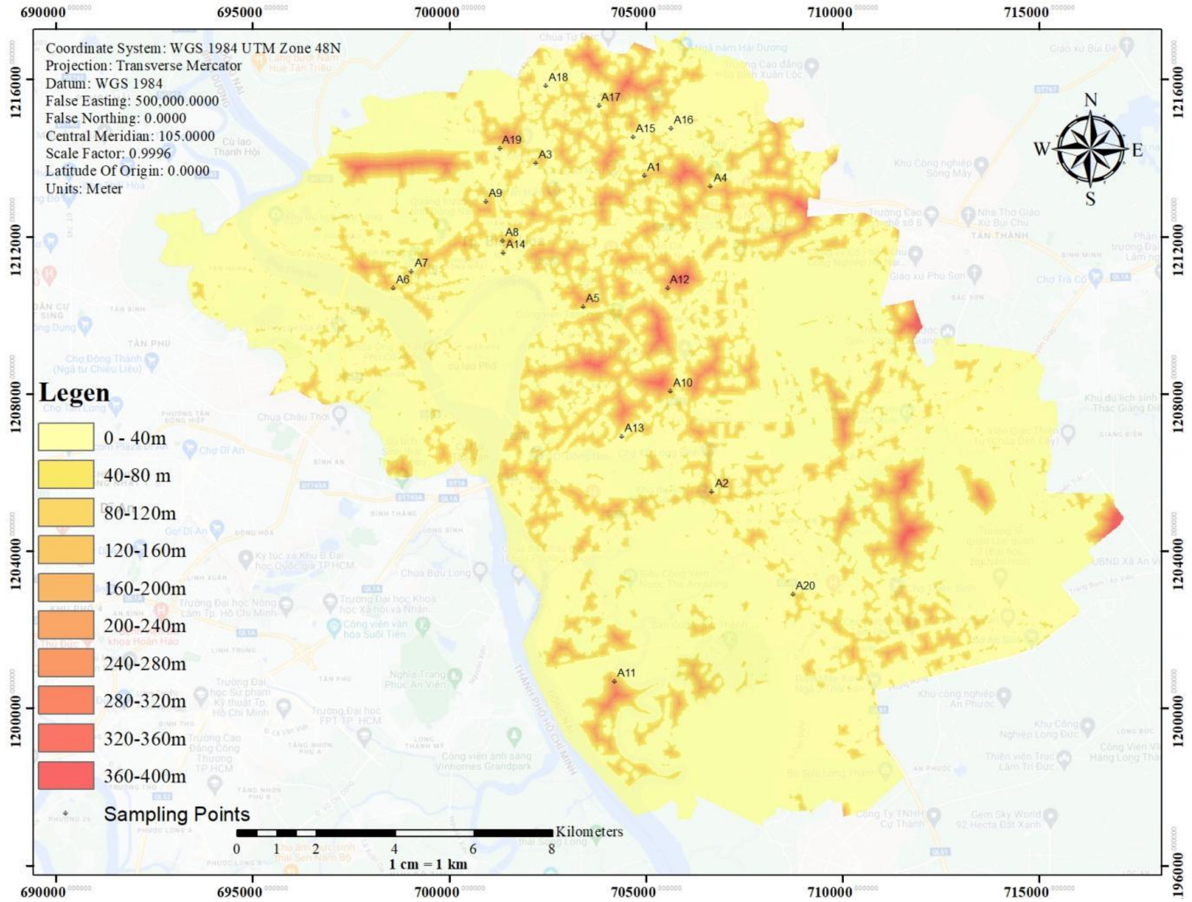

Figure 11. Map of the approach distance to the natural permeable surface

20 sample points were collected using a handheld GPS locator. In which, 12 points from points A1-A12 are frequently flooded when there is heavy rain and the remaining 8 points are taken in areas that are not flooded. The results of the analysis are shown in Table 3.

Table 3.

Analysis results of sample points

Point name	X	Y	Approach distance to naturally permeable surface (m)	Location in the ward
A1	704,972.61	1,213,554.17	215	Ho Nai
A2	706,684.64	1,205,506.55	150	Long Bình Tân
A3	702,213.59	1,213,869.77	185	Trang Dai
A4	706,651.24	1,213,271.40	186	Tan Bien
A5	703,411.83	1,210,208.24	146	Tam Hiep
A6	698,580.43	1,210,689.75	127	Thanh Binh
A7	699,052.71	1,211,103.49	132	Thanh Binh
A8	701,360.15	1,211,895.07	185	Tan Mai
A9	700,943.47	1,212,885.38	167	Tan Phong
A10	705,633.20	1,208,064.12	220	An Binh
A11	704,208.76	1,200,685.30	167	Long Hung
A12	705,554.24	1,210,685.64	215	Long Bình
A13	704,398.47	1,206,903.94	28	An Binh
A14	701,388.65	1,211,586.45	46	Thong Nhat
A15	704,688.91	1,214,531.82	25	Trang Dai
A16	705,646.18	1,214,747.99	32	Ho Nai
A17	703,810.63	1,215,331.00	34	Trang Dai
A18	702,473.11	1,215,834.19	12	Trang Dai
A19	701,290.82	1,214,238.78	47	Tan Phong
A20	708,750.48	1,202,902.28	12	Phuoc tan

The results in Table 3 show that the frequently flooded points (A1-A12) have a relatively high approach distance to the naturally permeable surface, in the range of 127-220 m. Some of the sites with severe inundation were due to proximity to areas with large impervious surface areas (A1, A4, A10) and all of these sites were located in wards with >60% impervious surface area. Meanwhile, the remaining points from A13-A20 are locations that are not flooded when it rains, they have a shorter distance to the natural permeable surface (12-47m), and are distributed in the fringes or in wards with an impervious surface rate <60%. This proves that, in areas with impermeable surface ratio >60% and access distance to natural permeable surface >120m are areas with higher risk of inundation compared to other areas. Therefore, it can be said that the urban surface drainage capacity depends not only on the percentage of impervious surface but also on its distribution in space with the natural permeable surface. The classification map according to the approach distance to the naturally permeable surface is shown in Figure 11. It can be useful in supporting sustainable drainage planning. Some solutions are to increase the natural permeable surface area (build green parks, trees on both sides of the road) in areas with a high percentage of impermeable surfaces (over 60%) to reduce the degree of disparity between the impervious surface/naturally permeable surface ratio, at the same time, measures must be taken to renovate and upgrade the drainage system in these areas.

4. Discussion

Research results show that each classification index (NDVI, MNDWI, NDBI) has the ability to clearly display a different type of object. In which, the studies using NDVI give very high classification accuracy of plants [24]. Meanwhile, MNDWI and NDBI indexes are effective in classifying water surface and impervious surface [14,25]. However, the classification by these indexes also shows their disadvantage that there is a mistaken classification between the remaining objects (with pixel value overlap), shown in figure 2-3, 6-9. The study applied the use of three different indexes to create a Synthetic overlay classification map. The classification results achieved high accuracy K=0.87. This shows that applying each indicator to separate each object separately will help eliminate errors due to mistaken classification.

To assess the natural drainage capacity of urban areas based not only on the ratio of natural permeable surface, but also analysis on the distribution of areas with natural permeable surface in the urban area. This is done based on determining the minimum distance from any point in the city to the natural permeable surface. The results of urban surface coverage isolation help determine the ratio of these surface types within wards, communes or according to urban drainage basins. On the other hand, the results of asymptotic analysis of areas with natural permeable surfaces in urban areas help determine the distribution characteristics between this space and spaces with impervious surfaces.

In the central wards of Bien Hoa city, the values of the average approach distance and the maximum distance to these drainage spaces are many times higher than the surrounding areas, and correspondingly the level of inundation risk in these areas. The low degree of interweaving between permeable and impervious surfaces has reduced urban porosity. Thereby reducing the drainage capacity in the center of Bien Hoa city. In conditions of flat terrain, low slope, the interweaving of permeable surfaces with impervious surfaces is an important factor to assess the potential for surface drainage towards sustainability. Areas with greater distance access to naturally permeable surfaces are at greater risk of flooding. In addition, these areas are more difficult to drain surface water, may be more affected by urban heat islands, lack open spaces, and lack ecosystems with biodiversity.

5. Conclusion

The results show the effective application of sentinel-2 images in analyzing the current state of urban surface water drainage. The extraction of each component of water, vegetation and impervious surface based on NDVI, MNDWI and NDBI indexes has contributed very effectively in the formation of the composite cover map. Overall classification accuracy T = 0.92, Kappa coefficient = 0.87. Areas with greater access distance to naturally permeable surfaces, the greater the risk of flooding. Most of the flood hot spots in Bien Hoa city are distributed in wards with a surface area impervious rate of more than 60% and the distance to naturally absorbent surfaces is from 120-400m. The percentage of impervious surface areas and their distribution are important indicators in building a sustainable drainage system.

References:

1. Zhou, Y., Dong, J., Xiao, X., Xiao, T., Yang, Z., Zhao, G., ... & Qin, Y. Open surface water mapping algorithms: A comparison of water-related spectral indices and sensors. Water, 9(4), 2017, pp. 256.

2. Statistical report of the Ministry of Natural Resources and Environment of Vietnam in 2021, 476 pages

3. Brisco, B.; Short, N.; Sanden, J.V.D.; Landry, R.; Raymond, D. A semi-automated tool for surface water mapping with RADARSAT-1. Can. J. Remote Sens., vol. 35, 2009, pp. 336–344.

4. Klemenjak, S.; Waske, B.; Valero, S.; Chanussot, J. Automatic detection of rivers in high-resolution SAR data. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., vol 5, 2012, pp. 1364–1372.

5. Canaz, S.; Karsli, F.; Guneroglu, A.; Dihkan, M. Automatic boundary extraction of inland water bodies using LiDAR data. Ocean Coasta. Manage, vol. 118, 2015, pp. 158–166.

6. Crasto, N.; Hopkinson, C.; Forbes, D.L.; Lesack, L.; Marsh, P.; Spooner, I.; Van der Sanden, J.J. A LiDAR-based decision-tree classification of open water surfaces in an Arctic delta. Remote Sens. Environ, vol. 164, 2015, pp. 90–102.

7. Lu, S.; Jia, L.; Zhang, L.; Wei, Y.; Baig, M.H.A.; Zhai, Z.; Zhang, G. Lake water surface mapping in the Tibetan Plateau using the MODIS MOD09Q1 product. Remote Sens. Lett., vol. 8, 2016, pp. 224–233.

8. Sharma, R.C.; Tateishi, R.; Hara, K.; Nguyen, L.V. Developing superfine water index (SWI) for global water cover mapping using MODIS data. Remote Sens., vol. 7, 2015, pp. 13807–13841.

9. Huang, C.; Chen, Y.; Wu, J.; Li, L.; Liu, R. An evaluation of Suomi NPP-VIIRS data for surface water detection. Remote Sens. Lett., Vol. 6, 155–164.

10. Sarp, G. Spectral and spatial quality analysis of pan-sharpening algorithms: A case study in Istanbul. Eur. J. Remote Sens., vol. 47, 2014, pp. 19–28.

11. Anderson, M.C.; Allen, R.G.; Morse, A.; Kustas, W.P. Use of Landsat thermal imagery in monitoring evapotranspiration and managing water resources. Remote Sens. Environ., vol. 122, 2012, pp. 50–65.

12. Tulbure, M. G., Broich, M., Stehman, S. V., & Kommareddy, A. Surface water extent dynamics from three decades of seasonally continuous Landsat time series at subcontinental scale in a semi-arid region. Remote Sensing of Environment, vol. 178, 2016, pp. 142-157.

13. Storey, J.; Roy, D.P.; Masek, J.; Gascon, F.; Dwyer, J.; Choate, M. A note on the temporary misregistration of Landsat-8 Operational Land Imager (OLI) and Sentinel-2 Multi 17. Spectral Instrument (MSI) imagery. Remote Sens. Environ., Vol. 186, 2016, pp. 121–122.

14. McFeeters S.K. The use of the Normalized Difference Water Index (NDWI) in the zelineation of open water features," International Journal of Remote Sensing, vol 17(7), 1996, pp. 1425-1432.

15. Xu H. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing, vol. 27(14), 2006, pp. 3025-3033.

16. Li, W., Du, Z., Ling, F., Zhou, D., Wang, H., Gui, Y., ... & Zhang, X. A Comparison of Land Surface Water Mapping Using the Normalized Difference Water Index from TM, ETM+ and ALI," Remote Sensing, vol 5(11), 2013, pp. 5530-5549.

17. Hoang Van Hue: Drainage network. Science & Technology Publishing House, Ha Noi, 2002.

18. Woods-Ballard B., R. Kellagher, P. Martin, Christopher Jefferies, R. Bray, P. Shaffer. The SuDS Manual (C753). London: CIRIA. 2015.

19. Xu, R., Liu, J., & Xu, J. Extraction of high-precision urban impervious surfaces from sentinel-2 multispectral imagery via modified linear spectral mixture analysis. Sensors, vol. 18(9), 2018, pp. 2873.

20. Doan Thi Noi. (2018). Research using GIS to build flow coefficient map of Bac Kan province. Transportation magazine, 10

21. Le Van Trung, Nguyen Nguyen Vu. (2018). Application of remote sensing and GIS to assess urbanization trend in Can Tho city. Environmental Science, 2, 57-62.

22. Dang Minh Duc. Report on environmental status of Dong Nai. 2020, pp. 45-63.

23. Nguyen Phuoc Huy. Report on hydrometeorological situation in Dong Nai province, 2021, pp. 25-35.

24. Yang Ju 1 and Gil Bohrer 2 (2022). Classification of Wetland Vegetation Based on NDVI Time Series from the HLS Dataset. Remote Sens. Remote Sens.14, 2107.

25. Iswari Nur Hidayati [1,*], R. Suharyadi [2], Projo Danoedoro (2018. Developing an Extraction Method of Urban Built-Up Area Based on Remote Sensing Imagery Transformation Index. Forum Geografi, 32(1).

26. Yang, X., Zhao, S., Qin, X., Zhao, N., & Liang, L. Mapping of urban surface water bodies from Sentinel-2 MSI imagery at 10 m resolution via NDWI-based image sharpening. Remote Sensing, vol 9(6), 2017, pp. 596.