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The use of Landsat image in monitoring the desertification in Ninh Phuoc District

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Abstract

Ninh Phuoc District is a coastal district located in the south of Ninh Thuan Province. In recent years, this district is faced with serious desertification. This phenomenon causes negative impacts on the lives of communities and massive damages to the economy of this district. For that reason, the managers must have effective solutions to monitor this phenomenon. This paper presents the obtained results on the use of Modified Soil Adjusted Vegetation Index 2 (MSAVI2), Normalized Difference Built-up Index (NDBI) and supervised classification in monitoring the desertification in Ninh Phuoc District from 1988 to 2016 with Landsat image. The Kappa coefficients of the classification results in 2009 and 2016 greater than 0.8 (respectively 0.8057 and 0.8183) has shown that this solution is reasonable for monitoring desertification in this region. This research has identified the changing trend of desert land area in Ninh Phuoc District from 1988 to 2016, provided the basis for the development of effective solutions to respond and prevent the desertification in this region.

Keywords: desertification; Modified Soil Adjusted Vegetation Index 2; Normalized Difference Built-up Index; supervised classification; Landsat image.

1. Introduction

Ninh Phuoc District is a coastal district of Ninh Thuan Province, adjacent with East Sea in the east and south. The people in this district live mainly by agriculture, fishing and producing salt. In recent years, Ninh Phuoc District is faced with serious desertification compared with 30 years ago. This makes the desert land area in this district tends to change quickly. The desert land is an area of land that receives no more than 25 centimetres of precipitation a year, has almost no vegetation and is often covered with sand or rocks. This phenomenon causes negative impacts on the lives of communities and massive damages to the economy of this district. In order to alleviate the negative impacts of desertification for Ninh Phuoc District, the managers must have effective solutions to monitor this phenomenon. One of the possible solutions to resolve that issue is using Landsat image - a type of medium-resolution satellite - to monitor desertification. This solution has been used in many parts of the world and Vietnam [1-8]. To settle the research objectives, the authors use Modified Soil Adjusted

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Vegetation Index 2 (MSAVI2), Normalized Difference Built-up Index (NDBI) and supervised classification in monitoring the desertification in this district from 1988 to 2016. The study area is the entire of Ninh Phuoc District.

The MSAVI2 is an index proposed by J. Qi, A. Chehbouni, A. R. Huete, Y. H. Kerr and S. Sorooshian in 1994 to distinguish non-vegetation and vegetation areas in Landsat image [9]. This index is developed to increase the dynamic range of the vegetation signal while further minimizing the soil background influences [9]. The theoretical values of MSAVI2 are between -1.0 and 1.0: values approaching 1.0 are vegetation areas, values approaching 0.0 are low vegetation areas, values approaching -1.0 are waterbody areas [9]. The MSAVI2 equation is calculated as follow [9]:

$$MSAVI2 = \frac{\left(2 \times NIR + 1 - \sqrt{(2 \times NIR + 1)^2 - 8 \times (NIR - Red)}\right)}{2}$$

The NDBI is an index proposed by Y. Zha, J. Gao and S. Ni in 2003 to distinguish non-built-up and built-up areas in Landsat image [10]. The theoretical values of NDBI are between -1.0 and 1.0: values approaching 1.0 are built-up areas, values approaching 0.0 are vegetation areas, values approaching -1.0 are waterbody areas [10]. The NDBI equation is calculated as follow [10]:

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$$

In MSAVI2 equation and NDBI equation mentioned above, NIR is near infrared band (0.76-0.96 µm), Red is red band (0.60-0.70 µm) and SWIR is shortwave infrared band (1.55-1.75 µm) in Landsat image.

2. Methods and data

2.1 Methods

The research process includes six phases: (1) collecting related data, (2) correcting Landsat images, (3) enhancing and transforming Landsat images, (4) classifying Landsat images and assessing the accuracy, (5) building desert land distribution maps and estimating desert land area, (6) evaluating results and drawing conclusions. Three types of software included ArcGIS Desktop 10.1, ENVI 5.3 and Microsoft Excel 2016 are mainly used to do this research. ArcGIS Desktop 10.1 is a GIS software of ESRI Corporation used to build desert land distribution maps, while ENVI 5.3 is a RS software of Harris Corporation used to calculate two related indexes (MSAVI2, NDBI) and interpret Landsat images. The detailed research process diagram is shown in the Figure 1. In six phases mentioned above, phase (3) and (4) are most important because they determine the accuracy of the results obtained.

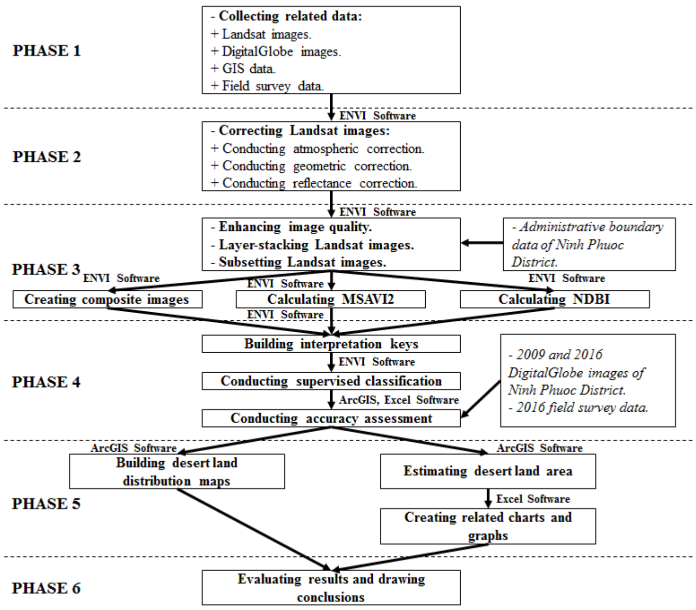


Figure 1. Detailed research process diagram

2.2 Data

To carry out this research, the authors use three types of data: (1) remote sensing data, (2) GIS data, (3) field survey data. The remote sensing data used are the Landsat images of seven years 1988, 1990, 1996, 2000, 2004, 2009 and 2016 of the study area. Besides that, the DigitalGlobe images (a type of high-resolution satellite image that collected from Google Earth) of the study area are also used to build base error matrices, provide the basis for assessing the classification accuracy. The GIS data used are the administrative boundaries of the study area. And the last is the field survey data that are collected in 2016 with Garmin GPSMAP 60CSx handheld GPS navigator.

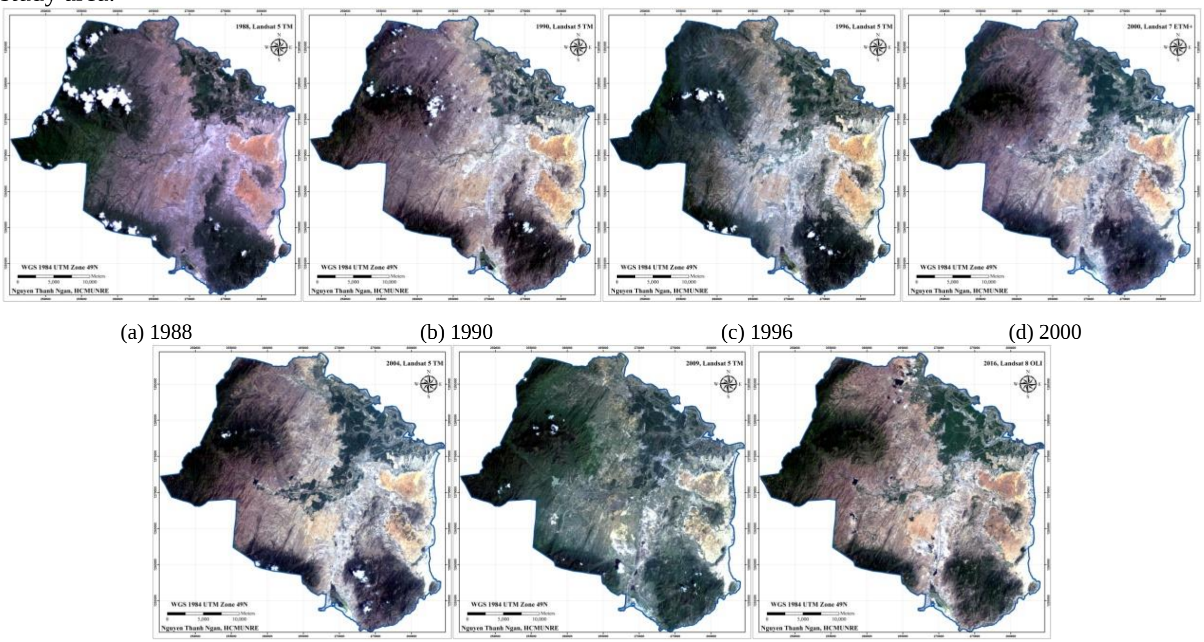
Table 1. Summary information of Landsat images used in this research

ID	Date Acquired	Satellite	Sensor	Path Row - Coordinate System
1	10/07/1988	Landsat 5	TM	123052 - WGS 1984 UTM Zone 49N
2	26/03/1990	Landsat 5	TM	123052 - WGS 1984 UTM Zone 49N
3	17/08/1996	Landsat 5	TM	123052 - WGS 1984 UTM Zone 49N
4	29/03/2000	Landsat 7	ETM+	123052 - WGS 1984 UTM Zone 49N
5	29/02/2004	Landsat 5	TM	123052 - WGS 1984 UTM Zone 49N
6	09/11/2009	Landsat 5	TM	123052 - WGS 1984 UTM Zone 49N
7	01/03/2016	Landsat 8	OLI&TIRS	123052 - WGS 1984 UTM Zone 49N

3. Results and discussion

3.1 Results of creating color composite images and calculating two related indexes

All the Landsat images in this research are downloaded from the GloVis website of USGS. After collected from the GloVis website, these images are corrected, enhanced and subsetted with the administrative boundaries of Ninh Phuoc District. In order to discriminate land cover types, the authors use these subsetted images to create the color composite images of the study area. Each land cover type is shown by a different specific color in color composite images. These specific colors help the interpreter easy to distinguish land cover types, provide the basis to determine interpretation keys. The Figure 2 shows the natural-color composite images of the study area.

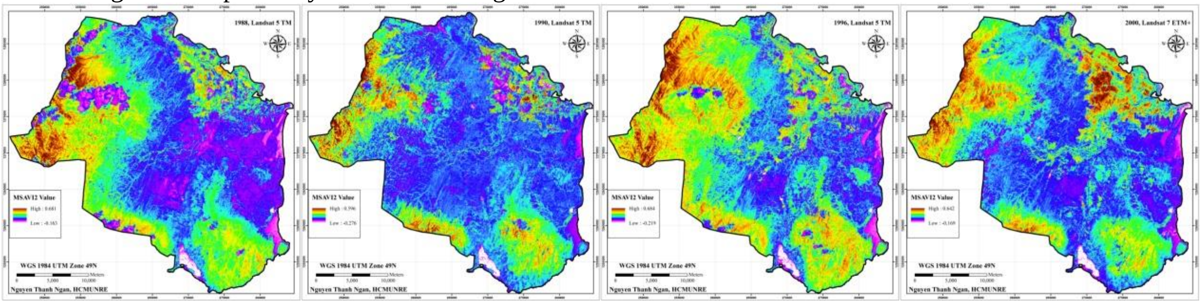


(a) 1988 (b) 1990 (c) 1996 (d) 2000

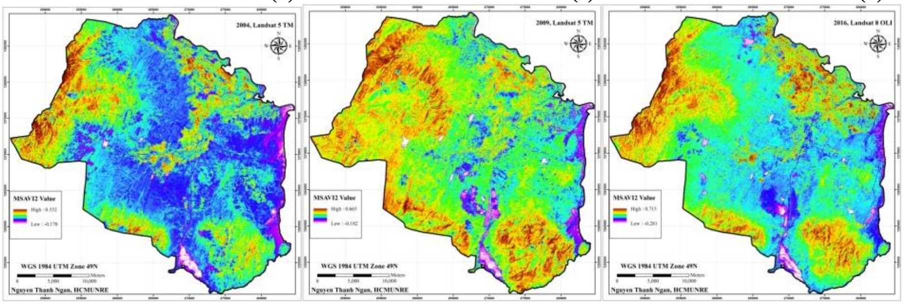
(e) 2004 (f) 2009 (g) 2016

Figure 2. Natural-color composite images of the study area

Besides creating color composite images, the authors also calculate MSAVI2 and NDBI for the subsetted images. The MSAVI2 and NDBI are calculated by three bands of Landsat images: (1) near infrared band, (2) red band, (3) shortwave infrared band. The MSAVI2 is used to differentiate thick vegetation, sparse vegetation and non-vegetation areas, while the NDBI is used to differentiate built-up, bare soil and desert areas. The combination of two indexes (MSAVI2 and NDBI) helps to discriminate desert areas with other objects in Landsat images. This provides a basis for identifying interpretation keys for desert areas. The MSAVI2 and NDBI images are respectively shown in the Figure 3 and 4.

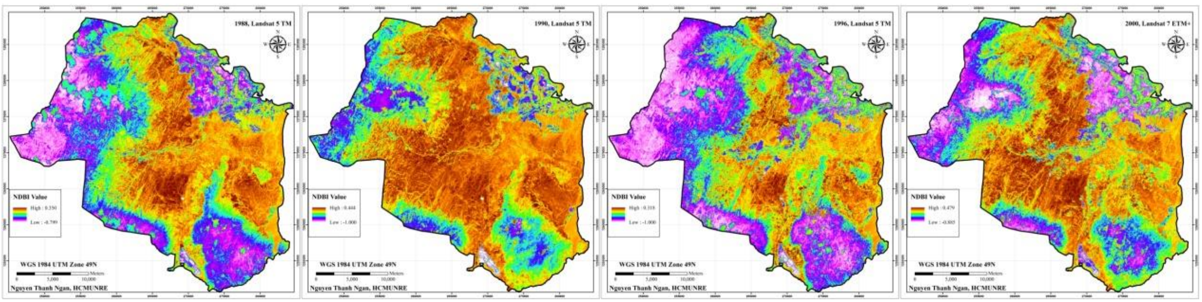


(a) 1988 (b) 1990 (c) 1996 (d) 2000

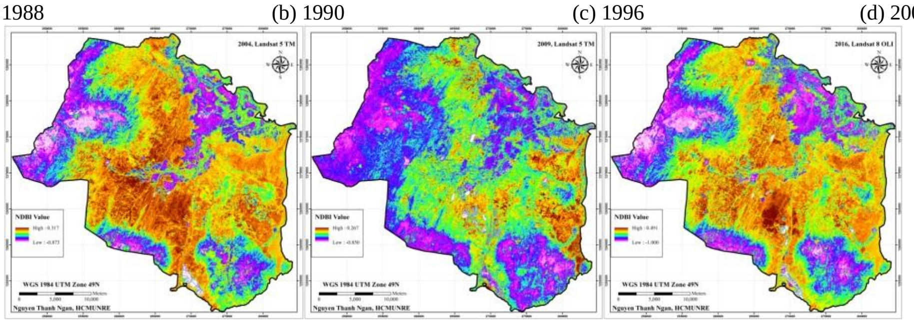


(e) 2004 (f) 2009 (g) 2016

Figure 3. The results of the MSAVI2 calculation



(a) 1988 (b) 1990 (c) 1996 (d) 2000



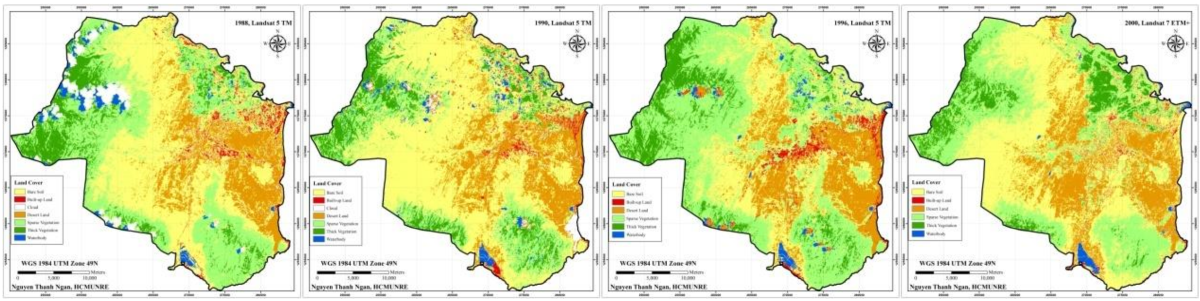
(e) 2004 (f) 2009 (g) 2016

Figure 4. The results of the NDBI calculation

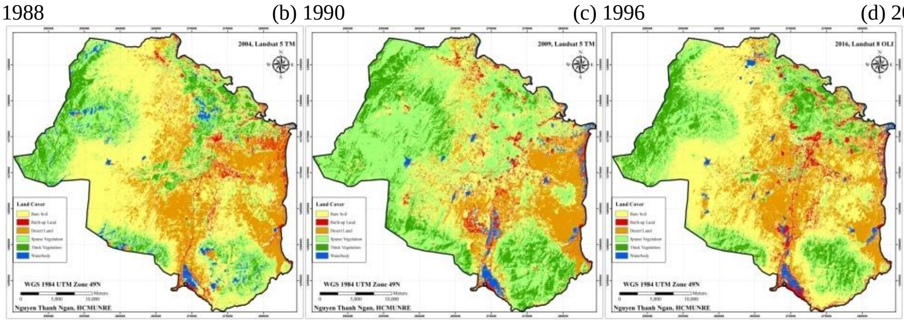
3.2 Results of classifying images and assessing the classification accuracy

After creating color composite images and calculating two related indexes, the subsetted images are classified with Maximum Likelihood algorithm. The color composite images, the MSAVI2 images and the NDBI images are combined to determine interpretation keys. The desert land pixels are chosen based on the value of MSAVI2, NDBI and the specific color of desert land in natural-color composite images (bright yellow or pale orange). Determining interpretation keys has an important role in classifying Landsat images because it affects the accuracy of the classification process. This process separates the study area into six main classes: (1) bare soil, (2) built-up land, (3) desert land (4) sparse vegetation, (5) thick vegetation, (6) waterbody. The Figure 5 shows the supervised classification results of the study area.

Based on the classification results obtained, the authors conduct to build the base error matrices. These matrices are the basis to estimate the Kappa coefficient and the overall accuracy of the classification process. These two coefficients help to assess the accuracy of the classification process. Because of the lack of reference data, the authors can only assess the accuracy for the classification results from 2009 and 2016 images (Google Earth only provides the DigitalGlobe images of the study area from 2009 to 2016). With the classification results from 2009 image, the Kappa coefficient value is 0.8057 and the overall accuracy value is 81.34%. With the classification results from 2016 image, the Kappa coefficient value is 0.8183 and the overall accuracy value is 82.63%.



(a) 1988 (b) 1990 (c) 1996 (d) 2000



(e) 2004 (f) 2009 (g) 2016

Figure 5. Supervised classification results of the study area

From the classification results mentioned above, the authors estimate the percentage of land cover types in the study area over the years. The percentage of land cover types in the study area from 1988 to 2016 is illustrated in the chart shown in the Figure 6.

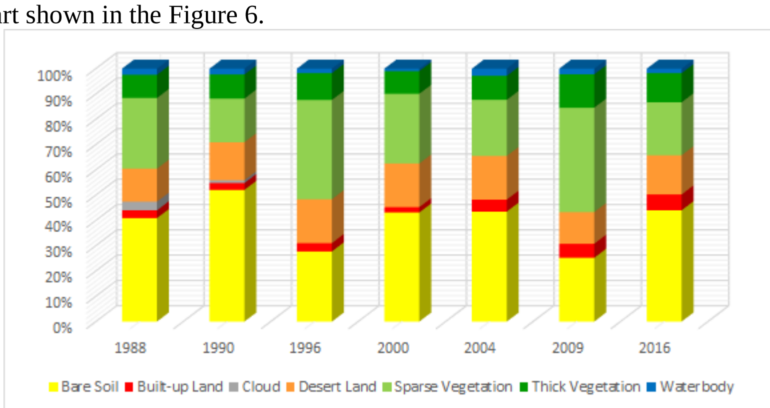
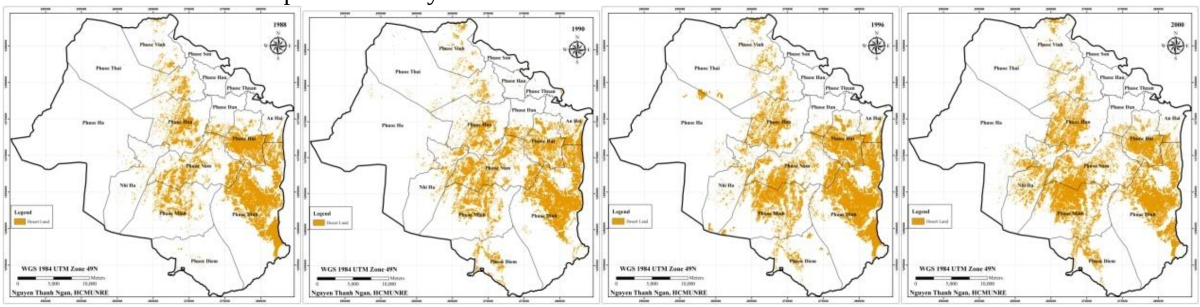


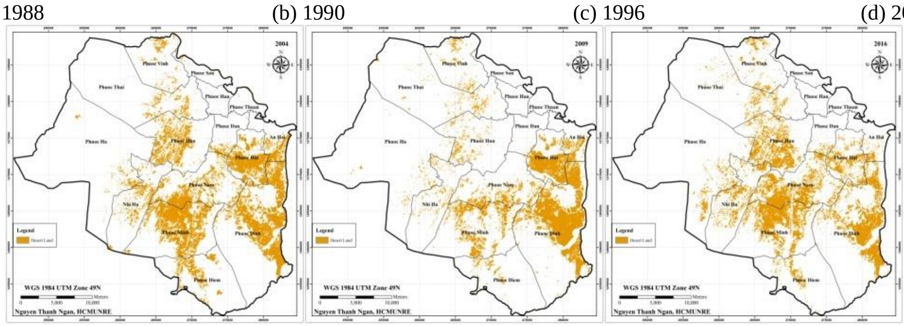
Figure 6. Chart of percentage of land cover types in the study area from 1988 to 2016

3.3 Results of building desert land distribution maps and estimating desert land area

After performing supervised classification, the desert land data is extracted from classification results in order to build desert land distribution maps. These maps help to identify densities and spatial distributions of desert land in the study area. The desert land data extracted from classification results are combined with the administrative boundaries data of the study area to make desert land distribution maps. The Figure 7 shows the desert land distribution maps of the study area.



(a) 1988 (b) 1990 (c) 1996 (d) 2000



(e) 2004 (f) 2009 (g) 2016

Figure 7. Desert land distribution maps of the study area

Besides building desert land distribution maps, the desert land data are also used to estimate the area value, the percentage change and the annual percentage change over the years in the study area. The results of this process are shown in the Table 2. The area values of desert land are used to create the graph of the desert land area in the study area from 1988 to 2016. This graph is shown in the Figure 8.

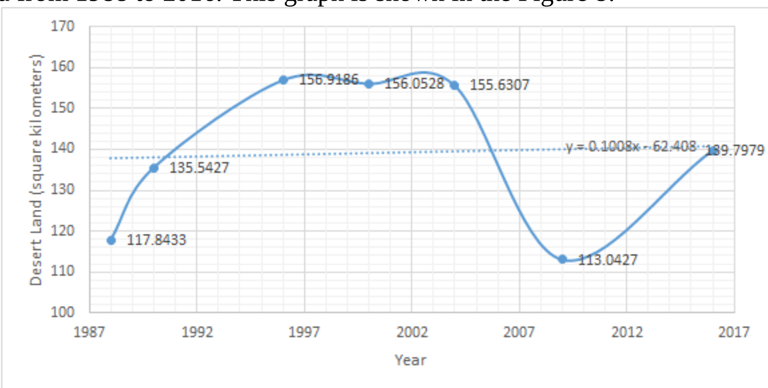


Figure 8. Graph of the desert land area in the study area from 1988 to 2016

According to the data in Table 2 and the graph in the Figure 8, the authors determine the changing trend of desert land area in the study area from 1988 to 2016. From 1988 to 1990, the desert land area in the study area tends to rise at a rate of 7.51% per year. From 1990 to 1996, the desert land area in the study area tends to rise at a rate of 2.63% per year. From 1996 to 2000, the desert land area in the study area tends to drop at a rate of 0.14% per year. From 2000 to 2004, the desert land area in the study area tends to drop at a rate of 0.07% per year. From 2004 to 2009, the desert land area in the study area tends to drop at a rate of 5.47% per year. From 2009 to 2016, the desert land area in the study area tends to rise at a rate of 3.38% per year. The desert land area values in the study period range from 113.04 km^2 (minimum value, in 2009) to 156.92 km^2 (maximum value, in 1996). Besides, based on the maps in the Figure 7, the authors also identify the spatial distribution of desert land in the study area. The desert land is mainly distributed in An Hai Commune, Phuoc Dinh Commune, Phuoc Hai Commune, Phuoc Huu Commune, Phuoc Minh Commune and Phuoc Nam Commune. The desert land is largely concentrated at the east coastal area of Ninh Phuoc District.

Table 2. Area value and percent change of desert land from 1988 to 2016

Year	Pixel	Area (km^2)	Percent change (%)	Annual Percent change (%)
1988	130,937	**117.84**		
1990	150,603	**135.54**	**15.02**	**7.51**
1996	174,354	**156.92**	**15.77**	**2.63**
2000	173,392	**156.05**	**-0.55**	**-0.14**
2004	172,923	**155.63**	**-0.27**	**-0.07**
2009	125,603	**113.04**	**-27.36**	**-5.47**
2016	155,331	**139.80**	**23.67**	**3.38**

4. Conclusions

This research has determined the area value, the percentage, the changing trend, and the changing rate of desert land in the study area from 1988 to 2016. Moreover, this research has also pointed out the characteristics of the spatial distribution of desert land in the study area. The results obtained in this research show that the desertification in the study area has happened very complicated. These will be valuable data for the managers of Ninh Phuoc District, help them set out effective solutions to respond and prevent the desertification in this region. Both the Kappa coefficients of the classification results in 2009 and 2016 greater than 0.8 has indicated that the method proposed in this paper (the combination of MSAVI2, NDBI and supervised classification) is suitable for identifying the desert land in Landsat image. In addition, through this research, the authors have proposed a process to make desert land distribution map and estimate desert land area from Landsat image. This will be a useful reference for environmental managers to monitor desertification trends.

References

1. Tueller, P. T., 1987. Remote sensing science applications in arid environments, Remote Sensing of Environment 23 (2), pp. 143-154.
2. Tripathy, G. K., Ghosh, T. K., Shah, S. D., 1996. Monitoring of desertification process in Karnataka state of India using multi-temporal remote sensing and ancillary information using GIS, International Journal of Remote Sensing 17 (12), pp. 2243-2257.
3. Collado, A. D., Chuvieco, E., Camarasa, A., 2002. Satellite remote sensing analysis to monitor desertification processes in the crop-rangeland boundary of Argentina, Journal of Arid Environments 52 (1), pp. 121-133.
4. Haijiang, L., Chenghu, Z., Weiming, C., En, L., Rui, L., 2008. Monitoring sandy desertification of Otindag Sandy Land based on multi-date remote sensing images, Acta Ecologica Sinica 28 (2), pp. 627-635.
5. Xu, D., Kang, X., Qiu, D., Zhuang, D., Pan, J., 2009. Quantitative Assessment of Desertification Using Landsat Data on a Regional Scale – A Case Study in the Ordos Plateau, China, Sensors 9 (3), pp. 1738-1753.
6. Dawelbait, M., Morari, F., 2012. Monitoring desertification in a Savannah region in Sudan using Landsat images and spectral mixture analysis, Journal of Arid Environments 80, pp. 45-55.
7. Li, J., Yang, X., Jin, Y., Yang, Z., Huang, W., Zhao, L., Gao, T., Yu, H., Ma, H., Qin, Z., Xu, B., 2013. Monitoring and analysis of grassland desertification dynamics using Landsat images in Ningxia, China, Remote Sensing of Environment 138, pp. 19-26.
8. Le, T. T. H., 2013. Áp dụng chỉ số thực vật (NDVI) của ảnh Landsat đánh giá hoang mạc hóa tỉnh Bình Thuận, Vietnam Journal of Earth Sciences (ISSN 0886-7187) 35 (4), pp. 357-363.
9. Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H., Sorooshian, S., 1994. A Modified Soil Adjusted Vegetation Index, Remote Sensing of Environment 48 (2), pp. 119-126.
10. Zha, Y., Gao, J., Ni, S., 2003. Use of normalized difference built-up index in automatically mapping urban areas from TM imagery, International Journal of Remote Sensing 24 (3), pp. 583-594.