Spatial Planning Influences Mangrove Forest Development in Kim Son District of Ninh Binh Province

Hong Quang NGUYEN, Thi Thanh Nga PHAM, Thi Van Hue LE and Van Tan DAO, Vietnam, Claire QUINN, Rachael CARRIE, and Lindsay STRINGER, UK

Key words: Coastal environment, Mangrove development, Land-use planning, Vietnam, remote sensing

SUMMARY

Mangrove forests provide critical ecosystem services and support the livelihoods of many coastal communities. They can store more carbon than rainforests, and provide crucial shoreline protection by reducing the impacts of storms and tidal surges on coastal villages. Spatial planning in the early 19th Century resulted in the creation of new administrative areas seaward, including Kim Son district in northern Vietnam, and ultimately the establishment of new communities along the coastline. In this study we investigate the influence of changes in land use and sea dyke construction on mangrove forest in Kim Son district following the establishment of two coastal villages over the last 2 decades. The results show that 3 dykes have been constructed over this time period and a 4th dyke is being planned. As a result of mangrove planting the mangrove forest is moving seawards and its extent varied rapidly. The dykes have also led to fragmentation of the mangrove forest and land use change as land is incorporated behind the dyke system. In other words, the mudflat where the mangroves growing are disturbed and blocked by the dykes and shrimp ponds. These changes in mangrove forests and livelihoods will have implications for the future trajectories of mangrove socio-ecological systems of Kim Son.

TÓM TẮT

Rừng ngập mặn cung cấp những dịch vụ quan trọng về hệ sinh thái và hỗ trợ nguồn thu nhập cho các cộng đồng sống quanh khu vực bờ biển. Rừng ngập mặn có thể lưu trữ lượng các bon lớn hơn rừng nhiệt đới và có chức năng bảo vệ và làm suy giảm tác động của bão, ảnh hưởng của sóng và thủy triều tới các làng mạc ở khu vực ven biển. Đầu thế kỷ 19 quy hoạch phát triển quai đê lấn biển đã tạo nên những vùng đất mới, đồng thời thành lập lên những cộng đồng dân cư theo hướng lấn ra biển ở huyện Kim Trung tỉnh Ninh Bình. Trong nghiên cứu này chúng tôi điều tra ảnh hưởng của thay đổi sử dụng đất và xây dựng những con đê tới rừng ngập mặn ở huyện Kim Sơn đã tạo lên các vùng đất ven biển trong 2 thập kỷ qua. Kết quả

nghiên cứu đã cho thấy có 3 con đê đã được xây dựng và đê thứ 4 đang được triển khai. Mặc dù rừng ngập mặn không phát triển được trong khu vực trong đê nhưng do có việc trồng rừng được thực hiện thường xuyên, dẫn đến rừng ngập mặn thay đổi về diện tích, được phát triển theo hướng ra biển và dẫn tới việc thay đổi sử dụng đất khu vực trong đê. Nói một cách khác, khu vực có bồi tụ bởi sông nơi rừng ngập mặn phát triển bị "bao vây" bởi các con đê và đầm nuôi tôm bị suy thoái dần và thay vào đó là rừng trồng mới ngoài đê. Sự thay đổi về rừng ngập mặn và sinh kế tại Kim Trung sẽ có ảnh hưởng tới sự biến đổi hệ sinh thái rừng ngập mặn tại Kim Trung.

Spatial Planning Influences Mangrove Forest Development in Kim Son District of Ninh Binh Province

Hong Quang NGUYEN, Thi Thanh Nga PHAM, Thi Van Hue LE and Van Tan DAO, Vietnam, Claire QUINN, Rachael CARRIE, and Lindsay STRINGER, UK

1. INTRODUCTION

Mangrove forests deliver numerous provisioning, regulating, cultural and supporting services which provide coastal and inland communities with wide-ranging benefits (Cummings & Shah, 2018). They act as nurseries that support global coastal and marine fisheries (Nagelkerken et al., 2008), and contribute resources that are of critical importance to local subsistence and cash economies (Orchard et al., 2015). Mangrove root systems promote sedimentation and can contribute to land expansion, and their above- and below-ground structures can reduce coastal erosion and damage caused by storms by attenuating wave or buffering wind energy (Lee et al., 2014). As the most carbon-dense of tropical forest ecosystems (Donato et al., 2011), mangroves also sequester and store significant quantities of carbon that otherwise has potential to worsen climate change (Cummings & Shah, 2018). As a result of these and other benefits that mangrove forests provide, their rehabilitation and restoration can form a key component of coastal zone planning, often supporting the role and reducing the maintenance costs of man-made coastal protection structures, including sea dykes. This is the case for Vietnam, where there is high dependence on services derived from marine and coastal ecosystems (Veettil et al., 2019), and where low-lying land, rapid coastline development and the prevalence of typhoon events leaves coastal livelihoods and infrastructure particularly vulnerable to extreme weather events (Veettil et al., 2019).

This study takes advantages of time-series Landsat images acquired over the last three decades to analyze mainly changes of dyke and mangrove in some coastal communes in Kim Son district, Ninh Binh province, Vietnam. In order to classify land use patterns, there have been two broaden used methods of supervised and unsupervised classifications using remote sensing data (Bocco et al., 2001). Although, both methods have their own advantages and disadvantages in specific uses, supervised classification is based on training data, therefore correct classification is assigned (Sathya and Abraham, 2013). In this study, a supervised classification of Support vector machines method (SVMM) and GIS spatial analysis are applied. The SVMM classification is a robust and reliable tool applied in remote sensing used and described in studies of (Melgani and Bruzzone, 2004, Shrestha and Shukla, 2015). Spatial analysis of multi-temporal Landsat imageries from 2 to 8 revealed some interesting information of both dykes and mangrove extent varied sharply in the study site.

Vietnam has a long coastline and is region of many estuaries where rivers discharge to the sea (Thanh et al., 2004) and dominant hydrodynamic processes on the banks of an estuary baring mudflats grade into mangrove zones (Janssen-Stelder et al., 2002). Beside, human activities such as changes in the supply and distribution of water, sediments (Thanh et al., 2004, Pham and Yoshino, 2016), dike buildings and aquaculture have had great influences on the changes of mangrove distribution and extent. A typical example is the Xuan Hai dyke constructed from 1981 to 1985 in Thai Binh Province destroyed 600 ha of mangroves, wasting 70 billion VND (Phan N. H, 1998). Although, Pham and Yoshino (2016) introduced to the loss of mangrove due to the human impacts like over exploitation of mangrove forests, conversion into agriculture. The area of mangrove extent in Kim Son district is reserved mostly thanks to mangrove plantation. From 1990 to 1997, funded by the Japanese Red Cross, 150 ha of mangroves in Kim Son district were planted while the number for the North Vietnam was 1500 ha (Phan 1998). The mangrove area planted here from 1997 to 2002 was 650 ha (Phan and Dao 2003). From 2001 to 2010 approximately 1000 ha of mangrove forest were inter-planted or diversely planted (Mai 2010).

Since early 19s, Nguyen Cong Tru, a famous Vietnamese military leader, economist and a poet who was very actively in land reclamation and Kim Son district established as his achievement (Bao Bien Phong 2013). The process of seaward land reclamation has been retaining recently with slogan "“Rice expanding to seagrass, seagrass expanding to mangrove and mangrove expanding to the sea”. The keys of the land reclamation success of Nguyen Cong Tru were building dykes, improving irrigation system and soil enrichment. Economic reforms (doi moi) introduced in 1986 in Vietnam, promoted to mitigate resource degradation and overexploitation including mangrove forest (Le, 2008). The REDD+ has become a reference framework for national forest governance across many forest countries (Pamela et al., 2016). In order to protect the land, aquaculture ponds and facilities from tides and waves, they have been building dykes and also used for transport. Altogether, it is resulted of whole Kim Son district established and some other new lands in neighbor provinces of Thai Binh and Nam Dinh and an increase of mangrove areas seaward.

Many previous studies have shown the advantages of remote sensing in time-series, large area and monitoring land use changes (Thu and Populus, 2007, Seto and Fragkias, 2007), vegetation study (Kappas et al., 2015), even aquatic vegetation (William et al., 2003) and many more. With the fast space technology in many nations, the remote sensing data have become widely (time and space) available for many users (Simons et al., 2016) and the computing platform, algorithm development could help set the agenda for environmental negotiations, and provide information for monitoring, facilitating, and enforcing compliance (Seto and Fragkias, 2007). In addition, remote sensing together with GIS applications could support for land-use planning in terms of providing spatial and temporal supportive data. Despite of that, remote sensing technique has limitation as well such as dependency on the date of image acquisitions, uncertainties due to atmospheric effects or geometric distortion.

2. STUDY SITE

Kim Son district, a part of Red River delta, is located at the east of Ninh Binh province. It has a population of approximately 169,000 and covers an area of 215 km^2 (statistics of 2016). The district includes four communes and two zones managed directly by the province (Figure 1). The main economy is based on agriculture (rice) and aquaculture (shrimps, clams, fish etc.). Other income for small households comes from collecting crabs, and clams in the mangrove forest.

Located on the same coastal zone of the North Vietnam, climatic and hydrological conditions are similar to those the Red River Delta such as Nam Dinh Province. Kim Son is situated in the tropical monsoon region with a hot season and a cold dry season. The hot season lasts from April to October and the cold dry season lasts from November to March. The average annual temperature is 24 °C. The average annual rainfall is 1760 mm, the highest rainfall can be seen in August and September, amounting to 395 mm. Average humidity is 85%. (Nguyen et al, 2000). Salinity varies greatly, 11-30 ‰, depending areas. The region has diurnal tidal regime with a cycle of under or over 23 hours. The mean tidal amplitude is about 150-180 cm. A large tidal amplitude can be seen from December to February (Phan et al, 2004).

The area currently covered by the district three time larger than when it was established (Bao Ninh Binh 2013) with land rapidly expanding out to the sea. This process occurs because of the location of the district at the mouths of the Day, Chinh Dai and Lan rivers where sediment continuously accumulates. Accreted land in the Red river Delta was reported to be high sediment accumuation, with the average rate of expansion 28 m/ year (Nguyen et al. 2011). Approximately 80 m of new land is created annually out to the sea (Mai 2010).

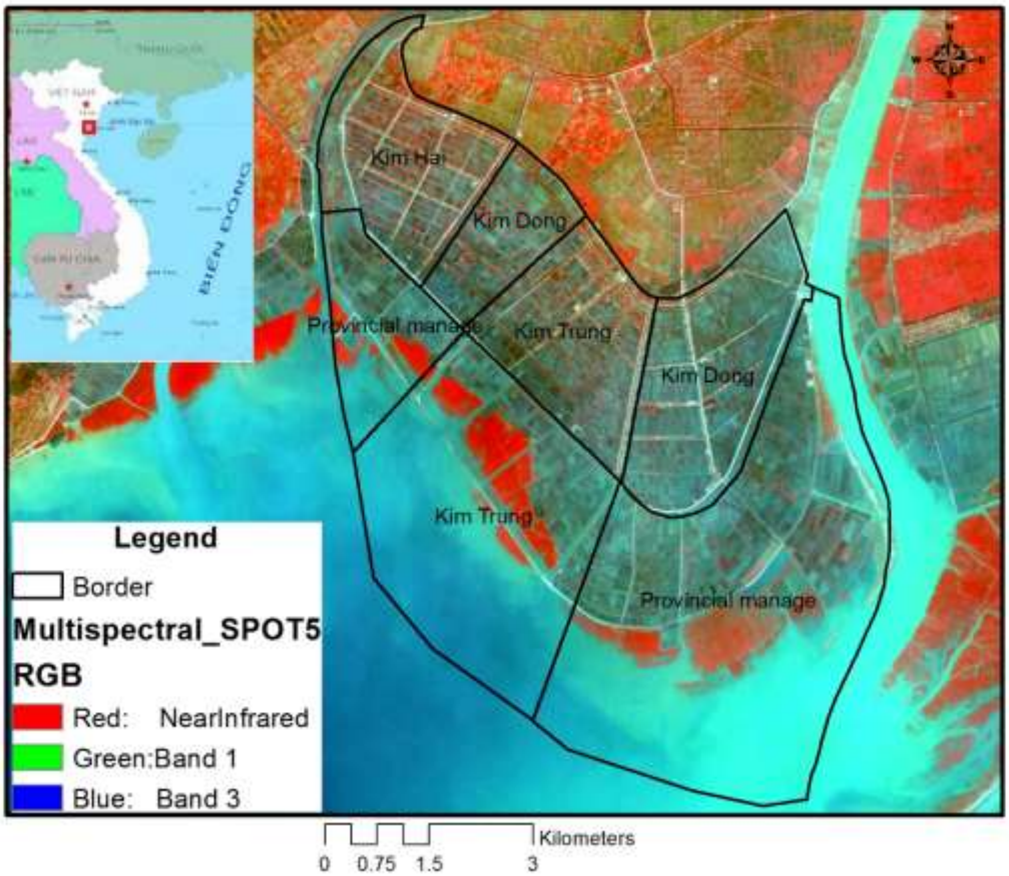

Figure 1: Study site at Kim Son District based on a SPOT5 image acquired in 2010 with vegetation highlighted in red

3. METHODOLOGY

3.1 Study flow of work

A simple study flow of tasks was designed to process time series Landsat 2,5 and 8 data (due to missing data in Landsat 7 images they were not used). All tasks presented in the Figure 2 are compact; some sub-tasks are hidden in that graph. As basic optical satellite processes are well-explained in previous literature (Mountrakis et al., 2011, Leichtle et al., 2017), we present only the core tasks here.

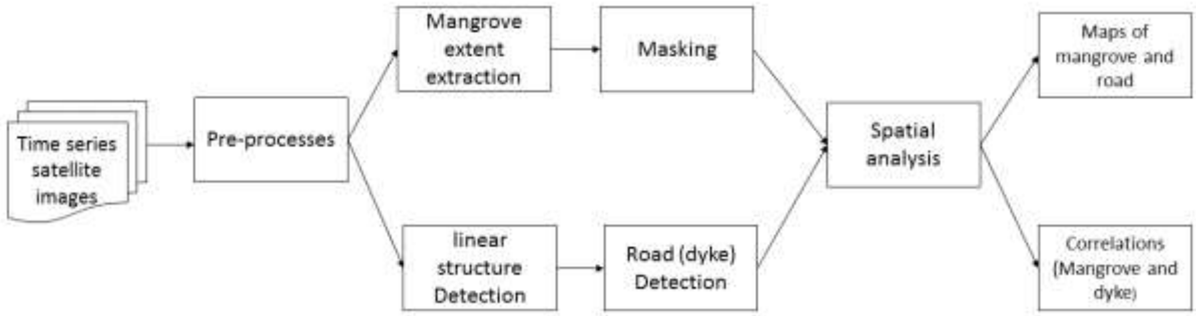

Figure 2. Flow work to illustrate processing of Landsat images to accomplish the study goals

3.2 Data used

Landsat scenes (Landsat 2,5,8 acquired years 1975-2018) providing comprehensive coverage and enabling analysis of current and historical mangrove and dyke conditions were obtained from the U.S. Geological Survey website (https://earthexplorer.usgs.gov/) and a SPOT 5 image is collected. Basic information about the scenes is summarized in Table 1.

Table 1. Summary of remote sensing data used for this study

Satellite sensor	Date of acquisition	Pixel size	Spectral resolution	Band used
Landsat OLI_TIRS	2018-Oct-06 2013-Oct-08	30 m	11 band	3, 4,5,6
SPOT 5 HRG 2	2010-Oct-22	10 m	4 band	1,2,3,4
Landsat TM	2008-Nov-11 2003-Jul-9 1998-Oct-15 1993-Nov-02 1988-Nov-04	30 m	7 band	2,3,4,5
Landsat MSS	1975-Aug-07	60 m	4 band	4,5,6,7

To overcome seasonal changes in graphical features, particularly vegetation cover, most images were acquired for the same season of autumn. However, seasonal and tidal influences still affected reflectance resulting in variation in water present. The color images composited from bands (differently for each image) of the scenes are shown in Figure 3.

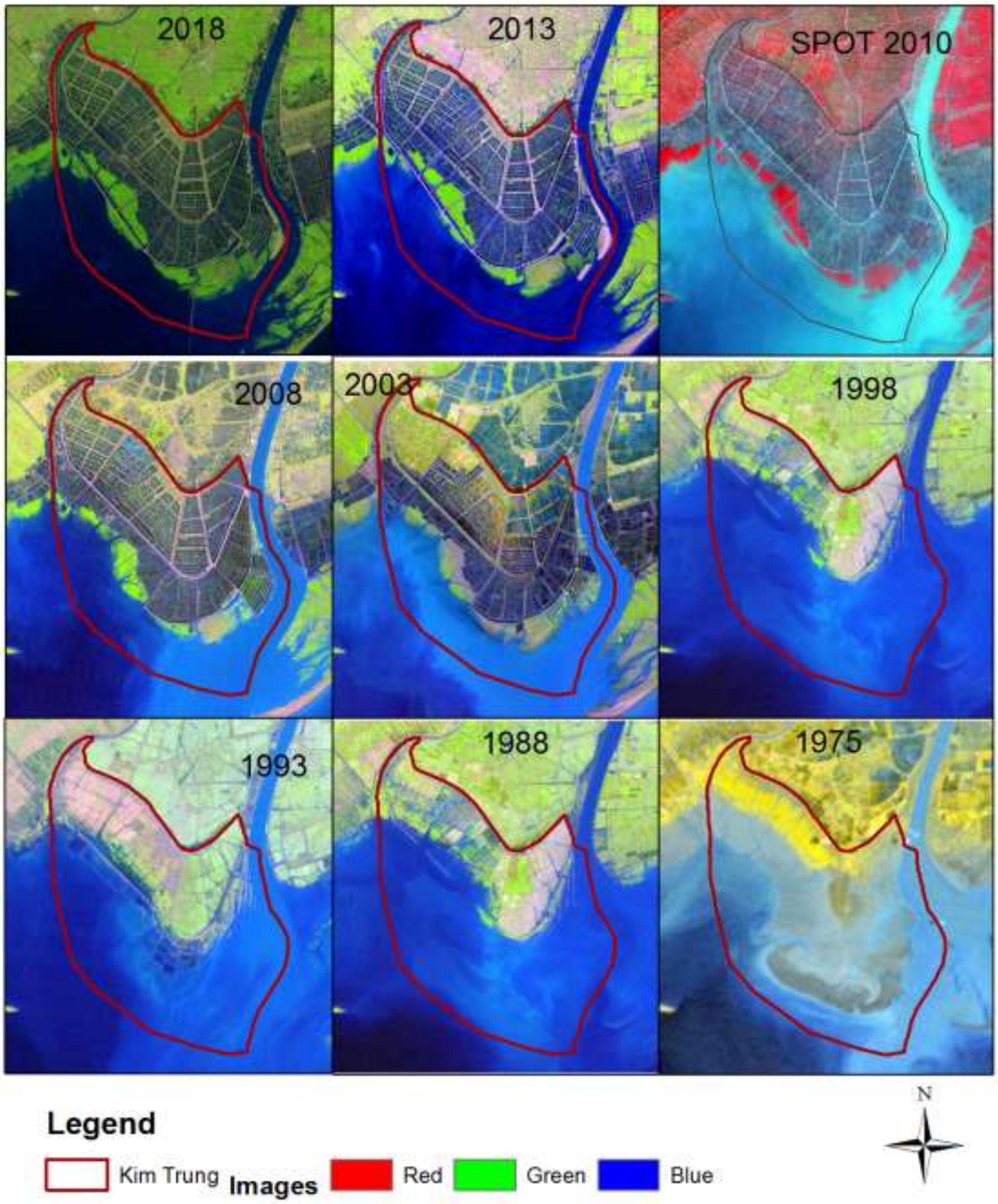

Figure 3. Color composition images of Landsat and SPOT data clipping for Kim Son District.

A Land-use map produced in 2010 by photogrammetry technique using airborne photos was considered precise enough for reference region of interests (ROIs) of the classification SPOT 5 satellite image. The land use of Kim Son was categorized in 14 classes (Figure 4). However, we would not use all of them for controlling the classifying process. We used mangrove, road, water, aquaculture, and residence classes and other layers are out of this study interests hence useless.

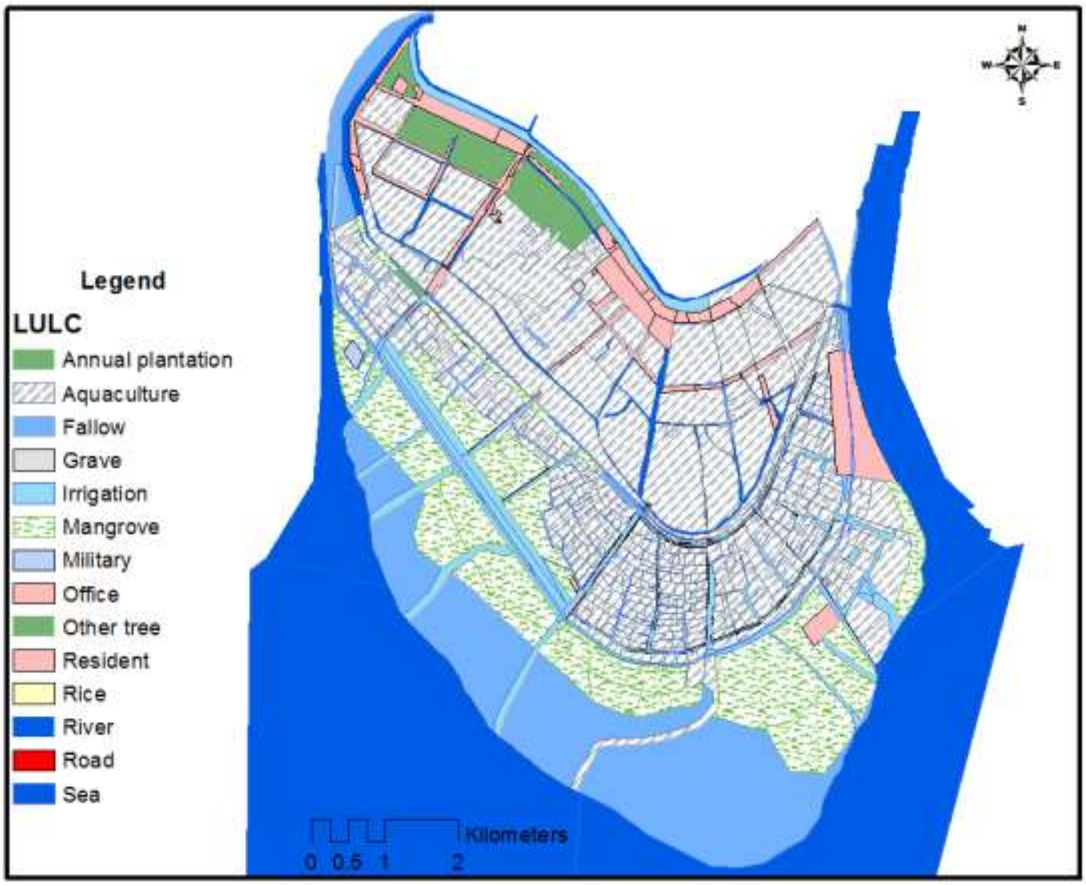

Figure 4. Land-used land cover of Kim Son in 2010

3.2 Mangrove and road classification

Support vector machines (SVMs)(Ben-Hur et al., 2001) a supervised non-parametric statistical learning technique was applied for classification of all images. The SVMs method is widely used and thoroughly reviewed by (Melgani and Bruzzone, 2004, Mountrakis et al., 2011). Bands were selected for SVMs clustering (Table 1) after testing sensitivity of reflection of the bands (corresponding with wavelength) to vegetation and roads (main targets of this classification) and referring to previous literature.

Accuracy assessment is necessary to clarify remote sensing (RS) classification precise. We used the 2010 land-use land cover (LULC) map (Figure 4) as ground truth data and created a confusion matrix to calculate produce/user and kappa ratios. We achieved an overall accuracy of 98.3% and Kappa coefficient of 0.97 (Table 2). Furthermore, the SPEAR Lines of Communication (LOC) – Roads (Wollmer, 1970) tool in ENVI software was used to highlight roads to aid manual digitizing with Use the supervised spectral processing workflow (see more at Wollmer, (1970)).

Table 2: Confusion matrix and error coefficients computed for SPOT 5 image Support vector machines classification

Confusion Matrix

Overall Accuracy = (34067/34664) 98.2778%
Kappa Coefficient = 0.9727

Class	Ground Truth (Pixels) Mangrove	River	AquaCul	Resident	Road
Unclassified	0	0	0	0	0
Mangrove [Whi	3346	0	279	11	0
River [Green]	0	7659	90	0	0
AquaCul [Blue	0	0	18815	0	12
Resident [Cya	8	0	5	3085	159
Road [Yellow]	0	0	2	31	1162
Total	3354	7659	19191	3127	1333

3.3 Spatial analysis and changes detection

We use with inputs are results of the classification task and the LOC-roads performance describing in the section 3.3.
ArcGIS tools including spatial spatial analyst tools, geostatistical analyst and statistics were used to determine correlations between dyke length (km) and mangrove extent (ha). Inputs to the analysis were the outputs from the classification task, and the digitized roads.

4. RESULTS

4.1 Change in mangrove forest

Mangrove extent and main roads were classified in time-series from 1975 to 2018 at time intervals of 5 years (except the SPOT images in 2010) shown in the Figure 5. Time series classification revealed that mangrove extent increased and moved seaward approximately five kilometers between 1975 and 2018 (Figure 5). Although the result does not present the height of the mangrove forest but we could see the distribution and the density changing as well. The overall trend is the mangroves grow outside the dykes and blocked by new dykes and become degraded gradually. In the year 1998 and 2003, forest extent was minimal compared to other years. In contrast, mangrove extent in 1993 and 2018 was greatest. However, the mangrove forest was much denser in 2018 than in 1993.

4.2 Change in roads

One dyke was present in 1975 (number 1, in Figure 5). A second dyke (2) was completed by 1993, a third (3) between 1998 and 2010, and a fourth (4) was under construction in 2018. Dyke 2 appears to have been broken within the 1993-1998 period, as it was continuous in 1993, but fragmented in 1998. In the decade of 2008 to 2018 a number of roads were constructed between the dykes.

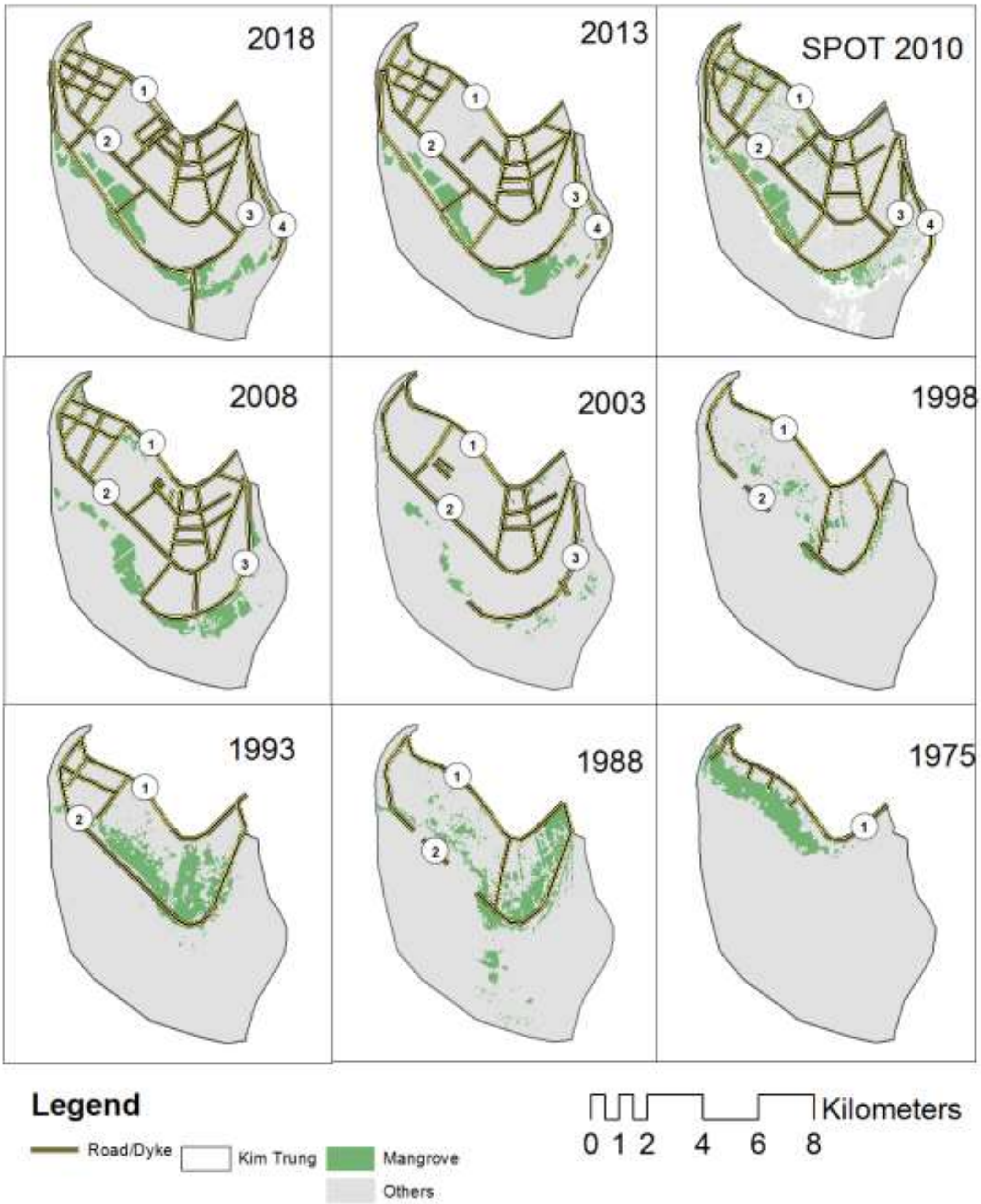

Figure 5: Time series maps illustrating change in mangrove and road/dyke in Kim Son district.

4.3 Correlations between dyke and mangrove changes

The ratio of mangrove extent to dyke length declined between 1975 and 2018 and that means more dyke constructed and less mangrove is (Figure 6). However, when we look at the value the mangrove extent was slightly increasing except the year 2003 with the area of 360 ha. Although the classification was supervised and examined by accuracy assessment, the resolution of used images was quite low (30m) could led to uncertainty of the results. Hence, we should look at the trend rather than at the values.

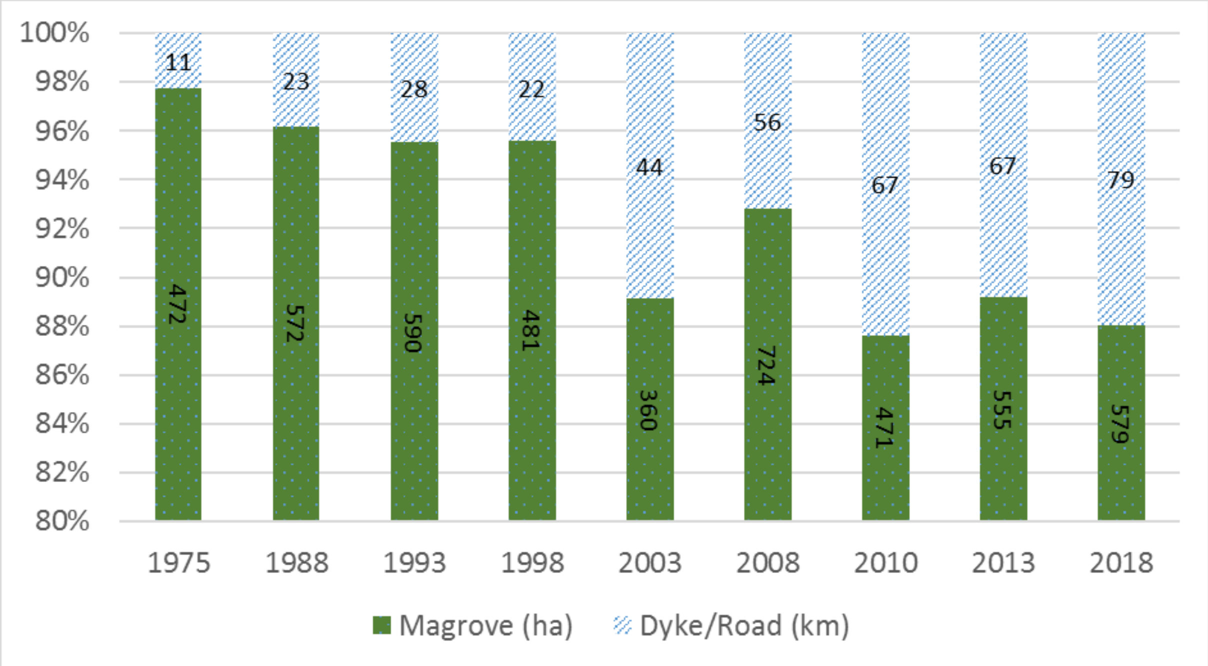

Figure 6: Ratios of dyke and mangrove area (if both values account for 100%) and the values of dyke/road length (km) and mangrove area (ha) in the bars, in Kim Son District between 1975 and 2108

Figure 7 shows trends of mangrove and road development over 1975-2018 periods with both rises of road network and mangrove forest area. However, the road length increased sharply from 11 to 79 km in total while the mangrove extent fluctuated and the general trend going up slightly (see the trend line in the figure 7). The drop of mangrove area in 2003 might be the result of dyke break in few years prior. However, that is our assumption we need more investigation for this statement.

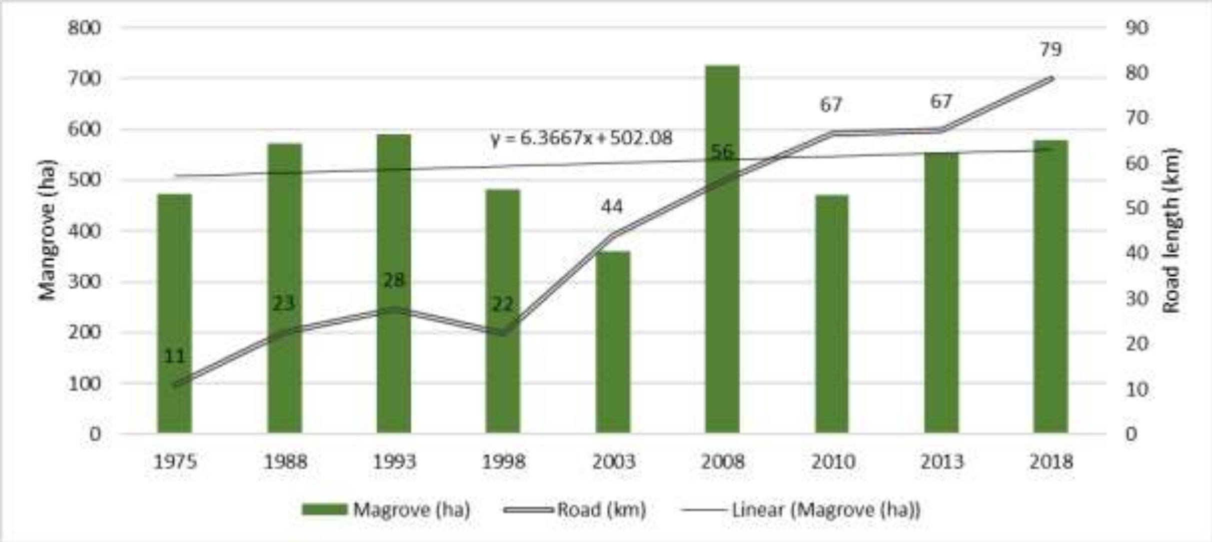

Figure 7: Trends of mangrove and road developement from 1975 to 2018

4.4 Spatial analysis of Mangrove changes

Figure 8 reveals clearly the seaward movement of the mangrove forest every ten years from 1975 to 2018. In 1975 the forest was approximately 5km further inland than the current coastline. The speed of mangrove development was not identical over the different time periods; the forest appears to have extended much faster between 1998 and 2008, than between 1988 and 1998, although some forest gain and loss was evident in this period.

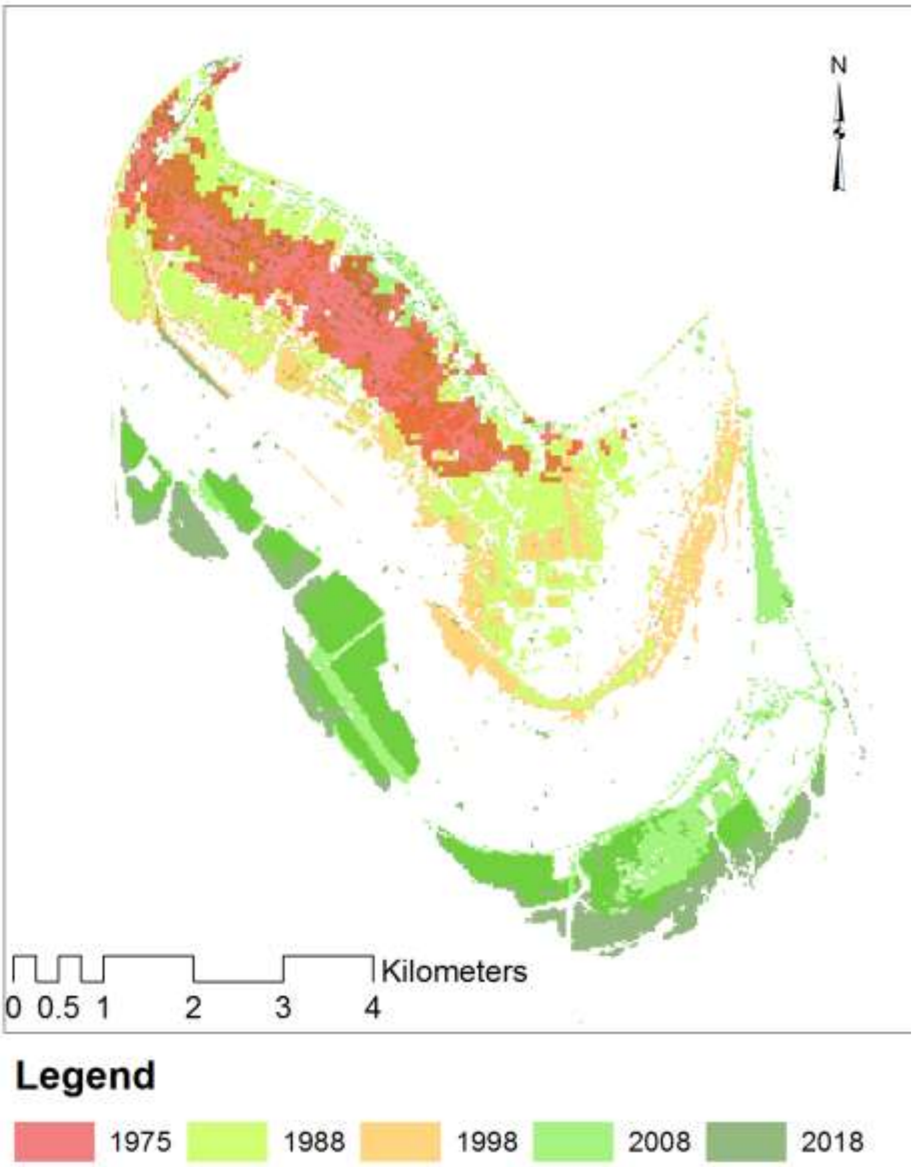

Figure 8. Maps of mangrove forest in Kim Son

5 DISCUSSION

The most flagrant trend is the fast dyke end roads (on dyke or in resident) which is agreed with our study hypothesis and also with information we gained in a field survey at Kim Son district. The reasons for this trend is originated from the “Khai hoang” plan of Nguyen Cong Tru in early 19s and continued until recent Bao Binh Minh (2009). Further reasons could be a need of protection the aquaculture from the damages of waves and tide, high dykes are an effective barrier (Wickramanayake, 1994).

In 1980s, using soil for the construction of dykes, mangroves were cut down. Due to the development of aquaculture, a number of mangroves were cleared for dyke construction in the mangrove areas. After the construction of dykes, tidal exchange between ponds and outside areas is restricted, causing pollution. Many mangrove species inside the ponds die due to lack of oxygen in the soil. In the anaerobic condition, litters are decomposed by microorganisms in the soil. In such condition, many toxic substances such as H2S, Fe(OH)3 are formed. This will make aquaculture species die, therefore the productivity of fish and shrimp greatly decreases after several year of pond construction.

Both dykes and mangrove have a function of facilities, aquaculture etc. (Pham and Yoshino, 2016). In addition, Pham and Yoshino (2016) concluded that dyke systems, especially concrete sea dykes near coastline can reduce mangrove deforestation. However, we discuss other point of view that dykes are blocking mangroves and reduced sedimentation and tide in the mangrove stand hence gradually blighting the mangrove forest as the mangrove pieces there cannot live without tide and sediment.

Undoubtedly, mangrove bring benefits to local households and generally to the region (Pham and Yoshino, 2016, Le 2008). Hence, any changes in the mangrove system, land use planning could affect them in terms of livelihoods, economy and environment protection. In Kim Son district, mangrove moving seaward and dyke construction generates large areas for aquaculture such as shrimp and clam ponds, which is pushing up the economy of the region, but not all people can benefit from that. Many poor people must collect natural craps and clam manually outside the dyke, or they have to work on resources owned by someone else, while the rich work on their own resources.

This study could not complete without remote sensing data and in many cases remote sensing plays indispensable roles for the remote study areas where the in situ measurement could not conduct (Nguyen, 2016). It is the fact that the remote sensing technology is developing quickly and that means more and quality data are increasingly available. Time-series data were sometimes very costly, however nowadays they are reasonable and freely access occasionally. Despite of that, with the low standing and small size of mangrove pieces of Kim Son, the medium resolution remote sensing images limit us study more inside the forest such as mangrove structure or classify pieces accurately. Better spatial, spectral resolution data could promise better results.

6 CONCLUSION

The case of Kim Son district, Ninh Binh province shows that mangrove forests provide critical ecosystem services and support the livelihoods of the coastal communities. The findings demonstrate dyke development since the early 19th Century resulted in the establishment of new communities along the coastline on the one hand. One the other hand, dyke development changed land use and adversely affected mangrove forest in Kim Son district. These changes in the mangrove system, land use planning could affect the mangroves in terms of livelihoods, economy and environment protection.

7 ACKNOWLEDGMENT

We would like to acknowledge the Sponsors; Economic and Social Research Council (ESRC) and National Foundation for Science & Technology Development (NAFOSTED) for granting the project “Harnessing Multiple Benefits from Resilient Mangrove Systems”

REFERENCES

Bao Bien Phong (2013): http://www.bienphong.com.vn/nguyen-cong-tru-va-su-nghiep-chinh-phuc-bien-tien-nui-vang/

Bao Binh Minh (2009): http://baoninhbinh.org.vn/nguyen-cong-tru-voi-sy-nghiep-mo-dat-kim-son-20090102100000000p1c87.htm

Bao Ninh Binh 2013 "http://www.dulichninhbinh.com.vn/ninhbinh-news/Huyen-Kim-Son.html

BEN-HUR, A., HORN, D., SIEGELMANN, H. T. & VAPNIK, V. 2001. Support vector clustering. Journal of machine learning research, 2, 125-137.

BOCCO, G., MENDOZA, M. & VELÁZQUEZ, A. 2001. Remote sensing and GIS-based regional geomorphological mapping—a tool for land use planning in developing countries. Geomorphology, 39, 211-219.

CUMMINGS, C. A., TODHUNTER, P. E. & RUNDQUIST, B. C. 2012. Using the Hazus-MH flood model to evaluate community relocation as a flood mitigation response to terminal lake flooding: The case of Minnewaukan, North Dakota, USA. Applied Geography, 32, 889-895.

DONATO, D. C., KAUFFMAN, J. B., MURDIYARSO, D., KURNIANTO, S., STIDHAM, M. & KANNINEN, M. 2011. Mangroves among the most carbon-rich forests in the tropics. Nature geoscience, 4, 293.

JANSSEN-STELDER, B., AUGUSTINUS, P. & VAN SANTEN, W. 2002. Sedimentation in a coastal mangrove system, Red River Delta, Vietnam. Proceedings in Marine Science. Elsevier.

KAPPAS, M., PROPASTIN, P., DEGENER, J. & RENCHIN, T. 2015. Inter-Comparison and Evaluation of the Global LAI Product (LAI3g) and the Regional LAI Product (GGRS-LAI) over the Area of Kazakhstan. Remote Sensing, 7, 3760.

LE, H. 2008. Economic reforms and mangrove forests in central Vietnam. Society and Natural Resources, 21, 106-119.

LEE, S. Y., PRIMAVERA, J. H., DAHDOUH-GUEBAS, F., MCKEE, K., BOSIRE, J. O., CANNICCI, S., DIELE, K., FROMARD, F., KOEDAM, N. & MARCHAND, C. 2014. Ecological role and services of tropical mangrove ecosystems: a reassessment. Global Ecology and Biogeography, 23, 726-743.

LEICHTLE, T., GEIß, C., WURM, M., LAKES, T. & TAUBENBÖCK, H. 2017. Unsupervised change detection in VHR remote sensing imagery – an object-based clustering approach in a dynamic urban environment. International Journal of Applied Earth Observation and Geoinformation, 54, 15-27.

Mai L.X, 2010. The results of the mangrove afforestation project in Kim Son coastal eareas 1997-2010 funded by the Japanese Red Cross. Restoring and managing mangrove ecosystems in the context of climate change. Proceedings of the Can Gio national workshop in Can Gio District- Ho Chi Minh City 23-25 October 2010. Editor Phan Nguyen Hong, Nguyen Thi Kim Cuc. 303-308 (In Vietnamese)

MELGANI, F. & BRUZZONE, L. 2004. Classification of hyperspectral remote sensing images with support vector machines. IEEE Transactions on Geoscience and Remote Sensing, 42, 1778-1790.

MOUNTRAKIS, G., IM, J. & OGOLE, C. 2011. Support vector machines in remote sensing: A review. ISPRS Journal of Photogrammetry and Remote Sensing, 66, 247-259.

NAGELKERKEN, I., BLABER, S. J. M., BOUILLON, S., GREEN, P., HAYWOOD, M., KIRTON, L. G., MEYNECKE, J. O., PAWLIK, J., PENROSE, H. M., SASEKUMAR, A. & SOMERFIELD, P. J. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review. Aquatic Botany, 89, 155-185.

NGUYEN, H. Q. 2016. Modelling Soil Erosion, Flash Flood Prediction and Evapotranspiration in Northern Vietnam. Georg-August-Universitaet Goettingen, Germany, PhD dissertation.

Nguyen Thi Kim Cuc, 2011. Adaptation of coastal mangrove ecosystem under the impact of sea level rise: Case Study in the Red River Delta. In Proceedings of the National Scientific Conference on Wetlands and Climate Change. Hanoi, December 2011, Research Center for Natural Resources and Environment, HNU. 440-448. (in Vietnamese)

Nguyen Khanh Van (editor) Nguyen Thi Hien, Phan Ke Loc, Nguyen Tien Hiep, 2000. Bioclimatic charts of Vietnam. Vietnam National University Press, Hanoi. (in Vietnamese)

ORCHARD, S. E., STRINGER, L. C. & QUINN, C. H. 2015. Impacts of aquaculture on social networks in the mangrove systems of northern Vietnam. Ocean & Coastal Management, 114, 1-10.

PAMELA, LE, H. V. T., NGHIEM, T. P. & VU, H. D. T. 2016. Using REDD+ Policy to Facilitate Climate Adaptation at the Local Level: Synergies and Challenges in Vietnam. REDD+ Crossroads Post Paris: Politics, Lessons and Interplays, 323.

PHAM, T. D. & YOSHINO, K. 2016. Impacts of mangrove management systems on mangrove changes in the Northern Coast of Vietnam. Tropics, 24, 141-151.

Phan Nguyen Hong, 1999. The role of mangroves in sea dyke protection and in the control of natural disasters. Proceedings of the National workshop: Sustainable and economically efficient utilization of natural resources in mangrove ecosystem. Nha Trang city 1-3 November 1998: 190-196.

Phan Nguyen Hong and Quan Thi Quynh Dao, 2003. Mangrove reforestation in Vietnam achievements and challences. In the proceedings of National scientific workshop on Evaluation of effects of mangrove reforestation on the environment and coastal local life in JRC funded project areas. Hanoi, 23 January 2003.

Phan Nguyen Hong, Vu Thuc Hien, Nguyen Huu Tho and Tran Van Thuy, 2004. Some Natural feature of the mud flats in the coastal estuarine mangrove area of Thai Binh and Nam Dinh Provinces. In Mangrove Ecosystem in the Red River Coastal Zone. Agriculture Publishing House, Hanoi 2004: 1-15.

SATHYA, R. & ABRAHAM, A. 2013. Comparison of supervised and unsupervised learning algorithms for pattern classification. International Journal of Advanced Research in Artificial Intelligence, 2, 34-38.

SETO, K. C. & FRAGKIAS, M. 2007. Mangrove conversion and aquaculture development in Vietnam: A remote sensing-based approach for evaluating the Ramsar Convention on Wetlands. Global Environmental Change, 17, 486-500.

SHRESTHA, N. K. & SHUKLA, S. 2015. Support vector machine based modeling of evapotranspiration using hydro-climatic variables in a sub-tropical environment. Agricultural and Forest Meteorology, 200, 172-184.

SIMONS, G., BASTIAANSSEN, W., NGÔ, L., HAIN, C., ANDERSON, M. & SENAY, G. 2016. Integrating Global Satellite-Derived Data Products as a Pre-Analysis for Hydrological Modelling Studies: A Case Study for the Red River Basin. Remote Sensing, 8, 279.
THANH, T. D., SAITO, Y., VAN HUY, D., NGUYEN, V. L., TA, T. K. O. & TATEISHI, M. 2004. Regimes of human and climate impacts on coastal changes in Vietnam. Regional Environmental Change, 4, 49-62.
THU, P. M. & POPULUS, J. 2007. Status and changes of mangrove forest in Mekong Delta: Case study in Tra Vinh, Vietnam. Estuarine, Coastal and Shelf Science, 71, 98-109.
VEETTIL BK,., WARD, R., NGO XUAN, Q. & THI THU TRANG, N. 2019. Mangroves of Vietnam: Historical development, current state of research and future threats.
WICKRAMANAYAKE, E. 1994. Flood Mitigation Problems in Vietnam. Disasters, 18, 81-86.
WILLIAM, D. J., RYBICKI, N. B., LOMBANA, A. V., O'BRIEN, T. M. & GOMEZ, R. B. 2003. Preliminary investigation of submerged aquatic vegetation mapping using hyperspectral remote sensing. Environ Monit Assess, 81, 383-92.
WOLLMER, R. D. 1970. Algorithms for targeting strikes in a lines-of-communication network. Operations Research, 18, 497-515.

BIOGRAPHICAL NOTES

CONTACTS

Dr. Nguyen Hong Quang
Institution: Vietnam National Space Center
Address: 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam
City: Ha Noi
COUNTRY: Vietnam
Tel. +84.968844250
Email: nhquang@vnsc.org.vn
Web site: https://vnsc.org.vn/en/

Dr. Pham Thi Thanh Nga
Institution: Vietnam National Space Center
Address: 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam
City: Ha Noi
COUNTRY: Vietnam
Tel. +84.945803088
Email: pttnga@vnsc.org.vn
Web site: https://vnsc.org.vn/en/

Dr. Le Thi Van Hue
Institution: Central Institute for Natural Resources and Environmental Studies, Vietnam National University (VNU)

Address: No 19 Le Thanh Tong, Hoan Kiem, Ha Noi
City: Ha Noi
COUNTRY: Vietnam
Tel. +84.986239898
Email: thivanhue@gmail.com
Web site: http://cres.vnu.edu.vn/en/

Dr. Dao Van Tan
Institution: Hanoi National University of Education (HNUE), Vietnam
Address: No 136 Xuan Thuy - Cau Giay - Ha Noi
City: Ha Noi
COUNTRY: Vietnam
Tel. +84.936696931
Email: daotanvn@yahoo.com
Web site: http://www.hnue.edu.vn/directories/?tandv

Dr. Claire Quinn
Institution: Environment Building Sustainability Research Institute, School of Earth and Environment, University of Leeds, UK
Address: Leeds LS2 9JT, UK
City: Leeds
COUNTRY: United Kingdom
Tel. +44(0)113 343 8700
Email: C.H.Quinn@leeds.ac.uk
Web site: https://environment.leeds.ac.uk/see/staff/1489/dr-claire-helen-quinn

Prof. Lindsay C. Stringer
Institution: Environment Building Sustainability Research Institute, School of Earth and Environment, University of Leeds, UK
Address: Leeds LS2 9JT, UK
City: Leeds
COUNTRY: United Kingdom
Tel. +44(0)113 343 7530
Email: L.Stringer@leeds.ac.uk
Web site: https://environment.leeds.ac.uk/see/staff/1556/professor-lindsay-c-stringer

Dr. R.H.Carrie@leeds.ac.uk
Institution: Environment Building Sustainability Research Institute, School of Earth and Environment, University of Leeds, UK
Address: Leeds LS2 9JT, UK
City: Leeds
COUNTRY: United Kingdom
Tel.

Email: R.H.Carrie@leeds.ac.uk
Web site: https://environment.leeds.ac.uk/faculty/staff/1195/dr-rachael-carrie