Pertanika J. Sci. & Technol. 26 (3): 899 - 922 (2018)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Review Article

Remotely Sensed Imagery Data Application in Mangrove Forest: A Review

Zulfa, A. W.[1] and Norizah, K.[1,2]*

[1]*Department of Forest Management, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*

[2]*Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia*

ABSTRACT

The mangrove forest ecosystem acts as a shield against the destructive tidal waves, preventing the coastal areas and other properties nearby from severe damages; this protective function certainly deserves attention from researchers to undertake further investigation and exploration. Mangrove forest provides different goods and services. The unique environmental factors affecting the growth of mangrove forest are as follows: distance from the sea or the estuary bank, frequency and duration of tidal inundation, salinity, and composition of the soil. These crucial factors may under certain circumstances turn into obstacles in accessing and managing the mangrove forest. One effective method to circumvent this shortcoming is by using remotely sensed imagery data, which offers a more accurate way of measuring the ecosystem and a more efficient tool of managing the mangrove forest. This paper attempts to review and discuss the usage of remotely sensed imagery data in mangrove forest management, and how they will improve the accuracy and precision in measuring the mangrove forest ecosystem. All types of measurements related to the mangrove forest ecosystem, such as detection of land cover changes, species distribution mapping and disaster observation should take advantage of the advanced technology; for example, adopting the digital image processing algorithm coupled with high-resolution image available nowadays. Thus, remote sensing is a highly efficient, low-cost and time-saving technique for mangrove forest measurement. The application of this technique will further add value to the mangrove forest and enhance its in-situ conservation and protection programmes in combating the effects of the rising sea level due to climate change.

Keywords: Geoinformation technology, mangrove, remote sensing, sustainable management, tropical forest

ARTICLE INFO

Article history:
Received: 30 August 2018
Accepted: 09 March 2018

E-mail addresses:
zulfawahab@yahoo.com (Zulfa, A. W.)
norizah_k@upm.edu.my (Norizah, K.)
*Corresponding Author

ISSN: 0128-7680

MANGROVE FOREST

The mangrove forest forms an intertidal ecosystem represented by a variety of tree species that grows mainly along the tropical and subtropical coasts worldwide (Kovacs et al., 2011). Mangrove forest is characterised by dicotyledonous woody shrubs or trees that are virtually confined to the tropics (Hogarth, 2007). Mangrove forest is a highly productive ecosystem usually scattered along the intertidal zone of the low-energy tropical coastlines (Kathiresan et al., 2001 and Lugo et al., 1974). These unique forests grow abundantly in the saline soil and brackish water, subject to periodic fresh and salt water inundation; they are generally found along the sheltered coast where all vegetation adapt to a highly saline environment that would normally be uninhabitable for other kinds of trees (Ibharim et al., 2015).

According to Giri et al. (2011), approximately 13.7 million km^2 of mangrove forest exist worldwide in 118 countries and territories within the tropical and subtropical regions of the world in 2000. During the time this review was written, accurate, up-to date and reliable information about mangrove forest coverage worldwide was not available. Thus, this study reports the statistics of the mangrove forest 11 years ago (Spalding et al, 2010; Giri et al., 2011). According to Giri et al. (2016) and Ghosh et al. (2016), due to the climate change issues and anthropogenic factors, the mangrove forest ecosystem was under pressure. Anthropogenic activities and climate change has led to degradation, pollution, sea-level rise, coastal erosion, increased salinity, increased number of cyclones and higher levels of the storm to the mangrove forest. Over the past 3 decades, the world has lost almost 50% of the mangrove forest areas (Osti et al., 2009). Spalding et al. (2010) reported that based on the 2006 record from Food and Agriculture Organization, (FAO), Asia had the biggest mangrove forest cover, about 40.4%, followed by America 30.4%, Africa 18.4%, Africa 18.4%, Australasia 6.7%, Pacific Ocean 3.8% and Middle East 0.4% (Figure 1). Asia has 25 countries with mangrove forest under a wide range of climatic conditions such as Arid (Arabian Peninsula), Subtropical (China and Japan) and Humid tropical (Southeast Asia). Table 1 shows the 12 countries with the largest mangrove forest areas in the world; Indonesia has the biggest mangrove forest area in the world with 31,894 km^2 covering about 20.9% of 68% of the world's mangrove forest area in 2006 (Spalding et al., 2010).

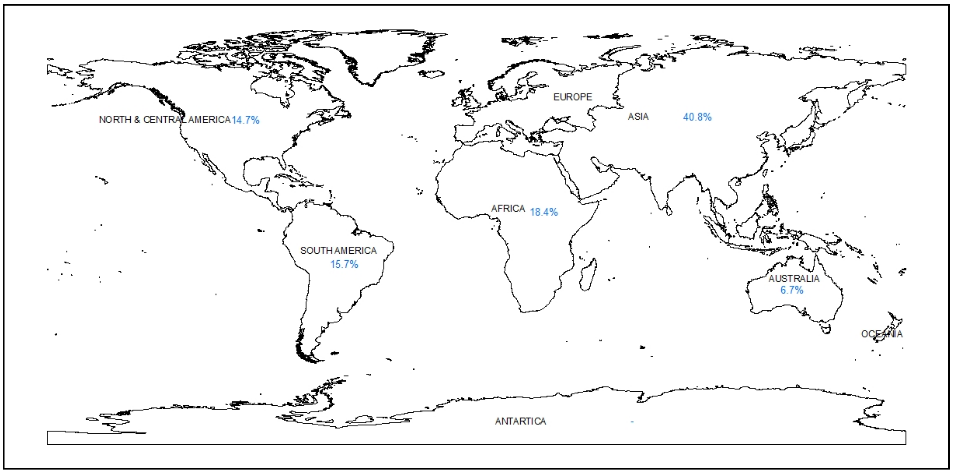

Figure 1. World mangrove forest distribution (Spalding et al., 2010)

Table 1
Mangrove forest coverage in the World (Spalding et al., 2010)

Countries	Region	Area (km^2)
Indonesia	Asia	31,894
Brazil	South America	13,000
Australia	Australia	9910
Mexico	North and Central America	7710
Nigeria	Africa	7356
Malaysia	Asia	7097
Myanmar	Asia	5029
Bangladesh	Asia	4951
Cuba	North and Central America	4944
India	Asia	4326
Papua New Guinea	Oceania	4265
Colombia	South America	4079
Total		104,561

Humans benefit in many ways from the mangrove forest ecosystem, directly or indirectly such as forest products (Kridiborworn et al., 2012; Walters, 2005; Kairo et al., 2002; Adegbehin, 1993), fisheries (Rhyma & Norizah, 2016; Thu & Populus, 2007; Manson et al., 2005; Rönnbäck, 1999; Feller & Sitnik, 1996), and protection against natural disaster (Pearce, 2014; Danielsen et al., 2005; Feller & Sitnik, 1996). From all the benefits gained and impacts reported from the mangrove forest function, the role of mangrove forest in ecological significance is very important; there is an urgent need to examine the role and function of the mangrove forest periodically. Monitoring the spatial and temporal changes of the mangrove forest area is the first step in this process. However, it is a costly and laborious task to obtain reliable, accurate and timely information, especially when dealing with a tidal event in relation to unique mangrove forest characteristics.

By employing the manual surveying method, it is impossible to identify changes in a large mangrove forest area with a tidal event. However, with the modern technologies of monitoring such as satellite remote sensing and digital image processing algorithm, monitoring work can be done in a couple of hours or days and details can be mapped with improved accuracy and precision (Giri, 2016; Ibrahim et al., 2015; Heenkeda et al., 2014; Rao et al., 2014; Ibrahim et al., 2013; Chun et al., 2011; Wang & Sousa, 2009). These articles review and discuss the use of satellite images in the mangrove forest and the details that can be mapped from the satellite image of this era; i.e., detection of land cover changes, species distribution mapping and disaster observation.

REMOTE SENSING

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from the aircraft or satellite known as a sensor. There are two categories of sensors: passive and active sensors. A passive sensor will detect the sunlight radiation reflected from the earth and thermal radiation in the visible and infrared of the electromagnetic spectrum (Barrett, 2013; Tyo et al., 2006; Turner et al., 2003; Fingas & Brown, 1997; Jackson, 1995). It does not emit its own radiation, but it receives the light and thermal radiation from the Earth's surface. Landsat, SPOT, Quickbird, IKONOS and Worldview are some examples of the passive sensors, and they have been widely used to monitor land cover and land use changes (Goetz & Dubayah, 2011; Muttitanon & Tripathi, 2005; Turner et al., 2003). An active satellite sensor functions as it emits artificial radiation to monitor the earth surface or atmospheric feature. Examples of active sensors are radar and laser scanner; Light Detection and Ranging (LIDAR), which uses a short pulse of electromagnetic radiation in the microwave spectral range. These sensors do not rely on daylight, and they are slightly affected by clouds, dust, fog, wind and weather conditions (Starek, 2016; Zink et al., 2004; Turner et al., 2003; Clothiaux et al., 2000; Fingas & Brown, 1997). Active sensors are used to identify the vegetation structure and ground surface elevation (Faridhouseini et al., 2011; Rosette et al., 2008; Holmgren & Persson, 2004; Patenaude et al., 2004; Dowling & Accad, 2003; Lefsky et al., 2002).

In principle, an object captured by a sensor can be identified from the spectral reflectance signature (or electromagnetic radiation-EMR) of the remote sensing, if the sensing system has sufficient spectral resolution to distinguish its spectrum from those of other materials (Zulfa & Norizah, 2016; Ranchin &Wald, 2000; Martin & Aber, 1997; Goetz et al., 1985). A different sensor has a different wavelength. The finer the spectral resolution and the higher the resolution, the narrower is the wavelength range for a particular channel or band; thus, objects on the Earth can be easily identifiable and differentiated as spectral resolution increases (Zhang & Zhu, 2011; Ehlers et al., 2003; Turner et al., 2003; Clark et al., 1990). To date, the spectral resolutions of some satellite sensors have up to hundreds and thousands spectral wavelength, which can be used to identify objects easily. Here are some examples of sensors that have high spectral and spatial resolutions: Worldview sensor (Kamal et al., 2014; Heenkenda et al., 2014; Heumann, 2011b), airborne sensor (Herweg et al., 2012; Tarabalka et al., 2010; Dalponte et al., 2008; Van

Aardt et al., 2007; Kamaruzaman & Kasawani, 2007; Kruse et al., 2003; Cocks et al., 1998; Martin & Aber, 1997), LiDAR sensor (Greaves et al., 2016; Wei et al., 2012; Hakala et al., 2012; Dalponte et al., 2008) and some multispectral cameras used with unmanned automated vehicles (UAV); these sensors are more flexible in terms of time of image capturing (Bareth et al., 2015; Saari et al., 2011; Mäkynen et al., 2011; Berni et al.,2009; Held et al., 2003).

The spatial resolution also plays an important role in viewing, identifying and evaluating captured images (Lillesand et al., 2014; Verma et al., 2014; Xie et al., 2008). The spatial resolution is presented by the square picture elements or pixels. The pixel size is determined by the sampling distance (Ayoub et al., 2009; Leprince et al., 2007; Schowengerdt, 2006; Kaufman et al., 1997). For example, 30 m data spatial resolution from Landsat sensor refers to data in a matrix of 30 m x 30 m pixels; this is an example of low spatial resolution image where only coarse features can be observed in the image (Lillesand et al., 2014). Meanwhile, a high spatial resolution image refers to one with a small spatial resolution size (Lillesand et al., 2014; Sawaya et al., 2003). Fine details can be seen in a high spatial resolution image, and these are some matrix examples: 0.41 m x 0.41 m pixels and 1.65 m x 1.65 m pixels respectively from panchromatic and multispectral sensor of GeoEye-1; 0.5 m x 0.5 m pixels and 2 m x 2 m pixels respectively from panchromatic and multispectral sensor of Worldview2; 0.6 m x 0.6 m pixels and 2.4 m x 2.4 m pixels respectively from panchromatic and multispectral sensor of Quickbird; and 1 m x 1 m pixels and 4 m x 4 m pixels respectively from panchromatic and multispectral sensor of IKONOS (Rhyma et al., 2015). The matrix of pixels is often called a scene. A different type of sensor has a different scene size. Sensors widely used in mangrove forest are listed in Table 2.

Table 2
Sensor used in mangrove forest mapping

Sensor	No. of band(s)	Spectral range	Spatial resolution	Sources
Spot XS	3	Red, green, blue	20 m X 20 m	Pasqualini et al. (1999); Gao, (1999); Jensen et al. (1991); Green et al. (1998);
Landsat TM	7	Blue, green, red, NIR, shortwave infrared and thermal	30 m	Rhyma et al. (2016); Che Ku Akmar et al. (2009); Alatorre et al. (2016); Kovacs et al. (2001)
Quickbird	5	Panchromatic, Red, green, blue and NIR	Panchromatic:0.65 m and Multispectral 2.62 m	Lee and Yeh. (2009) Neukermans et al. (2008); Wang et al. (2004)
IKONOS	4 bands and panchromatic	Panchromatic, Red, Green, Blue and NIR	Panchromatic:0.82 m and Multispectral 3.2 m	Huang et al. (2009); Proisy et al. (2007); Kovacs et al. (2005); Rodriguez and Feller. (2004); Wang et al. (2004); Wang et al. (2004)

Table 2 *(continue)*

Sensor	No. of band(s)	Spectral range	Spatial resolution	Sources
RapidEye	5	Blue, red, green, red edge and NIR	5 m	Son et al. (2017); Giardino et al. (2015); Roslani et al. (2014); Roslani et al. (2013); Ibrahim et al. (2013)
Spot 4 and 5	5	Monospectral, green, red, NIR and short-wave infrared	Panchromatic: 10 m and Multispectral: 20 m	Santos et al. (2015); Vo et al. (2013); Conchendda et al. (2008); Saito et al. (2003)
LiDAR		Blue, red and green	Laser scanner system: x,y,z coordinate	Wannasiri et al. (2013); Chadwick, (2011); Knight et al. (2009); Proisy et al. (2009); Zhang, (2008)
WorldView	9	Blue, red and green Panchromatic, multispectral (red, green, blue, near-infrared, coastal, yellow, red edge and near-infrared-2)	0.5 m	Wang et al. (2015); Zhu et al.,(2015); Hassan et al. (2014); Heenkenda et al. (2014); Kamal et al. (2013); Kux and Souza. (2012); Heumann. (2012)

With the advances and precision of remotely sensed imagery data and the modern technology of digital image processing algorithm (Giri, 2016), the application in management, monitoring and mapping of mangrove forest ecosystem has been proven very valuable. The use of remotely sensed imagery offers many advantages because obtaining information and performing observations by satellite sensors are beyond human ability. With the advances in the spatial and spectral resolution of remotely sensed imagery data, the application of satellite image in the mangrove forest area has been intensified. The following section reviews the use of remotely sensed imagery data with image/data analysis, and it discusses details mapped from the mangrove forest.

Early Application in Mangrove Forest

Traditional approaches to mangrove forest remote sensing has been described by the uses of pure visual imagery; aerial photography (AP) as primary source particularly for surveys conducted before 1990s (Kuenzer et al., 2011; Martinussi et al., 2009; Newton et al., 2009). Limited and lack of utility in data sources make mapping of mangrove forest difficult or even impossible to be surveyed. As technology has grown rapidly with the importance of the uses with mangrove forest, digital imagery; thematic mapper has been evolved to describe and monitor a variety of systems on a local or global scale (Newton et al., 2009; Farid, 2002). There are still limitations related to the early application of digital imagery in mangrove forest such as pointed by Adam et al. (2010) and Ozesmi and Bauer (2002). Their paper stresses that these limitations were related to spatial and spectral resolution where differentiating the spectral reflectance is difficult to performe especially when dealing with low resolution images and the fact that vegetation in mangrove forest has the same basic components that contribute to its spectral reflectance (Kokaly et al., 2003; Price, 1992). Spectral reflections are measurements of the spectral response of different features (in case of mangrove forest, the feature refers to vegetation species) in the bands of the satellite image. Although digital imagery has evolved with the high resolution of data - discussed in the following section - AP sometimes excel in monitoring small area of mangrove forest and a number of classification are easily distinguishable (Heumann 2011b; Ozesmi & Bauer, 2002; Sulong et al., 2002).

Recently, the decline of mangrove forest has become major environmental issues worldwide. Mangrove forest become severe due to human activity or natural disaster. The needs to study mangrove forest highly important and the application of remote sensing has been widely used over a few decades ago with the development from pure visual imagery to multi-spectral imagery to the advances of narrow spectral imagery. Table 3 shows some of early remote sensing application in mangrove forest.

Table 3
Early remote sensing system and mangrove studies (Heumann, 2011b)

Sensor(s)	Studies
Aerial photography	Hossain et al. (2009); Eslami-Andargoli et al. (2009); Everitt et al. (2007); Thampanya et al. (2007); Dahdouh-Guebas et al. (2006); Benfield et al. (2005); Rodriguez and Feller (2004; Fromard et al. (2004); Jones et al. (2004); Krause et al. (2004); Manson et al. (2001); Murray et al. (2003); Chauvaud et al. (1998); Sulong (1999); Sulong and Ismail (1990)
Landsat MSS, TM, or ETMþ	Long et al. (2011); Che Ku Akmar et al., (2009); Alatorre et al., (2016; Beland et al. (2006); Cornejo et al. (2005); Giri et al. (2008); Green et al. (1998); James et al. (2007); Krause et al. (2004); Lee and Yeh (2009); Liu et al. (2008); Long and Skewes (1996); Kovacs et al., (2001); Manson et al. (2001); Mumby et al. (1999); Paling et al. (2008), Ruiz-Luna and Berlanga-Robles (2003); Vasconcelos et al. (2002)
SPOT HVR, HRVIR, or HRG	Chauvaud et al. (2001); Gao (1998, 1999); Green et al. (1998); Lee and Yeh (2009); Mumby et al. (1999); Rasolofoharinoro et al. (1998); Saito et al. (2003)
ASTER	Al Habshi et al. (2007); Vaiphasa et al. (2006)
IRS C or D	Mantri and Mishra (2006); Pattanaik et al. (2008); Ramachandran et al. (1998); Reddy and Pattanaik (2007)

Mangrove Forest Mapping

Monitoring and/or mapping mangrove forest using remotely sensed imagery data has been described as moderate and sometimes poor by Kamal et al. (2015), Wang et al. (2004), Liu et al. (2008) and Heumann (2011b), due to the presence of homogenous species in the mangrove forest and due to the limited spectral signature and spatial resolution of conventional imagery (Wang et al., 2004; Chun et al., 2011). The complexity of separating the spectral reflectance between species is the reason for their report. According to Ajithkumar et al. (2008) and Blasco and Aizpuru (2002), the spectral reflectance of the mangrove leaf is affected by the chlorophyll content; a high chlorophyll concentration will give lower reflectance value, and thus it is difficult to discriminate the mangrove species. On the other hand, others reported an opposite view, stating that the use of remotely sensed imagery data is easy in mangrove forest mapping (Giri, 2016) since the mangrove forest possesses a very distinct spectral signature. The general consensus seems to be that mangrove forest mapping is not straightforward with the remote sensing application. It may be based on the precision of the image, resolution, processing algorithm, or expertise in observing the data; in addition, it might be affected by the different location, as a different location has different vegetation composition and structure (Hossain & Nuruddin, 2016; Ghosh et al., 2016; Matsui et al., 2015; Heumann, 2011b; Adam et al., 2010).

A recent trend in processing the satellite image for mangrove forest is to perform it using science knowledge and engineering technology. Over the past few decades, innovations in remote sensing sensors and systems such as very High Resolution System (VHR) and Synthetic Aperture Radar (SAR) (i.e., Quickbird, IKONOS, GeoEye-1, Worldview-3, PRISM-ALOS PALSAR, ASAR ENVISAT) and airborne sensors (i.e., hyperspectral remote sensing) are a breakthrough due to their high resolution sensor and continuous spectral data that are helpful in discriminating features having similar spectra in the multispectral domain (Rhyma et al., 2016; Prasad et al., 2014). In parallel with the advances of sensors and systems that are extensively applied in mangrove forest, analysis techniques in order to improve the accuracy of mangrove forest classification have also been developed such as object-based classifications integrated with one of these methods: pixel-based classification (Walter, 2004), decision tree learning analysis of pixel-based classification (Liu et al., 2008a), receiver operating characteristics (ROC) curve analysis of spectral analysis (Alatorre et al., 2011), threshold and fuzzy rule classification approaches with that of the pixel-based (Hussain et al. 2013), and support vector machine (SVM) approach of object-based classification (Liu et al., 2008b, Heumann (2011a), Vidhya et al., 2014). The following section reviews details mapped from the mangrove forest with a number of examples of image/data analysis techniques.

Land Cover Changes. Mangrove forests have been altered by direct or indirect uses of the environment, socio-economic and natural resources. The mangrove forest change dynamics worldwide due to natural and anthropogenic forces such as reported by Misra et al. (2015) and Giri et al. (2007) in India, Ibrahim et al. (2015) and Abdullah and Nakagosi (2007) in Malaysia, Muttitanon and Tripathi (2005) in Thailand, Kirui et al. (2013) in Kenya, Nguyen (2014), Nguyen et al. (2013), and Thu and Populus (2007) in Vietnam, Souza-Filho and Paradella (2003) in Brazil. Due to the dynamic changes, area extent and distribution of mangrove forest need to be monitored as frequently as possible for management and conservation. Image classification technique is the main obstacle to have an accurate land use/cover detection in mangrove forest. Nowadays, with advance algorithm and/or procedure in image processing makes mangrove forest distinguishable from other land cover in one scene.

Alatorre et al. (2016) studied the temporal evolution of vegetation activity of mangroves in the South-eastern coastal area of the Gulf of California, Mexico by using multi-temporal Landsat TM images for 20 years (1990-2010). They used NDVI analysis to detect the changes within 20 years and used multivariate regression analysis to show the coverage of the mangrove forest. From the pixel-by-pixel spatial analysis complemented through image interpretation they conducted, they found that shrimp farms in the study area showed a spatial relationship with the zones of the great loss of vegetation activity. Meanwhile, Kanniah et al. (2015) used a maximum likelihood classification (MLC) and support vector machine (SVM) to classify the mangrove forest areas in Southern Johore, Malaysia to analyse the changes over a period of 25 years. Between these two techniques, MLC was reported to provide the significantly higher user, producer and overall accuracy compared with SVM. In different mangrove forest area in North of Malaysia, Perak, Ibrahim et al. (2015) also used MLC to classify land use and land cover for 18 years from Landsat TM and RapidEye imageries. To ensure the accuracy of their classification, normalised different vegetation index (NDVI) technique have been used. When dealing with area classification using remotely sensed imageries data, the accuracy of land cover changes for a certain period of time series with a number of periods will be affected with cloud cover. Kirui et al. (2013) in their study have paired (overlay and differentiate) all images for each time series to remove the areas with cloud cover, leaving images as cloud free over the same locations for area changes assessment. This study used MLC for classification as well.

Mathematical approach in image classification to enhance the accuracy to detect land use/ cover changes in mangrove forest has been widely used by several researchers. For example, Misra et al. (2015) used Principal Component Analysis (PCA) as a pre-classification and continue the common classification; supervised and unsupervised classification. Their accuracy reported as 95.56% (Kappa=0.0556), 92.93% (Kappa=0.92), 84.64% (Kappa=0.85) and 86.36% (Kappa =0.85) for four images in 2011, 2001, 1989 and 1973. According to Kanellopulos and Wilkinson (1997) and Civco (1993), advance algorithm coupled with artificial intelligence using software can be used reliably for routing operational requirement in remote sensing and will provide more accurate and useful data.

Species Distribution Mapping. From the previous research, a number of researchers have established a method that is able to distinguish the mangrove species from other species with the laboratory measurement of hyperspectral leaf reflectance (Wang & Sousa, 2016; Zhang, Kovacs, Liu, Flores-Verdugo, & Flores-de-Santiago, 2014; Chun et al., 2011; Chun et al., 2015; Neukermans et al., 2008). This is important as it provides reliable and accurate information about mangrove forest. According to Asner et al. (2009), having maps of individual tree locations is fundamental to understanding forest responses to global change, providing a basis for monitoring species distribution patterns, responding to stress, disease, and exotic species spread and deforestation.

Wang and Sousa (2009) find that the accuracy of classification of mangrove species increased by using a narrow band of hyperspectral data. They conducted a laboratory study of mangrove leaves using a high-resolution spectrometer in the Carribean coast. For bands that have significant difference (P value <0.01) in the mean reflectance across tree species measured, linear discriminant analysis (LDA) is performed to detail the classified the mangrove species. Eventually, the most useful bands for mangrove species classification are found to be at 780, 790, 800, 1480, 1530 and 1550 nm. In addition, their study used four narrow band ratios (R_{695}/R_{420}, R_{605}/R_{760}, R_{695}/R_{760} and R_{710}/R_{760}) to diagnose stress condition across mangrove species, and results revealed that at least one ratio index was proven useful from ANOVA. In a paper by Zhang et al. (2014), FieldSpec® 3JR spectrometer was used to examine the mangrove species in Mexico. Seven wavebands (520, 560, 650, 710, 760, 2100 and 2230 nm) are selected based on the principle component analysis and stepwise discriminant analyses to classify mangrove species. The waveband selected is able to identify the mangrove species and mangrove forest conditions with an overall accuracy of higher than 90% and a Khat coefficient higher than 0.9. Their study also examined the stress condition of the mangrove forest (poor and dwarf), and it is found to be satisfactory with accuracy higher than 80%. Roslani et al. (2014) used RapidEye satellite data in their study, and they concluded that using a high-resolution image, mangrove forest classification can be mapped with reliable information. In their study, textural analysis is used to make the classification. Their results show that the textured image produced high overall classification assessment recorded at 84%, and kappa statistics recorded at 0.8016. Meanwhile, the non-textural image produced about 80% of the overall accuracy and kappa statistics of 0.7061.

Advanced processing technique and algorithm can also yield reliable and accurate information of mangrove forest instead of using high-resolution remotely sensed imagery data. The classification approach, a part of the processing analysis, is found to influence discriminating the mangrove species. Kamal et al. (2015) stress that using a number of satellite data, various spatial and spectral resolution, and mapping technique would provide effective multi-scale mangrove forest composition mapping. Their study used the object-based approach to classify the mangrove species in the Moretan Bay, Australia by using various satellite data such as Landsat TM, ALOS AVNIR-2, WorldView-2, and LiDAR. Ghosh et al. (2016) in Sundarbans use the maximum likelihood classifier technique to classify objects from Landsat satellite image and utilise the post-classification comparison techniques to detect changes at the species level. From their study, accuracy rates of about 72%, 83%, 79% and 89% are reported from the images of 1977, 1989, 2000 and 2015 respectively. A total of five major species are detected from the Landsat image. Wang et al. (2016) explore the use of textural and differential spectral features classification technique to discriminate species that are complex to be identified. Their study use the WorldView-3 image in Hong Kong. They find that the differential spectral features could aid in reducing inner-species variability and increasing intra-species separation that might be due to the different arrangement of leaves, the branch density, and the average height and size of plants. Zhu et al. (2015) use a back-propagation artificial-neural-network (BP ANN) to accurately estimate the uneven-aged and dense mangrove forest biomass at the individual species level. Their study show a lower residual mean square error (RMSE), of about 19.17% from the classification conducted to estimate the biomass. Umroh et al. (2016) use the standard false colour composite of Landsat band 564 to map the mangrove forest areas in Pongok Island, South Bangka, Indonesia. They use NDVI value ranging from -1 to 0.33 to represent the area dominated with <1000 trees/ha; NDVI 0.33-0.42 to represent the area dominated with >1000 to <1500 trees/ha; and NDVI 0.42-1 to represent the area dominated with >1500 trees/ha. Their study recognized that Pongok Island are dominated by *Rhizophora* sp., *Avicennia* sp. and *Bruguiera* sp. Study by Heenkenda et al. (2014) used WorldView 2 and high-resolution aerial photograph to discriminate mangrove species in Australia. Initial step in their image analysis use object-based image classification to determine mangrove forest and non-mangrove forest area. Later, support vector machine algorithm with best-fit parameters are used to classify individual species. Species classified with WorldView 2 image show acceptable accuracy with 89%.

Disaster Management. The mangrove forest serves as a form of protection, especially sheltering the coastal inhabitants from natural disasters. The natural disaster (i.e., sea level rise) are mostly as a result of climate change. Advancement in remote sensing; spectral and spatial resolution including techniques in image processing have provided an opportunity to observe and monitor mangrove forest from local to global scales with unprecedented spatial and thematic detail. Practically, remote sensing application to map disaster observation are based on preparedness to support disaster and management of the risk. For example, Giri (2016) points out that the level of disaster protection will depend on the size of the tsunami; vegetation structure may influence the role of mangrove forest as a form of disaster protection. Thus, it is necessary to know the extent of the area and changes of mangrove forest to manage the probability of risk from disaster-tsunami and early warning for resource planning. While the remote sensing of disaster observation and early warning are major areas of research for terrestrial areas (Imen et al., 2015; Agatsiva & Oroda, 2000), relatively little research has been done on mangrove forest.

REMOTE SENSING AND MANGROVE FOREST; WAY FORWARD

Mapping extent and changes, species composition and disaster observation of mangrove forest by using remote sensing need to be significantly improved worldwide. Practical method in improving the accuracy of classification at early stage of remote sensing analysis show an extensive study done by innumerable researchers. Innovation and emerging of sensors and systems such as VHR, SAR, unmanned aerial vehicles (UAV) and LiDAR provide users with a high resolution of spatial and spectral imagery allowing them to map mangrove forest in detail and accurately. The UAV and LiDAR are a novel remote sensing platform to have the capability to store a large volume of data using cloud computing. Thus, management, monitoring work, resource planning and conservation become easier than before for a forest that has a different level of stress due to its inaccessibility. Recognising the features or objects that exist within a set of remotely satellite imagery data nowadays has become more advanced. Integration of mathematical algorithm- artificial intelligence with image processing have been developed to exploit the uses of VHR and SAR data. For example, individual species of mangrove can be discriminated by using PCA to perform linear discriminate analysis and/or stepwise discriminate analysis for narrow band imagery and use multiple sensors with object-based analysis. When dealing with species variability- due to similar chemical component for mangrove vegetation, textural and differential spectral classification techniques has been introduced. While, biomass estimation at species level has been assessed by artificial intelligence of BP ANN. Such advance image processing shows that the science of remote sensing and mangrove forest has advanced in the last decade. Yet, there are still gaps and limitations to overcome mangrove forest as well as in terrestrial remote sensing (Wang et al., 2009). Opportunities always exist in technology. For mangrove forest, this is not exempted. Heumann (2011b) suggested five opportunities to be improved in order to enhance remote sensing in mangrove forest; i) apply the existing sensors in mangrove forest that has never been used before, ii) use the existing methods of image processing from terrestrial forests into mangrove forest, iii) investigate new sensors that able to provide high quality data of mangrove forest, iv) integrate multiple types of remotely sensed imagery data to improve the accuracy of data processing, and v) global monitoring of mangrove forest to understand the extent and changes of mangrove forest worldwide including the structure, function and ecosystem services.

CONCLUSION

The purpose of this review paper is to provide a comprehensive overview of the usage and application of remote sensing, especially the mangrove forest. Remote sensing is a tool for accomplishing many objectives related to the mangrove forest ecosystem. The mangrove forest ecosystem is unique and difficult to be measured at the terrestrial landscape; aerial measurement is a very good alternative. Details can be measured by using remotely sensed imagery data with multiple available up-to-date sensors. Key requirements for a sustainable mangrove forest management include high-resolution images, advanced image analysis algorithm and integration with precision tools to improve spectral properties identification and characterisation. Since aerial measurement deals with the upper surface of an area, canopy reflectance, along with wet soil and water characteristics, was expected to distort the image analysis processing. Notwithstanding the above shortcoming, the use of remote sensing in managing the mangrove forest remains advantageous. It relies on the technical support drawn from the continuous research in the techniques and methods for image analyses, particularly in differentiating the biochemical and biophysical canopy attributes, which can improve the accuracy and precision of mangrove forest mapping and monitoring. It is important to carry out research in the mangrove forest ecosystem so that the quality of the mangrove forest can be maintained, and it continues to play its protective function against the effects of sea-level rise due to the increasing emission of atmospheric heat from the climate change.

REFERENCES

Abdullah, S. A., & Nakagoshi, N. (2007). Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia. *Forest Ecology and Management, 241*(1), 39-48.

Adam, E., Mutanga, O., & Rugege, D. (2010). Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: A review. *Wetlands Ecology and Management, 18*(3), 281-296.

Adegbehin, J. O. (1993). Mangroves in Nigeria. *Conservation and sustainable utilization of mangrove forests in Latin America and African Regions (Part 2: Africa). Mangrove Ecosystem Technical Reports, 3*, 135-153.

Adi, W., & Sari, S. P. & Sari, S. P. (2016). Detection of mangrove distribution in Pongok Island. *Procedia Environmental Sciences, 33*, 253-257.

Agatsiva, J., & Oroda, A. (2000). Remote sensing and GIS in the development of a decision support system for sustainable management of a drylands of eastern Africa: a case of the Kenyan drylands. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 34*(6), 42-49.

Ajithkumar, T. T., Thangaradjou, T., & Kannan, L. (2008). Spectral reflectance properties of mangrove species of the Muthupettai mangrove environment, Tamil Nadu. *Journal of Environmental Biology, 29*(5), 785-788.

Alatorre, L. C., Sánchez-Carrillo, S., Miramontes-Beltrán, S., Medina, R. J., Torres-Olave, M. E., Bravo, L. C., ... & Uc, M. (2016). Temporal changes of NDVI for qualitative environmental assessment of mangroves: Shrimp farming impact on the health decline of the arid mangroves in the Gulf of California (1990–2010). *Journal of Arid Environments, 125*, 98-109.

Al Habshi, A., Youssef, T., Aizpuru, M., & Blasco, F. (2007). New mangrove ecosystem data along the UAE coast using remote sensing. *Aquatic Ecosystem Health and Management, 10*(3), 309-319.

Aschbacher, J., Ofren, R., Delsol, J. P., Suselo, T. B., Vibulsresth, S., & Charrupat, T. (1995). An integrated comparative approach to mangrove vegetation mapping using advanced remote sensing and GIS technologies: preliminary results. *Hydrobiologia, 295*(1-3), 285-294.

Asner, G. P., Knapp, D. E., Balaji, A., & Páez-Acosta, G. (2009). Automated mapping of tropical deforestation and forest degradation: CLASlite. *Journal of Applied Remote Sensing, 3*(1), 033543.

Ayoub, F., Leprince, S., & Avouac, J. P. (2009). Co-registration and correlation of aerial photographs for ground deformation measurements. *ISPRS Journal of Photogrammetry and Remote Sensing, 64*(6), 551-560.

Bareth, G., Aasen, H., Bendig, J., Gnyp, M. L., Bolten, A., Jung, A., … & Soukkamäki, J. (2015). Low-weight and UAV-based hyperspectral full-frame cameras for monitoring crops: Spectral comparison with portable spectroradimeter measurements. *Photogrammetrie Fernerkundung- Geoinformation, 2015*(1), 69-79.

Barrett, E. C. (2013). *Introduction to environmental remote sensing.* New York, NY: Routledge.

Beland, M., Goita, K., Bonn, F., & Pham, T. T. H. (2006). Assessment of land-cover changes related to shrimp aquaculture using remote sensing data: a case study in the Giao Thuy District, Vietnam. *International Journal of Remote Sensing, 27*(8), 1491-1510.

Benfield, S. L., Guzman, H. M., & Mair, J. M. (2005). Temporal mangrove dynamics in relation to coastal development in Pacific Panama. *Journal of Environmental Management, 76*(3), 263-276.

Berni, J. A. J., Zarco-Tejada, P. J., Suárez, L., González-Dugo, V., & Fereres, E. (2009). Remote sensing of vegetation from UAV platforms using lightweight multispectral and thermal imaging sensors. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* Hannover, Germany.

Blasco, F., & Aispuru, M. (2002). Mangroves along the coastal stretch of the Bay of Bengal: Present status. *Indian Journal of Marine Sciences, 31*(1), 9-20.

Chadwick, J. (2011). Integrated LiDAR and IKONOS multispectral imagery for mapping mangrove distribution and physical properties. *International jJournal of Remote Sensing, 32*(21), 6765-6781.

Chauvaud, S., Bouchon, C., & Maniere, R. (1998). Remote sensing techniques adapted to high resolution mapping of tropical coastal marine ecosystems (coral reefs, seagrass beds and mangrove). *International Journal of Remote Sensing, 19*(18), 3625-3639.

Chauvaud, S., Bouchon, C., & Maniere, R. (2001). Thematic mapping of tropical marine communities (coral reefs, seagrass beds and mangroves) using SPOT data in Guadeloupe Island. *Oceanologica Acta, 24*, S3-S16.

Che Ku Akmar, C. K. O., Mohd Hasmadi, I., Kasawani, I., Norsaliza, U., & Kamaruzaman, J. (2009). Comparison of several vegetation indices for mangrove mapping using temotely sensed data. In *Environmental Science and Technology Conference (ESTEC2009)* (pp. 620–628). Kuala Terengganu Malaysia.

Chun, B. B., Jafri, M. Z. M., & San, L. H. (2011, July 12-13). Reflectance characteristic of certain mangrove species at Matang Mangrove Forest Reserve, Malaysia. In *Space Science and IEEE. Communication (IconSpace), 2011 IEEE International Conference on* (pp. 147-151). IEEE, Penang, Malaysia.

Chun, B. B., Keat, S. C., Syahreza, S., Jafri, M. Z. M., & San, L. H. (2015, April 24). Discrimination of mangrove species in Matang Mangrove Forest Reserve, Perak using in-situ measurement of hyperspectral leaf reflectance. In *AIP Conference Proceedings* (Vol. 1657, No. 1, p. 110004). AIP Publishing, United States of America.

Civco, D. L. (1993). Artificial neural networks for land-cover classification and mapping. *International Journal of Geographical Information Science, 7*(2), 173-186.

Clark, R. N., Gallagher, A. J., & Swayze, G. A. (1990, June). Material absorption band depth mapping of imaging spectrometer data using a complete band shape least-squares fit with library reference spectra. In *Proceedings of the Second Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Workshop* (pp. 176-186). JPL Publication, California, United States of America.

Clothiaux, E. E., Ackerman, T. P., Mace, G. G., Moran, K. P., Marchand, R. T., Miller, M. A., & Martner, B. E. (2000). Objective determination of cloud heights and radar reflectivities using a combination of active remote sensors at the ARM CART sites. *Journal of Applied Meteorology, 39*(5), 645-665.

Cocks, T., Jenssen, R., Stewart, A., Wilson, I., & Shields, T. (1998, October). The HyMapTM airborne hyperspectral sensor: the system, calibration and performance. In *Proceedings of the 1st EARSeL workshop on Imaging Spectroscopy* (pp. 37-42). EARSeL, University of Zurich, Switzerland.

Conchedda, G., Durieux, L., & Mayaux, P. (2008). An object-based method for mapping and change analysis in mangrove ecosystems. *ISPRS Journal of Photogrammetry and Remote Sensing, 63*(5), 578-589.

Dahdouh-Guebas, F. (2002). The use of remote sensing and GIS in the sustainable management of tropical coastal ecosystems. *Environment, Development and Sustainability, 4*(2), 93-112.

Dahdouh-Guebas, F., Verheyden, A., Kairo, J. G., Jayatissa, L. P., & Koedam, N. (2006). Capacity building in tropical coastal resource monitoring in developing countries: a re-appreciation of the oldest remote sensing method. *The International Journal of Sustainable Development and World Ecology, 13*(1), 62-76.

Dalponte, M., Bruzzone, L., & Gianelle, D. (2008). Fusion of hyperspectral and LIDAR remote sensing data for classification of complex forest areas. *IEEE Transactions on Geoscience and Remote Sensing, 46*(5), 1416-1427.

Danielsen, F., Sørensen, M. K., Olwig, M. F., Selvam, V., Parish, F., Burgess, N. D., ... & Quarto, A. (2005). The Asian tsunami: A protective role for coastal vegetation. *Science (Washington), 310*(5748), 643.

Dowling, R., & Accad, A. (2003). Vegetation classification of the riparian zone along the Brisbane River, Queensland, Australia, using light detection and ranging (lidar) data and forward looking digital video. *Canadian Journal of Remote Sensing, 29*(5), 556-563.

Ehlers, M., Gähler, M., & Janowsky, R. (2003). Automated analysis of ultra high resolution remote sensing data for biotope type mapping: New possibilities and challenges. *ISPRS Journal of Photogrammetry and Remote Sensing, 57*(5), 315-326.

Eslami-Andargoli, L., Dale, P. E. R., Sipe, N., & Chaseling, J. (2009). Mangrove expansion and rainfall patterns in Moreton Bay, southeast Queensland, Australia. *Estuarine, Coastal and Shelf Science, 85*(2), 292-298.

Everitt, J. H., Yang, C., Summy, K. R., Judd, F. W., & Davis, M. R. (2007). Evaluation of color-infrared photography and digital imagery to map black mangrove on the Texas Gulf Coast. *Journal of Coastal Research, 23*(1), 230-235.

Faridhouseini, A., Mianabadi, A., Bannayan, M., & Alizadeh, A. (2011). Lidar remote sensing for forestry and terrestrial applications. *International Journal of Applied Environmental Sciences, 6*(1), 99-114.

Feller, I. C., & Sitnik, M. (1996). Mangrove ecology: A manual for a field course. *Smithsonian Institution, Washington, DC*, 1-135.

Fingas, M. F., & Brown, C. E. (1997). Review of oil spill remote sensing. *Spill Science and Technology Bulletin, 4*(4), 199-208.

Fromard, F., Vega, C., & Proisy, C. (2004). Half a century of dynamic coastal change affecting mangrove shorelines of French Guiana: A case study based on remote sensing data analyses and field surveys. *Marine Geology, 208*(2), 265-280.

Gao, J. (1998). A hybrid method toward accurate mapping of mangroves in a marginal habitat from SPOT multispectral data. *International Journal of Remote Sensing, 19*(10), 1887-1899.

Gao, J. (1999). A comparative study on spatial and spectral resolutions of satellite data in mapping mangrove forests. *International Journal of Remote Sensing, 20*(14), 2823-2833.

Ghosh, M. K., Kumar, L., & Roy, C. (2016). Mapping long-term changes in mangrove species composition and distribution in the Sundarbans. *Forests, 7*(12), 305-321.

Giardino, C., Bresciani, M., Fava, F., Matta, E., Brando, V. E., & Colombo, R. (2015). Mapping submerged habitats and mangroves of Lampi Island Marine National Park (Myanmar) from in situ and satellite observations. *Remote Sensing, 8*(1), 2-14.

Giri, C., & Long, J. (2016). Is the Geographic Range of Mangrove Forests in the Conterminous United States Really Expanding? *Sensors, 16*(12), 2010-2026.

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., ... & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography, 20*(1), 154-159.

Giri, C., Pengra, B., Zhu, Z., Singh, A., & Tieszen, L. L. (2007). Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science, 73*(1), 91-100.

Giri, C., Zhu, Z., Tieszen, L. L., Singh, A., Gillette, S., & Kelmelis, J. A. (2008). Mangrove forest distributions and dynamics (1975–2005) of the tsunami-affected region of Asia. *Journal of Biogeography, 35*(3), 519-528.

Goetz, A. F., Vane, G., Solomon, J. E., & Rock, B. N. (1985). Imaging spectrometry for earth remote sensing. *Science, 228*(4704), 1147-1152.

Goetz, S., & Dubayah, R. (2011). Advances in remote sensing technology and implications for measuring and monitoring forest carbon stocks and change. *Carbon Management, 2*(3), 231-244.

Greaves, H. E., Vierling, L. A., Eitel, J. U., Boelman, N. T., Magney, T. S., Prager, C. M., & Griffin, K. L. (2016). High-resolution mapping of aboveground shrub biomass in Arctic tundra using airborne lidar and imagery. *Remote Sensing of Environment, 184*, 361-373.

Green, E. P., Clark, C. D., Mumby, P. J., Edwards, A. J., & Ellis, A. C. (1998). Remote sensing techniques for mangrove mapping. *International Journal of Remote Sensing, 19*(5), 935-956.

Hakala, T., Suomalainen, J., Kaasalainen, S., & Chen, Y. (2012). Full waveform hyperspectral LiDAR for terrestrial laser scanning. *Optics Express, 20*(7), 7119-7127.

Hassan, N., Hamid, J. R. A., Adnan, N. A., & Jaafar, M. (2014, August 26-29). Delineation of wetland areas from high resolution WorldView-2 data by object-based method. In *IOP Conference Series: Earth and Environmental Science* (Vol. 18, No. 1, p. 012017). IOP Publishing, Kuching, Sarawak, Malaysia.

Heenkenda, M. K., Joyce, K. E., Maier, S. W., & Bartolo, R. (2014). Mangrove species identification: Comparing WorldView-2 with aerial photographs. *Remote Sensing, 6*(7), 6064-6088

Held, A., Ticehurst, C., Lymburner, L., & Williams, N. (2003). High resolution mapping of tropical mangrove ecosystems using hyperspectral and radar remote sensing. *International Journal of Remote Sensing, 24*(13), 2739-2759.

Hernández Cornejo, R., Koedam, N., Ruiz Luna, A., Troell, M., & Dahdouh-Guebas, F. (2005). Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico. *Ecology and Society, 10*(1), 16.

Herweg, J. A., Kerekes, J. P., Weatherbee, O., Messinger, D., van Aardt, J., Ientilucci, E., ... & Meola, J. (2012, May 24). Spectir hyperspectral airborne rochester experiment data collection campaign. In *SPIE Defense, Security, and Sensing* (pp. 839028-839028). International Society for Optics and Photonics, Maryland, United States of America.

Heumann, B. W. (2011a). An object-based classification of mangroves using a hybrid decision tree—Support vector machine approach. *Remote Sensing, 3*(11), 2440-2460.

Heumann, B. W. (2011b). Satellite remote sensing of mangrove forests: Recent advances and future opportunities. *Progress in Physical Geography, 35*(1), 87-108.

Hogarth, P. J. (2007). *The biology of mangroves and seagrasses (Biology of Habitats)*. New York, NY: Oxford University Press.

Holmgren, J., & Persson, Å. (2004). Identifying species of individual trees using airborne laser scanner. *Remote Sensing of Environment, 90*(4), 415-423.

Hossain, M. D., & Nuruddin, A. A. (2016). Soil and mangrove: A review. *Journal of Environmental Science and Technology, 9*(2), 198.

Hossain, M. Z., Tripathi, N. K., & Gallardo, W. G. (2009). Land use dynamics in a marine protected area system in lower Andaman coast of Thailand, 1990–2005. *Journal of Coastal Research, 25*(5), 1082-1095.

Huang, X., Zhang, L., & Wang, L. (2009). Evaluation of morphological texture features for mangrove forest mapping and species discrimination using multispectral IKONOS imagery. *IEEE Geoscience and Remote Sensing Letters, 6*(3), 393-397.

Hussain, M., Chen, D., Cheng, A., Wei, H., & Stanley, D. (2013). Change detection from remotely sensed images: From pixel-based to object-based approaches. *ISPRS Journal of Photogrammetry and Remote Sensing, 80*, 91-106.

Ibharim, N. A., Mustapha, M. A., Lihan, T., & Mazlan, A. G. (2015). Mapping mangrove changes in the Matang Mangrove Forest using multi temporal satellite imageries. *Ocean and Coastal Management, 114*, 64-76.

Ibrahim, N. A., Mustapha, M. A., Lihan, T., & Ghaffar, M. A. (2013, November 31). Determination of mangrove change in Matang Mangrove Forest using multi temporal satellite imageries. In *AIP Conference Proceedings* (Vol. 1571, No. 1, pp. 487-492). AIP Publishing, United States of America.

Ibrahim, S., & Hashim, I. (1990). Classification of mangrove forest by using 1: 40 000-scale aerial photograph. *Forest Ecology and Management, 33*, 583-592.

Imen, S., Chang, N. B., & Yang, Y. J. (2015). Developing the remote sensing-based early warning system for monitoring TSS concentrations in Lake Mead. *Journal of Environmental Management, 160*, 73-89.

Jackson, T. J., Le Vine, D. M., Swift, C. T., Schmugge, T. J., & Schiebe, F. R. (1995). Large area mapping of soil moisture using the ESTAR passive microwave radiometer in Washita'92. *Remote Sensing of Environment, 54*(1), 27-37.

James, G. K., Adegoke, J. O., Saba, E., Nwilo, P., & Akinyede, J. (2007). Satellite-based assessment of the extent and changes in the mangrove ecosystem of the Niger Delta. *Marine Geodesy, 30*(3), 249-267.

Jensen, J. R., Lin, H., Yang, X., Ramsey III, E., Davis, B. A., & Thoemke, C. W. (1991). The measurement of mangrove characteristics in southwest Florida using SPOT multispectral data. *Geocarto International, 6*(2), 13-21.

Jones, J., Dale, P. E. R., Chandica, A. L., & Breitfuss, M. J. (2004). Changes in the distribution of the grey mangrove Avicennia marina (Forsk.) using large scale aerial color infrared photographs: are the changes related to habitat modification for mosquito control? *Estuarine, Coastal and Shelf Science, 61*(1), 45-54.

Kairo, J. G., Dahdouh-Guebas, F., Gwada, P. O., Ochieng, C., & Koedam, N. (2002). Regeneration status of mangrove forests in Mida Creek, Kenya: a compromised or secured future? *AMBIO: A Journal of the Human Environment, 31*(7), 562-568.

Kamal, M., Phinn, S., & Johansen, K. (2014). Characterizing the spatial structure of mangrove features for optimizing image-based mangrove mapping. *Remote Sensing, 6*(2), 984-1006.

Kamal, M., Phinn, S., & Johansen, K. (2015). Object-based approach for multi-scale mangrove composition mapping using multi-resolution image datasets. *Remote Sensing, 7*(4), 4753-4783.

Kamaruzaman, J., & Kasawani, I. (2007). Imaging spectrometry on mangrove species identification and mapping in Malaysia. *WSEAS Trans Biol Biomed, 8*, 118-126.

Kanellopoulos, I., & Wilkinson, G. G. (1997). Strategies and best practice for neural network image classification. *International Journal of Remote Sensing, 18*(4), 711-725.

Kanniah, K. D., Sheikhi, A., Cracknell, A. P., Goh, H. C., Tan, K. P., Ho, C. S., & Rasli, F. N. (2015). Satellite images for monitoring mangrove cover changes in a fast-growing economic region in southern Peninsular Malaysia. *Remote Sensing, 7*(11), 14360-14385.

Kathiresan, K., & Bingham, B. L. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology, 40*, 81-251.

Kaufman, Y. J., Tanré, D., Remer, L. A., Vermote, E. F., Chu, A., & Holben, B. N. (1997). Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer. *Journal of Geophysical Research: Atmospheres, 102*(D14), 17051-17067.

Kirui, K. B., Kairo, J. G., Bosire, J., Viergever, K. M., Rudra, S., Huxham, M., & Briers, R. A. (2013). Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. *Ocean and Coastal Management, 83*, 19–24. https://doi.org/10.1016/j.ocecoaman.2011.12.004

Knight, J. M., Dale, P. E., Spencer, J., & Griffin, L. (2009). Exploring LiDAR data for mapping the micro-topography and tidal hydro-dynamics of mangrove systems: An example from southeast Queensland, Australia. *Estuarine, Coastal and Shelf Science, 85*(4), 593-600.

Kokaly, R. F., Despain, D. G., Clark, R. N., & Livo, K. E. (2003). Mapping vegetation in Yellowstone National Park using spectral feature analysis of AVIRIS data. *Remote Sensing of Environment, 84*(3), 437-456.

Kovacs, J. M., Liu, Y., Zhang, C., Flores-Verdugo, F., & de Santiago, F. F. (2011). A field based statistical approach for validating a remotely sensed mangrove forest classification scheme. *Wetlands Ecology and Management, 19*(5), 409-421.

Kovacs, J. M., Wang, J., & Flores-Verdugo, F. (2005). Mapping mangrove leaf area index at the species level using IKONOS and LAI-2000 sensors for the Agua Brava Lagoon, Mexican Pacific. *Estuarine, Coastal and Shelf Science, 62*(1), 377-384.

Krause, G., Bock, M., Weiers, S., & Braun, G. (2004). Mapping land-cover and mangrove structures with remote sensing techniques: A contribution to a synoptic GIS in support of coastal management in North Brazil. *Environmental Management, 34*(3), 429-440.

Kridiborworn, P., Chidthaisong, A., Yuttitham, M., & Tripetchkul, S. (2012). Carbon sequestration by mangrove forest planted specifically for charcoal production in Yeesarn, Samut Songkram. *Journal of Sustainable Energy and Environment, 3*(2), 87-92.

Kruse, F. A., Boardman, J. W., & Huntington, J. F. (2003). Comparison of airborne hyperspectral data and EO-1 Hyperion for mineral mapping. *IEEE Transactions on Geoscience and Remote Sensing, 41*(6), 1388-1400.

Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T. V., & Dech, S. (2011). Remote sensing of mangrove ecosystems: A review. *Remote Sensing, 3*(5), 878-928.

Kux, H. J., & Souza, U. D. (2012). Object-based image analysis of WORLDVIEW-2 satellite data for the classification of mangrove areas in the city of São Luís, Maranhão State, Brazil. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (pp. 95-100). Melbourne, Australia.

Lee, T. M., & Yeh, H. C. (2009). Applying remote sensing techniques to monitor shifting wetland vegetation: A case study of Danshui River estuary mangrove communities, Taiwan. *Ecological Engineering, 35*(4), 487-496.

Lefsky, M. A., Cohen, W. B., Harding, D. J., Parker, G. G., Acker, S. A., & Gower, S. T. (2002). Lidar remote sensing of above-ground biomass in three biomes. *Global Ecology and Biogeography, 11*(5), 393-399.

Leprince, S., Barbot, S., Ayoub, F., & Avouac, J. P. (2007). Automatic and precise orthorectification, coregistration, and subpixel correlation of satellite images, application to ground deformation measurements. *IEEE Transactions on Geoscience and Remote Sensing, 45*(6), 1529-1558.

Lillesand, T., Kiefer, R. W., & Chipman, J. (2014). *Remote sensing and image interpretation.* New York, NY: John Wiley & Sons.

Liu, K., Li, X., Shi, X., & Wang, S. (2008). Monitoring mangrove forest changes using remote sensing and GIS data with decision-tree learning. *Wetlands, 28*(2), 336-346.

Long, J. B., & Giri, C. (2011). Mapping the Philippines' mangrove forests using Landsat imagery. *Sensors, 11*(3), 2972-2981.

Lugo, A. E., & Snedaker, S. C. (1974). The ecology of mangroves. *Annual Review of Ecology and Systematics, 5*(1), 39-64.

Manson, F. J., Loneragan, N. R., Harch, B. D., Skilleter, G. A., & Williams, L. (2005). A broad-scale analysis of links between coastal fisheries production and mangrove extent: A case-study for northeastern Australia. *Fisheries Research, 74*(1), 69-85.

Manson, F. J., Loneragan, N. R., McLeod, I. M., & Kenyon, R. A. (2001). Assessing techniques for estimating the extent of mangroves: topographic maps, aerial photographs and Landsat TM images. *Marine and Freshwater Research, 52*(5), 787-792.

Manson, F. J., Loneragan, N. R., Skilleter, G. A., & Phinn, S. R. (2005). An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. In *Oceanography and marine biology* (pp. 493-524). USA: CRC Press.

Mantri, V. A., & Mishra, A. K. (2006). On monitoring mangrove vegetation of Sagar Island by remote sensing. *National Academy Science Letters, 29*(1/2), 45-48.

Martin, M. E., & Aber, J. D. (1997). High spectral resolution remote sensing of forest canopy lignin, nitrogen, and ecosystem processes. *Ecological Applications, 7*(2), 431-443.

Martinuzzi, S., Gould, W. A., Lugo, A. E., & Medina, E. (2009). Conversion and recovery of Puerto Rican mangroves: 200 years of change. *Forest Ecology and Management, 257*(1), 75-84.

Matsui, N., Meepol, W., & Chukwamdee, J. (2015). Soil Organic Carbon in Mangrove Ecosystems with Different Vegetation and Sedimentological Conditions. *Journal of Marine Science and Engineering, 3*(4), 1404-1424.

Mesta, P. N., Setturu, B., Subash Chandran, M. D., Rajan, K. S., & Ramachandra, T. V. (2014). Inventorying, mapping and monitoring of mangroves towards sustainable management of West Coast, India. *J Geophysics Remote Sensing, 3*(3), 130-138.

Misra, A., Murali, M. R. & Vethamony, P. (2015). Assessment of the land use/land cover (LU/LC) and mangrove changes along the Mandovi–Zuari estuarine complex of Goa, India. *Arabian Journal of Geosciences, 8*(1), 267-279.

Mumby, P. J., Green, E. P., Edwards, A. J., & Clark, C. D. (1999). The cost-effectiveness of remote sensing for tropical coastal resources assessment and management. *Journal of Environmental Management, 55*(3), 157-166.

Murray, M. R., Zisman, S. A., Furley, P. A., Munro, D. M., Gibson, J., Ratter, J., ... & Place, C. J. (2003). The mangroves of Belize: Part 1. distribution, composition and classification. *Forest Ecology and Management, 174*(1), 265-279.

Muttitanon, W., & Tripathi, N. K. (2005). Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. *International Journal of Remote Sensing, 26*(11), 2311-2323.

Mäkynen, J., Holmlund, C., Saari, H., Ojala, K., & Antila, T. (2011). Unmanned aerial vehicle (UAV) operated megapixel spectral camera. In *Proceedings of SPIE, Electro-Optical Remote Sensing, Photonic Technologies, and Applications* (Vol. 8186, p. 81860Y). International Society for Optics and Photonics.

Nayak, S., & Bahuguna, A. (2001). Application of remote sensing data to monitor mangroves and other coastal vegetation of India. *Indian Journal of Marine Sciences, 30*(4), 195-213.

Neukermans, G., Dahdouh-Guebas, F. J. G. K., Kairo, J. G., & Koedam, N. (2008). Mangrove species and stand mapping in Gazi Bay (Kenya) using Quickbird satellite imagery. *Journal of Spatial Science, 53*(1), 75-86.

Newton, A. C., Hill, R. A., Echeverría, C., Golicher, D., Rey Benayas, J. M., Cayuela, L., & Hinsley, S. A. (2009). Remote sensing and the future of landscape ecology. *Progress in Physical Geography, 33*(4), 528-546.

Nguyen, H., Mcalpine, C., Pullar, D., Johansen, K., & Duke, N. C. (2013). Ocean and coastal management the relationship of spatial e temporal changes in fringe mangrove extent and adjacent land-use: Case study of Kien Giang coast, Vietnam. *Ocean and Coastal Management, 76*, 12–22. https://doi.org/10.1016/j.ocecoaman.2013.01.003

Nguyen, H. H. (2014). The relation of coastal mangrove changes and adjacent land-use: A review in Southeast Asia and Kien Giang, Vietnam. *Ocean and Coastal Management, 90*, 1-10.

Osti, R., Tanaka, S., & Tokioka, T. (2009). The importance of mangrove forest in tsunami disaster mitigation. *Disasters, 3*3(2), 203-213.

Ozesmi, S. L., & Bauer, M. E. (2002). Satellite remote sensing of wetlands. *Wetlands Ecology and Management, 10*(5), 381-402.

Paling, E. I., Kobryn, H. T., & Humphreys, G. (2008). Assessing the extent of mangrove change caused by Cyclone Vance in the eastern Exmouth Gulf, northwestern Australia. *Estuarine, Coastal and Shelf Science, 77*(4), 603-613.

Pasqualini, V., Iltis, J., Dessay, N., Lointier, M., Guelorget, O., & Polidori, L. (1999). Mangrove mapping in North-Western Madagascar using SPOT-XS and SIR-C radar data. *Hydrobiologia, 413*(0), 127-133.

Patenaude, G., Hill, R. A., Milne, R., Gaveau, D. L., Briggs, B. B. J., & Dawson, T. P. (2004). Quantifying forest above ground carbon content using LiDAR remote sensing. *Remote Sensing of Environment, 93*(3), 368-380.

Pattanaik, C., Reddy, C. S., & Prasad, S. N. (2008). Mapping, monitoring and conservation of Mahanandi wetland ecosystem, Orissa, India using remote sensing and GIS. In *Proceedings of the National Academy of Sciences India Section B-Biological Science*s (vol. 78, pp. 81-89). India.

Pearce, F. (2014). Power to the people. *New Scientist, 223*(2980), 26-27.

Pohl, C., & Van Genderen, J. L. (1998). Review article multisensor image fusion in remote sensing: concepts, methods and applications. *International Journal of Remote Sensing, 19*(5), 823-854.

Prasad, K. A., & Gnanappazham, L. (2014). Species discrimination of mangroves using Derivative Spectral Analysis. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2*(8), 45-52.

Price, J. C. (1992). Variability of high-resolution crop reflectance spectra. *International Journal of Remote Sensing, 13*(14), 2593-2610.

Proisy, C., Couteron, P., & Fromard, F. (2007). Predicting and mapping mangrove biomass from canopy grain analysis using Fourier-based textural ordination of IKONOS images. *Remote Sensing of Environment, 109*(3), 379-392.

Proisy, C., Gratiot, N., Anthony, E. J., Gardel, A., Fromard, F., & Heuret, P. (2009). Mud bank colonization by opportunistic mangroves: A case study from French Guiana using lidar data. *Continental Shelf Research, 29*(3), 632-641.

Ramachandran, S., Sundaramoorthy, S., Krishnamoorthy, R., Devasenapathy, J., & Thanikachalam, M. (1998). Application of remote sensing and GIS to coastal wetland ecology of Tamil Nadu and Andaman and Nicobar group of islands with special reference to mangroves. *Current Science, 75*(3), 236-244.

Ranchin, T., & Wald, L. (2000). Fusion of high spatial and spectral resolution images: The ARSIS concept and its implementation. *Photogrammetric Engineering and Remote Sensing, 66*(1), 49-61.

Rao, K. R., & Yip, P. (2014). *Discrete cosine transform: algorithms, advantages, applications.* United States of America, USA: Academic press.

Rasolofoharinoro, M., Blasco, F., Bellan, M. F., Aizpuru, M., Gauquelin, T., & Denis, J. (1998). A remote sensing based methodology for mangrove studies in Madagascar. *International Journal of Remote Sensing, 19*(10), 1873-1886.

Reddy, C. S., & Pattanaik, C. (2007). Mangrove vegetation assessment and monitoring in Balasore district, Orissa using remote sensing and GIS. *National Academy Science Letters, 30*(11/12), 377-382.

Rhyma, P. P., & Norizah, K. (2016). Kriging analysis- optimizing values in unknown areas using known data point. In *Proceedings of International Conference on Sustainable Forest Development in view of Climate Change (SFDCC2016),* (pp. 96-99). Hotel Bangi-Putrajaya, Malaysia.

Rhyma, P. P., Norizah, K., Ismail Adnan, A. M., Faridah-hanum, I., & Ibrahim, S. (2015). Canopy density classification of Matang mangrove forest reserve using machine learning approach in remote sensing. *The Malaysian Forester, 78*(1&2), 75-86.

Rodriguez, W., & Feller, I. C. (2004). *Mangrove landscape characterization and change in Twin Cays, Belize using aerial photography and IKONOS satellite data.* National Museum of Natural History.

Rosette, J. A. B., North, P. R. J., & Suarez, J. C. (2008). Vegetation height estimates for a mixed temperate forest using satellite laser altimetry. *International Journal of Remote Sensing, 29*(5), 1475-1493.

Roslani, M. A., Mustapha, M. A., Lihan, T., & Juliana, W. W. (2013, November). Classification of mangroves vegetation species using texture analysis on Rapideye satellite imagery. In *AIP Conference Proceedings* (Vol. 1571, No. 1, pp. 480-486). AIP Publishing, United States of America.

Roslani, M. A., Mustapha, M. A., Lihan, T., & Juliana, W. W. (2014). Applicability of Rapideye satellite imagery in mapping mangrove vegetation species at Matang mangrove forest reserve, Perak, Malaysia. *Journal of Environmental Science and Technology, 7*(2), 123-136.

Ruiz-Luna, A., & Berlanga-Robles, C. A. (2003). Land use, land cover changes and coastal lagoon surface reduction associated with urban growth in northwest Mexico. *Landscape Ecology, 18*(2), 159-171.

Rönnbäck, P. (1999). The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics, 29*(2), 235-252.

Saari, H., Pellikka, I., Pesonen, L., Tuominen, S., Heikkilä, J., Holmlund, C., ... & Antila, T. (2011). Unmanned Aerial Vehicle (UAV) operated spectral camera system for forest and agriculture applications. In *Proceedings of the SPIE, Remote Sensing for Agriculture, Ecosystems, and Hydrology XIII.* (Vol. 8174, p. 81740H). International Society for Optics and Photonics.

Saito, H., Bellan, M., Al-Habshi, A., Aizpuru, M., & Blasco, F. (2003). Mangrove research and coastal ecosystem studies with SPOT-4 HRVIR and TERRA ASTER in the Arabian Gulf. *International Journal of Remote Sensing, 24*(21), 4073-4092.

Santos, L. C. M., Matos, H. R., Schaeffer-Novelli, Y., Cunha-Lignon, M., Bitencourt, M. D., Koedam, N., & Dahdouh-Guebas, F. (2014). Anthropogenic activities on mangrove areas (São Francisco River Estuary, Brazil Northeast): A GIS-based analysis of CBERS and SPOT images to aid in local management. *Ocean and Coastal Management, 89*, 39-50.

Sawaya, K. E., Olmanson, L. G., Heinert, N. J., Brezonik, P. L., & Bauer, M. E. (2003). Extending satellite remote sensing to local scales: land and water resource monitoring using high-resolution imagery. *Remote Sensing of Environment, 88*(1), 144-156.

Schowengerdt, R. A. (2006). *Remote sensing: models and methods for image processing.* USA: Academic press.

Setlur, V., Gleicher, M., Gooch, B., Takagi, S., & Raskar, R. (2009). *U.S. Patent No. 7,574,069.* Washington, DC: U.S. Patent and Trademark Office.

Son, N. T., Chen, C. F., & Chen, C. R. (2017). Mapping mangrove density from RapidEye Data in Central America. *Open Geosciences,* 9(1), 211-220.

Souza-Filho, P. W., & Paradella, W. R. (2003). Use of synthetic aperture radar for recognition of Coastal Geomorphological Features, land-use assessment and shoreline changes in Bragança coast, Pará, Northern Brazil. *Anais da Academia Brasileira de Ciências, 75*(3), 341-356.

Spalding, M. (2010). *World atlas of mangroves.* London: Routledge.

Spalding, M., Blasco, F., & Field, C. (1997). *World mangrove atlas.* Okinawa (Japan): International Society for Mangrove Ecosystems.

Starek, J. A., Açıkmeşe, B., Nesnas, I. A., & Pavone, M. (2016). Spacecraft autonomy challenges for next-generation space missions. In *Advances in Control System Technology for Aerospace Applications* (pp. 1-48). Springer Berlin Heidelberg.

Sulong, I. (1999). Remote sensing and geographic information system (GIS) application to environmental sensitivity index mapping. In *Environmental Sensitivity Index Mapping of the Chukai to Penor Coastline* (pp. 29-39). Terengganu, Malaysia.

Sulong, I., & Veddin, I. (1999). *Mapping in the coastal area of Sabak Bernam, Kuala Selangor and Klang district with emphasis on mangrove forest using remote sensing and geographical information systems'*. Assessment and Monitoring of Marine Systems, Universiti Putra Malaysia Terengganu (in press). Google Scholar.

Sulong, I., Mohd-Lokman, H., Mohd-Tarmizi, K., & Ismail, A. (2002). Mangrove mapping using Landsat imagery and aerial photographs: Kemaman District, Terengganu, Malaysia. *Environment, Development and Sustainability, 4*(2), 135-152.

Tarabalka, Y., Fauvel, M., Chanussot, J., & Benediktsson, J. A. (2010). SVM-and MRF-based method for accurate classification of hyperspectral images. *IEEE Geoscience and Remote Sensing Letters, 7*(4), 736-740.

Terchunian, A., Klemas, V., Segovia, A., Alvarez, A., Vasconez, B., & Guerrero, L. (1986). Mangrove mapping in Ecuador: the impact of shrimp pond construction. *Environmental Management, 10*(3), 345-350.

Thampanya, U., Vermaat, J. E., Sinsakul, S., & Panapitukkul, N. (2006). Coastal erosion and mangrove progradation of Southern Thailand. *Estuarine, Coastal and Shelf Science, 68*(1), 75-85.

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*(1), 98-109.

Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., & Steininger, M. (2003). Remote sensing for biodiversity science and conservation. *Trends in Ecology and Evolution, 18*(6), 306-314.

Tyo, J. S., Goldstein, D. L., Chenault, D. B., & Shaw, J. A. (2006). Review of passive imaging polarimetry for remote sensing applications. *Applied Optics, 45*(22), 5453-5469.

Vaiphasa, C., Skidmore, A. K., & de Boer, W. F. (2006). A post-classifier for mangrove mapping using ecological data. *ISPRS Journal of Photogrammetry and Remote Sensing, 61*(1), 1-10.

Van Aardt, J. A. N., & Wynne, R. H. (2007). Examining pine spectral separability using hyperspectral data from an airborne sensor: An extension of field-based results. *International Journal of Remote Sensing, 28*(2), 431-436.

Vasconcelos, M. J. P., Biai, J. M., Araujo, A., & Diniz, M. A. (2002). Land cover change in two protected areas of Guinea-Bissau (1956-1998). *Applied Geography, 22*(2), 139-156.

Verma, M., Fisher, J. B., Mallick, K., Ryu, Y., Kobayashi, H., Guillaume, A., ... & Sikka, M. (2016). Global surface net-radiation at 5 km from MODIS Terra. *Remote Sensing, 8*(9), 739-758.

Vo, Q. T., Oppelt, N., Leinenkugel, P., & Kuenzer, C. (2013). Remote sensing in mapping mangrove ecosystems—an object-based approach. *Remote Sensing, 5*(1), 183-201.

Walters, B. B. (2005). Patterns of local wood use and cutting of Philippine mangrove forests. *Economic Botany, 59*(1), 66-76.

Wang, L., Sousa, W. P., & Gong, P. (2004). Integration of object-based and pixel-based classification for mapping mangroves with IKONOS imagery. *International Journal of Remote Sensing, 25*(24), 5655-5668.

Wang, L., Sousa, W. P., Gong, P., & Biging, G. S. (2004). Comparison of IKONOS and QuickBird images for mapping mangrove species on the Caribbean coast of Panama. *Remote Sensing of Environment, 91*(3), 432-440.

Wang, L. E., & Sousa, W. P. (2009). Distinguishing mangrove species with laboratory measurements of hyperspectral leaf reflectance. *International Journal of Remote Sensing, 30*(5), 1267-1281.

Wang, L. E., & Sousa, W. P. (2009). Distinguishing mangrove species with laboratory measurements of hyperspectral leaf reflectance. *International Journal of Remote Sensing, 3*0(5), 1267-1281. https://doi.org/10.1080/01431160802474014

Wannasiri, W., Nagai, M., Honda, K., Santitamnont, P., & Miphokasap, P. (2013). Extraction of mangrove biophysical parameters using airborne LiDAR. *Remote Sensing, 5*(4), 1787-1808.

Wei, G., Shalei, S., Bo, Z., Shuo, S., Faquan, L., & Xuewu, C. (2012). Multi-wavelength canopy LiDAR for remote sensing of vegetation: Design and system performance. *ISPRS Journal of Photogrammetry and Remote Sensing, 69*, 1-9.

Xie, Y., Sha, Z., & Yu, M. (2008). Remote sensing imagery in vegetation mapping: A review. *Journal of Plant Ecology, 1*(1), 9-23.

Zhang, C., Kovacs, J. M., Liu, Y., Flores-Verdugo, F., & Flores-de-Santiago, F. (2014). Separating mangrove species and conditions using laboratory hyperspectral data: A case study of a degraded mangrove forest of the Mexican Pacific. *Remote Sensing, 6*(12), 11673–11688. https://doi.org/10.3390/rs61211673

Zhang, K. (2008). Identification of gaps in mangrove forests with airborne LIDAR. *Remote Sensing of Environment, 112*(5), 2309-2325.

Zhang, R., & Zhu, D. (2011). Study of land cover classification based on knowledge rules using high-resolution remote sensing images. *Expert Systems with Applications, 38*(4), 3647-3652.

Zhu, Y., Liu, K., Liu, L., Wang, S., & Liu, H. (2015). Retrieval of mangrove aboveground biomass at the individual species level with WorldView-2 images. *Remote Sensing, 7*(9), 12192-12214.

Zink, F., Vincent, R. A., Murphy, E., & Cote, O. (2004). Comparison of radar and in situ measurements of atmospheric turbulence. *Journal of Geophysical Research: Atmospheres, 109*(D11), 1-7.

Zulfa, A. W., & Norizah, K. (2016). Examining the radiation of electromagnetic reflectance of satellite image in identifying object on earth. In *Proceedings of International Conference on Sustainable Forest Development in view of Climate Change (SFDCC2016)*, (pp. 100-104). Hotel Bangi-Putrajaya, Malaysia. 8-11 August 2016.