INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 3)
Available online at: www.ijariit.com

Assessing forest degradation and analysis of future scenarios using GIS and remote sensing

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ABSTRACT

The study entails detecting forest degradation and modeling future scenario using GIS and remote sensing, in Elgeyo/Marakwet County, a case study of Embobut forest, it is evident that forests have been managed for several years in the world, but in most cases especially in the developing world, various regimes have tried to come up with institutional to guide forest management with no much success, in many countries, there is no regular monitoring system that collects information about the situation of the forests and trends of the distribution. This makes it difficult to quantify the status of the existing forest cover. We used high-resolution satellite imagery as well as GIS and remote sensing software (ArcGIS and ENVI) with mathematical models to project the forest status, apart from satellite images there will be a ground truthing using Global positioning system (GPS) as data collection tool to as well as use of Auxiliary data; which will include Socio economic and data for the years 1980, 1990, 2000 and 2010. Policy implications especially with the enactment of Kenya forest act, 2005 was examined. Recorded positive changes hence increased in size while all other forest classes decreased in size. The study found out that the total forest loss was 7,172.31 hectares, this represents a loss of 28 percent of the total forested area that existed in 1986 which corresponds to an annual forest loss of 286.892 hectares. According to this study, as population increased the rate of deforestation also increased. The future scenarios from the studies were based on a fixed annual deforestation rate and a conclusion is made that Bare land & rocky and water bodies classes increased in area while Mixed Podocarpus latifolius, Juniperus-Nuxia-Podocarpus factus, Tree ferns Cyathea manniana & Bamboo, Acacia abyssica & Scrubby grassland classes decreased in size. As Population grew forestry loss increased, between 1986 and 2011, the total forest loss was 7,172.31 hectares. Future Scenario found that with the same trend, there will be no forest remaining natural forest block by the year 2038 in the study area.

Keywords: *Forest degradation GIS, Remote sensing, NDVI, Global positioning system.*

1. INTRODUCTION

For centuries the world's forests have been under pressure due to ever-increasing human population. Food and Agricultural Organization (FAO) defines deforestation as the process where forests are cut down, burned and damaged. Current reports point out that deforestation is the second largest source of greenhouse gas (GHG) emissions after the energy sector accounting for about 20%.

According to Oebaka et al. 2012, deforestation is occurring in developing countries especially in sub-Saharan Africa where its rate is increasing because of uncontrolled timber harvesting, conversion of forests to farm land and pasture lands increased human population, migration, education, energy prices, road construction, fire outbreaks, and other forest mortality factors.

Forests are of great essential in terms of sustaining life support systems on Earth. Forests are also important for the development of the socio-economic sector for many people since forests provide timber, fuel and raw materials for industry, wood for the basic needs and employment of the population (UNEP, 2001). There are several criteria for an area to be defined as forest. UNEP's (2001) definition of forested area is not the same for developed and less developed nations. In developing countries, forests must have a crown cover of at least 10 percent, consisting of either tree and/or bamboo. Wild vegetation and wildlife are also needed, as is a natural soil condition. Furthermore, to be defined as forest the area cannot be under agriculture. The most significant difference in the criteria for developed countries is that a crown cover of 20 percent or more is needed (UNEP, 2001).

In 2009, UNEP, FAO, and UNFF in an attempt to classify forestry, defined closed forests as areas with a tree cover of 40 percent or more. Forests with an undisturbed ecology and with no indications of human activity are referred to as primary forests (Lung and Schaab, 2009). In comparison to all terrestrial ecosystems, primary forests are the most species-rich and diverse (Mubea and Menz 2014). Zones that have vegetation cover other than forests, but are not under intensive land use, are defined as woodland. The predominant land use in woodland areas is pasture (Holmgren, 2006).

At present, the world's forests cover about 4 billion hectares, which accounts for 31 percent of the world's land area. It illustrates the distribution of forests on a global scale. Other wooded land covers about 1.1 billion hectares (Mubea and Menz 2014).
Africa's forests cover is approximately 21.4 percent of the land area (FAO, 2009), which covers a total of 674 million hectares (Mubea and Menz 2014). In the greater East Africa, approximately 13 percent of the land area is covered by forests and woodlands which make the resources rather limited.

As mentioned earlier, Kenya is the most forested nation in Eastern Africa with a forest and woodland cover of 17 million hectares which corresponds to a third of the land area (UNEP, 2006). Even with this fact, closed forest cover only 1.7 percent of the total land area in Kenya (Lung and Schaab, 2009.
Several reports and research have been done concerning the extension of forested areas and deforestation. Though, in many countries, there is no regular monitoring system that collects information about the situation of the forests and trends of the distribution (UNEP, 2001). This makes it difficult to quantify the status of the existing forest cover. Particularly in Africa, only handful studies on tropical forest environments focusing on deforestation have been conducted (Lung and Schaab, 2009). Kenya is an example of a country which it is difficult to obtain accurate and updated records on forest loss and forest degradation (Matiru, 1999). To understand about change developments in these environments more studies are needed (Lung and Schaab, 2009).

In the 1990's, the global reduction of forests was 16 million hectares per year. Now, the forest loss has decreased to approximately 13 million hectares per year. The largest net loss of forest occurs in South America and Africa. Between 2000 and 2010, about 4.0 million hectares were lost annually in South America followed by Africa with a forest loss of 3.4 million hectares per year. The net loss of forests has been significantly reduced, mainly because of several projects including forest planting, restoration of landscape and natural expansion of forests (Mubea and Menz 2014). But even if the net loss of forests is decreasing in some parts of the world, it continues at a high rate in other countries (FAO, 2006). In recent times, industrialized countries have experienced a decreased deforestation rate, but deforestation has accelerated in developing countries (Boahene, 1998).

In the past hundred years, there have been major land cover changes in East Africa. Between 1900 and 1990 cropland increased 200 percent at the expense of tropical forests. This has a distinctly negative effect on tropical forest areas. The deforestation rate in East Africa between 1990 and 2000 was four times higher than the world average. The main reason for the large forest loss in East Africa is the increasing population (Lung and Schaab, 2009). The struggle towards sustainable forest management in Africa has during the last ten years shown positive trends, even if some regions still are experiencing negative effects on the forests. Expansion of protected areas with the purpose of conserving biodiversity has led to an overall reduction in deforestation. But problems remain.

Overall, forest plantations and protected areas are on the rise, but the loss of primary forests is continuing at a high rate as these forests are turned into other land uses. Africa is still facing rapid forest loss and most threatened are the primary forests. It is uncertain what will happen with the world 's forests in the future (Mubea and Menz 2014). If deforestation continues at the same rate as at present all productive forests in Africa are expected to be depleted within the next 100 years (Boahene, 1998).

2. PURPOSE OF THE RESEARCH

The purpose of this research is to detect forest cover change over the years and do an analysis to find out why forest trends are the way they are even with policies and institutional framework informing forest management in Kenya. The results will also be used to give detailed information about the forests types in the study area.

3. METHODOLOGY

3.1 Data acquisition and analysis

Remote sensing (Landsat Images)

Processing of images was done by ENVI 5.0 Image Processing software. Images appearing in single bands were layer stack and further geometric corrections of the images were performed by change detection analysis to remove possible noise. Geometric errors were corrected using ground control points which geocode the image from the topographic maps. The geocoded image was then used to register other images for photo-interpretation. Contrast stretching was applied to all images to produce false color composites that were eventually interpreted by digitization such that all different land cover groups are properly delineated. After all, images have been registered, image enhancement was necessary to allow clear and precise image interpretation by increasing the visible differences between various features. All images that are used for change detection analysis were finally classified using unsupervised classification technique for mapping of land cover groups. Supervised classification was done to specify and quantify the existing land cover types.

Visual Image Interpretation

Image interpretation is the act of examining images with a goal of identifying objects and judging their significance. Various image interpretation styles were tested in the study since the study area has a heterogeneous land cover, supervised classification gave satisfying results and therefore visual image interpretation was made. Image interpretation process was important in training site selection which contributed to true image classification. Training sites were areas in the image that represented a land cover type that is for each land cover type of interest.

Elements of image interpretation which aided in identifying the sites during the process of training site selection include Height, shadow, shape Tone/color, texture, size, pattern and site, and association. Such classes in image interpretation acted as training sites (spectral examples of classes).

Training classification files

Areas in the image that were known to be represented by a land cover type were digitized. Sample training areas were then used as spectral signatures during the classification. This involved using the Region of Interest (ROI) tool and adding classes respective to the anticipated output. Each class had at least 500 pixels to have a good classification. Pixel hygiene was ensured i.e. pixels of a similar color was put together thus one would have several classes of cropland and forests. In some areas, the pixels were not that clear since they had different tones and texture, training areas were not picked in such. Also, Google Earth was used to verify the type of vegetation cover in a place. This was done in the image of the year 2011 classification process. The image was converted into a kml file then opened in Google Earth. This was possible since ENVI has a tool 'Jump to' that directly navigates to the chosen location in Google Earth or converts the image into kml. The training areas were saved and used for the other years as guidelines to produce uniform classification. Corrections were made later by combining various related classes to have fewer classes that are relevant to the study.

Image classification

Digital image classification used the spectral information represented by the digital numbers in one or more spectral bands and classified each pixel based on this spectral information. Supervised Classification using Maximum Likelihood Algorithm was adopted.

Post classification processing

Combining sub-classes

After classification different levels of land-cover classes were combined to form one class e.g. in the case where different spectral reflectance existed in one class (which translate to different colors), training areas in such a case which were picked differently. The classes were then merged after classification. The acquired satellite images were classified using the dominant forest classes in the area which are *Cupressus lusitanica* mixed *Podocarpus latifolius*, *Juniperus-Nuxia-Podocarpus factus*, Tree ferns *Cyathea manniana* & Bamboo and *Acacia abyssinica* & Scrabby grassland. To make sure that the classification was complete, two non-forest types which are part of the forest ecosystem were added, the classes were Bare land & rocky and Water Bodies. For the Bare land & rocky land cover types, built area, as well as constructed roads, were classified as one, this was mainly since most of the bare land was fallow agricultural land.

Decision tree

Coding of the images was implemented using the decision tree; a decision tree in ENVI. The decision tree was populated by adding children to the default two children that are opened by default. The conditions are set in an else if condition. These codes were applied to the other years to enable an easy understanding. The color coding used several combinations of red, blue and green based on Inter-Governmental Panel on Climate Change (IPPC) classification.

Image cleaning

This process involved converting the mosaicked image which is in tiff format into the grid. The imaged was then opened in ArcView 3.2a to convert some of the classes that had spread all over the image. The classified image was overlaid on the Landsat image in ArcMap and the swipe tool was used to check for errors. Areas, where a class had spread giving false information, were digitized in ArcView using the manual grid editor into the correct class. After this process, the image was coded again.

Accuracy Assessment

The sample points from the field were used to check the level of confidence on the classified images. This was done using error matrix/confusion table.

This error matrix shows the proportion of correctly classified and misclassified pixels in a matrix making it possible to derive several accuracy measures. This was also done in ENVI 5.2 which generated an error matrix containing the accuracy of each class, the overall accuracy, and the kappa coefficient.

Population Data

The collected data was put in Microsoft Excel format, ArcGIS read Microsoft Excel format data for Desktop 10.2.2 as .xls. The data was concerted to file geodatabase ready and uploaded to ArcMap 10.2.2.

Data accuracy validation

Data accuracy validation or Assessment is a measure of the quality of maps by identifying errors (Obade, et al., 2009) ground truthing exercise using Global positioning system (GPS), the ground control points acted as reference data for accuracy assessment, it also acted as points of picking spectra and for classifying different land classes. Accuracy assessment raises the confidence of the final map data to be presented (RS/GIS Laboratories, 2004; Congalton & Green, 2009). According to (Congalton & Green, 2009), accuracy assessment can either be qualitative or quantitative; it can take time-consuming or quick, expensive or low-priced. A quantitative accuracy assessment compares imagery mapped data with reference data (GPS collected or correctly classified), whereby the reference data is expected to be accurate. The commonly used methods for GIS data accuracy assessment are Overall Accuracy Assessment and Kappa coefficient.

Overall Accuracy Assessment

Overall accuracy assessment is the percentage of classified points in the classified image and the Reference image. If there are 25 points picked at random from the classified image and compared to the Reference image, there would be points that will be accurately classified.
The accuracy was calculated as below;
If there are 25 points and 20 points are picked and correctly corresponds to the classified image, then the accuracy will be (25-20)/25*100. Which is 75% accurate. The study had 154 points out of 198 fell on the correct classified class giving a 77% accuracy; hence the classified satellite imagery gave a good degree of accuracy.

4. RESULTS

The summary of the forest class changes over the time periods under study is graphically represented in figure 4.1. The classes *Cupressus lusitanica*, Bare land and rocky and Water Bodies recorded positive changes hence increased in size while classes *Mixed Podocarpus latifolius*, *Juniperus-Nuxia-Podocarpus factus*, Tree ferns *Cyathea manniana* & Bamboo and *Acacia abyssica* & Scrabby grassland decreased in overall size. Looking at the changes if the trend continues in the same manner the area will be dominated by the classes Cupressus lusitanica and Bare land and rocky.

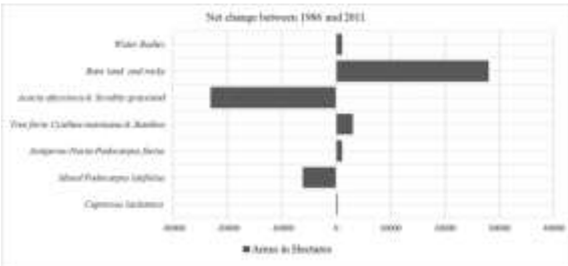

Figure 4.1

The combined of processed images for years 1986, 1995, 2003 and 2011 for individual vegetation type in the study area as shown in figure 4.1. Taking *Cypresus cupresus*, in 1986, the ad covered a large southern block with dots of *Juniperus-Nuxia-Podocarpus factus* and *Acacia abyssica* & Scrabby grassland. By the year 1995, the area had been replaced by *Acacia abyssinica* & Scrabby grassland and dots of Tree ferns *Cyathea manniana* & Bamboo.

This means that the strand harvested and thus Tree ferns *Cyathea manniana* which is a pioneer species was dominating. In 1999 non-logging ban was passed and adopted in Kenya followed by active reforestation (Mathu, 2007). The ban explains the trends on the southern block and western tip where Cypresus cupresus were grown and by the year 2011 the two blocks were covered by almost pure strands.

In 1986, Mixed *Podocarpus latifolius Juniperus-Nuxia-Podocarpus factus* and Tree ferns *Cyathea manniana* & Bamboo were dominant on the left and towards the extreme eastern bloc. During the whole study period as shown in figure 4.3, the two classes reduced. Apart from the size, it was also doted by Acacia a*byssinica* & Scrabby grassland and bare land and rocky classes. Bare land and rocky means that some areas were completely cleared while *Acacia abyssinica* & Scrabby denotes forest under regeneration. This can be explained by the encroachment of this areas to create more land for farming as well as general degradation.

As shown in figure 4.2, *Acacia abyssica* & Scrabby grassland and Bare land and rocky are characteristic of the drier areas of the study area which are on the extreme right and left. Over the study period, we can see an increase in the bare land and rocky class. This is because most of the land that was under *Acacia abyssinica* and Scrabby grassland was turned to bare land and rocky. The imagery was collected intentionally in February of each of the interval years, this is the time the land is fallow and has been prepared to await planting season, hence most of the land was converted to agricultural.

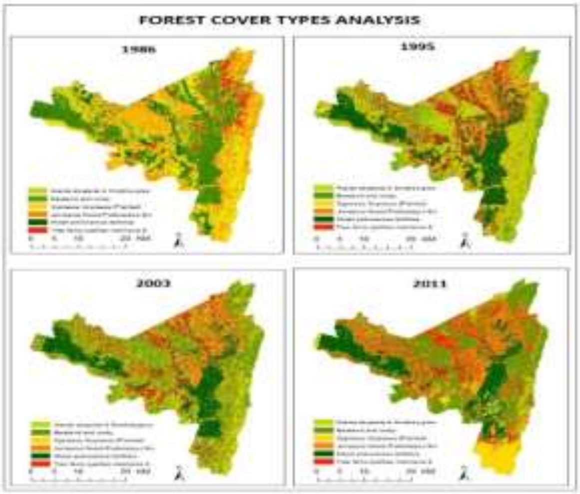

Figure 4.2

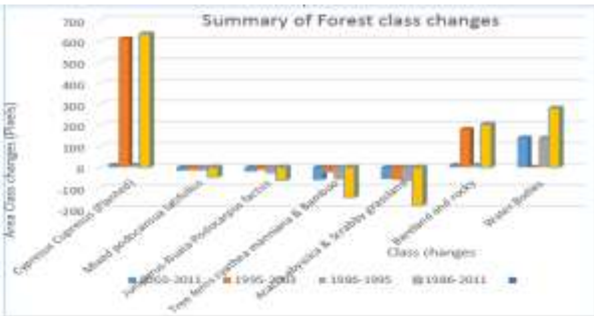

Figure 4.3

For the period 1986 and 1995, the annual deforestation rate was 1.61 percent. During this time 3,220.20 hectares of land that was forested transitioned into other land use types or was simply cleared. In the period 1995 and 2003 annual deforestation rate reduced to 0.88 percent. This means less forested land transitioned into other land cover types, about 1,997.36 hectares. The following time periods experienced decreased rates and for the period 2003 and 2011, the annual rate dropped to 0.97 percent which corresponds to 1,954.75 hectares. The significant changes after 1995 can be attributed to the policy on non-logging passed by the government in 1999. The policy banned logging in government forests (Mathu, 2007), the southern part in the 4.1.2 is a government a government forest.

During the whole study period, 1986 to 2011 a total of 7,172.31 hectares of land that was forested had been converted to other land cover types, this represents a forest loss of 28 percent in the study period. According to the study, an average of 286.89 hectares was lost on average every year between 1986 and 2011, see Table.

Table 4.4

Year	*Total forest Loss(Ha)*	*Annual Forest Loss (Ha)*	*Forest loss Rate (%)*
1986-1995	*3,220.20*	*402.525*	*1.6101*
1995-2003	*1,997.36*	*221.922*	*0.8877*
2003-2011	*1,954.75*	*244.343*	*0.9774*
1986-2011	*7,172.31*	*286.892*	*1.1475*

This represents 1.14% per year of the total forest that existed during the start of the study period. FAO 2014 puts the average forests loss in Kenya at 6.5% for the period 1986 and 2010, According to (Ng'ang'a, 2014), Aberdare lost 28%, Mau Complex and Cherangany forest lost a total of 30% each of forest cover between 1986 and 2011. This study noted a 28% forest loss in the same period; this slightly differs with the studies by (FAO, 2014) by 2%. The results show that deforestation in the area is 4.3 times more the average rates in Kenya. The rates can be attributed to illegal logging (Oeba et al., 2012), clearing land for agricultural use Shackleton et al., (2007) and population increase (Lung & Schaab, 2010). Therefore, most of the cleared land was bare land and rocky means that some areas completely cleared for agriculture. Form the year 1986 to 2011, Elgeyo Marakwet County's population had increased by 35.5 % and hence affirms the assertion by (Ng'ang'a, 2014) on logging. The logging ban of

1999 showed a tremendous reduction in the rates of deforestation (Table 4.1), deforestation still occurred at lower rates with increased population, this explains the trends of increased deforestation with increasing population.

5. FUTURE SCENARIOS

The future scenarios in this study were based on Markov chain analysis model. Population data, settlement and road data from satellite imagery was used as intervening variables in the study. The future time periods considered are 2020, 2050 and 2100. By adding all the forest class types, the future scenario showed that if the current rate of deforestation continues, there will be no natural forest by the year 3038. *Cupressus lusitanica* (Planted) will be the dominant type of forest.

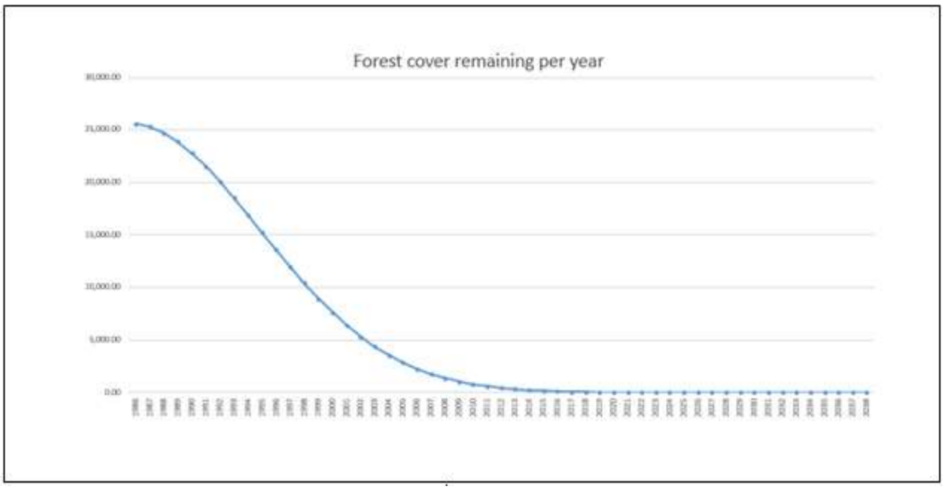

Figure 4.2

6. CONCLUSION

Bare land & rocky and water bodies classes increased in area while Mixed *Podocarpus latifolius*, *Juniperus-Nuxia-Podocarpus factus*, Tree ferns *Cyathea manniana* & Bamboo, *Acacia abyssica* & Scrubby grassland classes decreased in size. As Population grew forestry loss increased (1986 and 2011, the total forest loss was 7,172.31 hectares (28%). The Future Scenario foresees a that with the same trend, there will be no forest remaining in the forest block by the year 2038. The study, therefore, recommends awareness of provisions of Kenya Forests Act 2005- Community (on the assignment of user rights and formation of forest associations). It also recommends enforcement of Kenya Forests Act 2005, which stipulates state penalties and fines for offenders. Furthermore, it suggests exploitation of the provisions of Chapter 6 of the forests Kenya Act 2005 which mandates the Kenya forestry Board members to approve credits for training communities on sustainable forests management.

7. REFERENCES

[1]. De Gryze, S., Durschinger, L., and Lambert, M. (2009). Evaluation of the opportunities for carbon asset development from forest conservation avoided deforestation, and reforestation in the Congo Nile Divide Forest Region of the Republic of Rwanda (pp. 54): Government of Rwanda. Wildlife Conservation.

[2]. Oeba, V. O., Otor, S. C., Kung'u, J. B., and Muchiri, M. N. (2012). Modeling determinants of tree planting and retention on the farm for improvement of forest cover in central Kenya. *ISRN Forestry*, *2012*.

[3]. UNEP, 2001. *An Assessment of the Status of the World's Remaining Closed Forests*', UNEP/DEWA/TR 01-2. Division of Early Warning and Assessment (DEWA), United Nations Environment Programme, P.O. Box 30552, Nairobi, Kenya

[4]. Holmgren, M., Stapp, P., Dickman, C. R., Gracia, C., Graham, S., Gutiérrez, J. R., ... & Lima, M. (2006). Extreme climatic events shape arid and semiarid ecosystems. *Frontiers in Ecology and the Environment*, *4*(2), 87-95.

[5]. UNEP, 2006. Africa Environment Outlook 2, Our Environment, Our Wealth ', United Nations Environment Programme. SMI (Distribution Services) Ltd., Malta.

[6]. Lung, T., and Schaab, G. (2010). A comparative assessment of land cover dynamics of three protected forest areas in tropical eastern Africa. *Environmental monitoring and assessment*, *161*(1), 531-548.

[7]. Matiru, V. (1999). Forest cover and forest reserves in Kenya: Policy and practice. IUCN, Nairobi.

[8]. Boahene, K. (1998). The challenge of deforestation in tropical Africa: reflections on its principal causes, consequences, and solutions. Land Degradation and Development, 9(3), 247-258.

[9]. Mathu, W. (2007). Forest law enforcement and governance in Kenya. A paper prepared for the East African Community-led Regional Process in the Framework of the Ministerial Declaration, Yaoundé, Cameroon, October 16, 2003.

[10]. Mubea, K., and Menz, G. (2014). Spatial Effects of Varying Model Coefficients in Urban Growth Modeling in Nairobi, Kenya. Journal of Geographic Information System, 6(06), 636.

[11]. Ng'ang'a, L. M. (2014). Exploring population density and forest cover linkages: evidence from Kenya (Doctoral dissertation, University of Nairobi).

[12]. Russell G. Congalton, Kass Green, Assessing the Accuracy of Remotely Sensed Data - Principles and Practices Second edition (2009) CRC Press, Taylor & Francis Group, Boca Raton, FL 978-1-4200-5512-2 183 pp

