PERFORMANCE LEVEL OF ACCURACY MEASURING METHODS IN CLASSIFIED REMOTE SENSING IMAGES AS APPLIED TO THE BUILT ENVIRONMENT

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Assessing the accuracy of a classified image is an essential task that gives the user apriori information of the overall reliability of subsequent analysis performed with such classification methods. This research seeks to carry out an assessment of the accuracy measure for evaluating the integrity of the result of image classification using the overall accuracy and the Confusion Matrix. The effect of the size of the defined training site on the accuracy of the resulting classified image has also been examined. LandSAT image of part of South Western Nigeria was used in this study with three different classification methods (Maximum Likelihood, Mahalanobis distance and minimum distance Classifiers). The results obtained shows that the use of the confusion matrix gives a better analysis of the level of reliability of the classification than the use of chance adjusted indices or overall accuracy.

Keywords: Image Classification, Confusion matrix, Accuracy Measure, Spectral Classes, Training Sites

INTRODUCTION

Generally, Image classification involves computer based techniques for separating multiple features within an image into distinct classes each with homogeneous characteristics. It group pixels into different land spectral classes to represent different land cover features. It is primarily aimed at enhancing the ability to discriminate multiple objects from each other within an image, based on earlier assigned similarity levels to features with homogeneous characteristics. Image classification is classified into Supervised Image Classification, Unsupervised Image Classification and Object-based image analysis.

Image classification is used by professionals within the built environment as a fundamental operation prior to such applications which range from Urban Sprawl investigation, Modeling land use dynamics, investigating crop health/yield in largely forested areas (Francesco et al, 2014, Jones et al, 2008), change detection e.t.c

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Considering therefore the enormous areas of application to which image classification serves as basis (Campbell, 2002) and the many classification techniques available for such operations (Liu et al 2002, Ozesmi & Bauer 2002, Dean & Smith 2003, Pal & Mather 2003,); the need for assessment of the accuracy of the entire classification process cannot be over emphasized Lu & Weng (2007) Jipsa & Karunakaran (2012) and Pooja et al, (2013) gave a survey of existing image classification approaches and techniques while Nur et al (2015) compared image classification techniques using CalTech 101 Dataset.

Conventionally, Pixel based image classification accuracy assessment is done using either ***chance adjusted indices*** (such as the kappa co-efficient, tau co-efficient e.t.c), the ***overall accuracy*** measure or the ***confusion matrix*** (user and producer accuracies). In recent times however, despite its universal patronage, the use of chance-adjusted indices as accuracy measure in image classification has been greatly criticized as the degree of chance agreement may be over-estimated (Shiguo and Desheng 2011).

The overall accuracy on the other hand also suffers defect in the event when multiple classes are being classified as the accuracy in classification of various classes differ one from another. This has therefore raised much research interest in the need for more reliable indicators of accuracy estimate of which the confusion matrix appears to be a preferred option. Another research concern in recent times is determining the effect of choice of classifier technique (Akgun et al, 2004) and size of defined training site on the result of image classification.

In this paper, three different image classification techniques (Maximum likelihood, Mahalanobis distance and Minimum distance) were used to classify a Landsat Image covering part of South West Nigeria. The level of accuracy of the classification results was then assessed using three methods (Kappa co-efficient, the overall accuracy, the confusion matrix). Also, an attempt has been made to investigate the effect of the size of defined training sites on the resultant accuracy of the image classification

BACKGROUND OF THE STUDY

A brief and concise description of the underlying mathematical algorithms or models behind the image classification techniques and accuracy assessments used in this research are herein presented. Though not mathematically exhaustive, the basic formulae are stated and further references given:

MAXIMUM LIKELIHOOD CLASSIFIER

The maximum likelihood classifier is a supervised classifier that assumes that the distribution of data within a given class "*i*" obeys a multivariate Gaussian distribution. Derived from the Bayes theorem which states that the a posteriori distribution ($P(i\mathrm{I}\omega)$) i.e the probability that a pixel with feature vector ω belongs to class *i* is given by (Asmala and Shaun 2012) in (1) :

$$P(i\mathrm{I}\omega) = \frac{P(\omega\mathrm{I}i)\,P(i)}{P(\omega)} \qquad (1)$$

MAHALANOBIS DISTANCE CLASSIFIER

The Mahalanobis distance classifier is best used in cases where there is no correlation between the axes in feature space. The mahalanobis distance with variance-covariance matrix is given as (2):

$$d_k{}^2 = (X - \mu_k)^t . \Sigma_k^{-1}(X - \mu_k) \quad (2)$$

$where:$
$X = Vector\ of\ image\ data\ (n\ bands)$ $\quad X = [x_1, x_2, \ldots \ldots, x_n]$
$\mu_k = mean\ of\ kth\ class$ $\quad \mu = [\mu_1, \mu_2, \ldots \ldots, \mu_n]$
$\sum_k = Variance - covariance\ matrix$

$$\Sigma_k = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ \vdots & & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{bmatrix}$$

MINIMUM DISTANCE CLASSIFIER

Generally, minimum distance classifiers are used to classify unknown image data to classes which minimize the distance between the image data and the class in the multi feature space. The mahalanobis distance classifier is a variant form of the minimum distance.

$$d_k{}^2 = (X - \mu_k)^t . (X - \mu_k) \quad (3)$$

ACCURACY ASSESSMENT ALGORITHMS

The accuracy of a classification is usually assessed by comparing the classification with some reference data that is believed to accurately reflect the true land-cover. Sources of reference data include among other things ground truth, higher resolution satellite images, and maps derived from aerial photo interpretation (http//:www.yale.edu).

Once an error matrix is generated, the elements of the matrix could be used for computation of accuracy assessment parameters as given by (Asmala and Shaun 2012) in (4), (5) and (6)

$$\text{Kappa Co-efficient (k)} = \frac{\sum_{a=1}^{U} \frac{C_{aa}}{Q} - \sum_{a=1}^{U} \frac{C_{*i} C_{*a}}{Q^2}}{1 - \sum_{a=1}^{U} \frac{C_{a*} C_{*a}}{Q^2}} \quad (4)$$

Where: $C_{aa} = element\ at\ position\ ath\ row\ and\ ath\ column$
$C_{*a} = Column\ Sum$
$C_{i*} = Row\ Sum$

$$\text{Overall Accuracy} = \frac{\sum_{a=1}^{U} C_{aa}}{Q} \quad (5)$$

$$\text{User Accuracy} = \frac{C_{ii}}{C_{i*}} * 100\%$$

$$\text{Producer Accuracy} = \frac{C_{aa}}{C_{*a}} * 100\% \quad (6)$$

STUDY AREA

The study area is part of south western Nigeria comprising of Lagos State, Ogun State and Part of Oyo State. The area studied covers an area of about 34,000 Sq.Km extending across various natural and artificial features such as to allow for analysis of the behavior of different classifiers for different earth surface feature class.

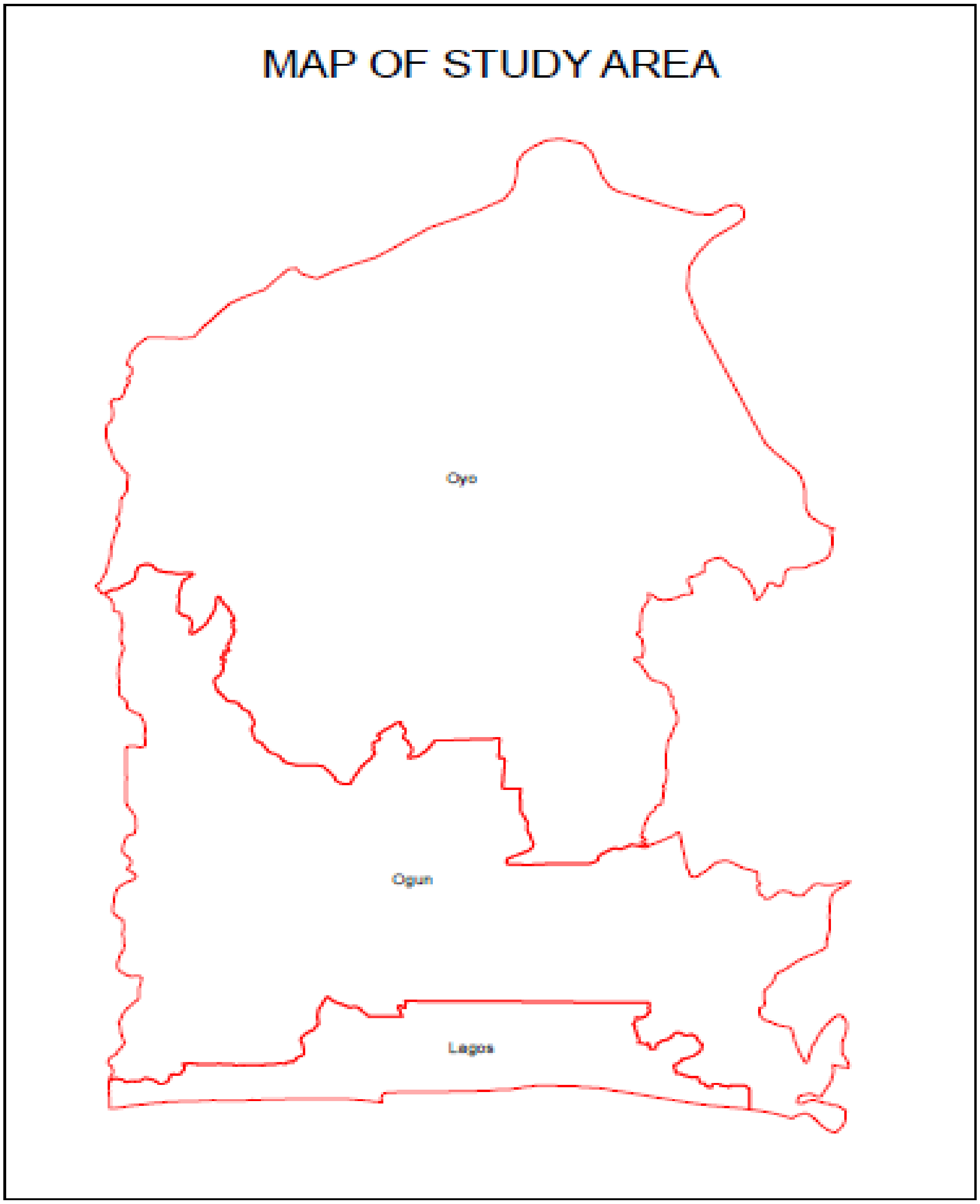


Fig 1: Study Area.

RESEARCH METHOD

Landsat image of the study area was obtained and classified using three different image classification techniques (maximum likelihood classifier, mahalanobis distance classifier and the minimum distance classifier).

After the acquisition of the Landsat imageries and prior to the image classification, a true colour composite was first generated from the image bands 1, 2 and 3 to aid easy identification of the feature classes. This true colour composite map was then used in defining the training sites that was used for the image classification.

Five feature classes were identified and created namely:

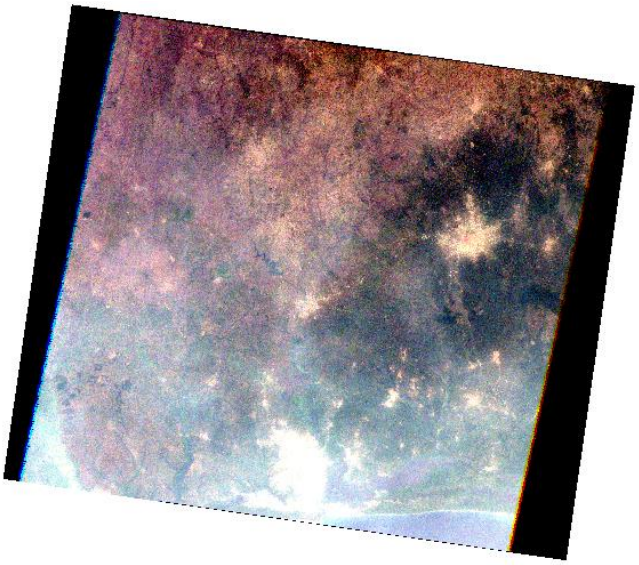
(1) Vegetation (2) Water Body (3) Bare Ground (4) Built Up and (5) Mangroove.

In order to assess the effect of the size of training site, two classifications were done with each of the earlier stated classifiers herein grouped as classification 1 and classification 2.
The training site region specified for classification 1 being smaller than that specified for classification 2.
After the image classifications have been done, the ground truth regions were then identified on the true composite and saved as a separate region of interest ensuring that the ground truth sites were completely independent of the training site used for either classification 1 or 2 respectively.
The results obtained from the classifications were then compared with ground truth region of interest in a post classification process via the generation of a confusion matrix (error matrix) from where all the accuracy measure used in this research was extracted.
The ENVI 4.7 Image processing software was used for the image classification and analysis and the results obtained are as presented in section 6.0 and further discussed in section 7.0
A sequence of the steps followed are as listed:

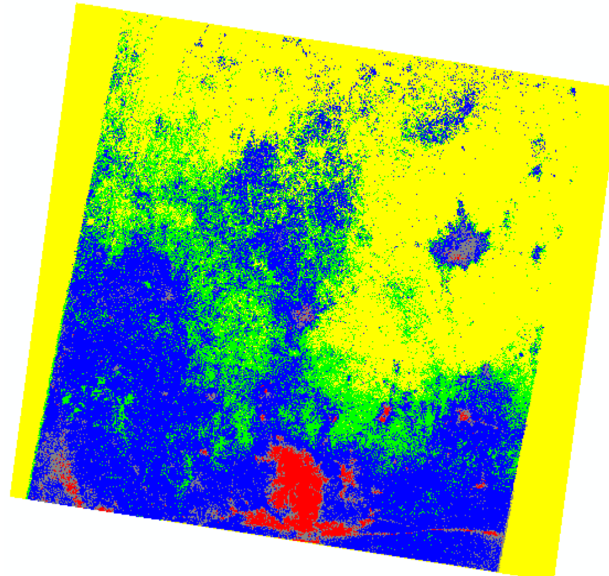
(a) Acquire LandSat Image bands 1, 2 and 3
(b) With the image bands, develop a True Colour composite
(c) Define training sites for each feature class
(d) Perform image classification using the three (3) different image classifiers
(e) Perform a post classification analysis and generate the confusion matrix.

RESULTS

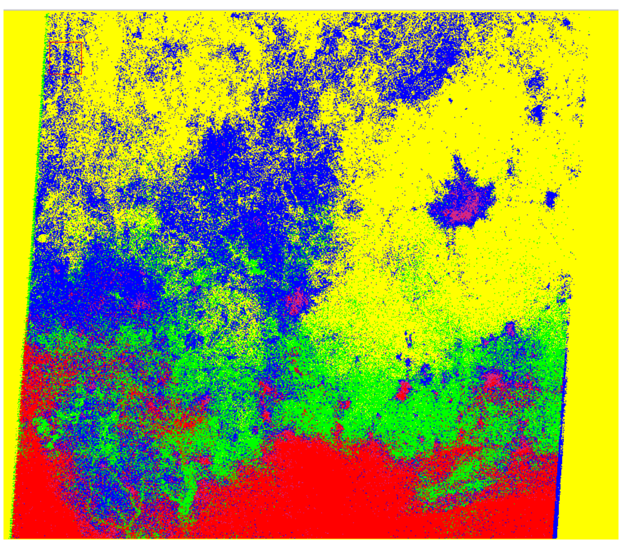
Shown in Figure 2(a – d) is the true composite map of the study area and the results obtained from the three different classification approaches using a small – sized training site hereafter called **classification 1**. Figure 3(a – d) however presents same results but with a larger sized training site hereafter called **classification 2**.
Tables 1(a and b) presents a summarized analysis of the accuracy level of the three (3) classifiers using the two specified training site sizes (Classification 1 and 2). The full confusion matrixes for each of the classifier technique used in the two (2) classifications are presented in the appendix.



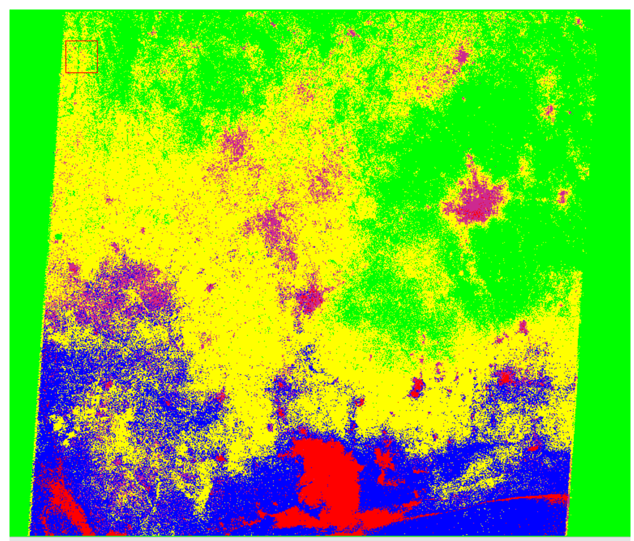
(a) True Composite



(c) Image Classified by Maximum Likelihood



(b) Image Classified by Mahalanobis

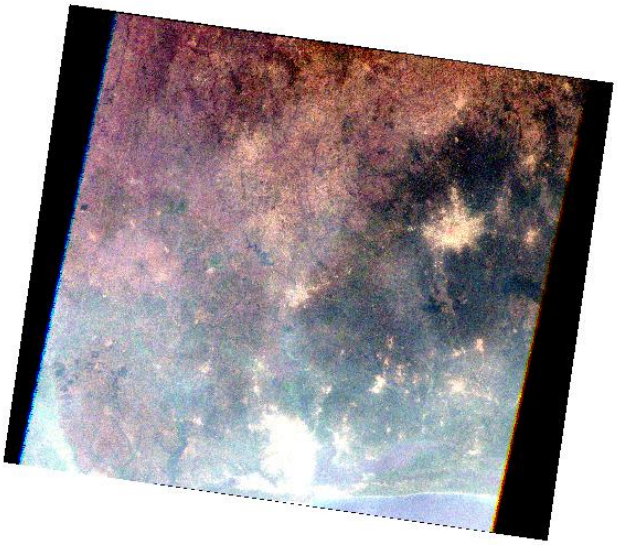


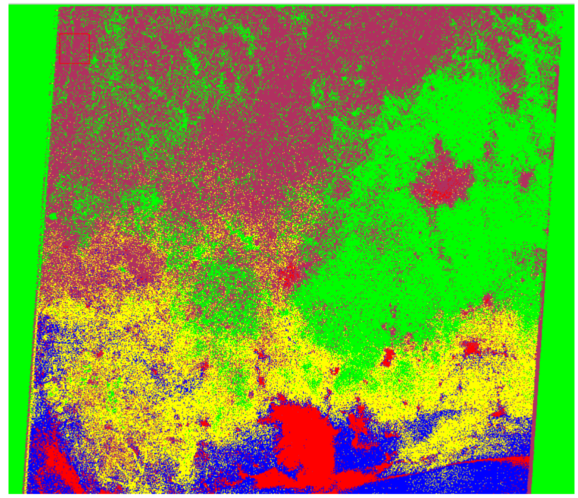
(d) Image Classified by Minimum Distance

Fig. 2(a – d): Result of image classification done with small-sized training site region (**CLASSIFICATION 1**)

Legend

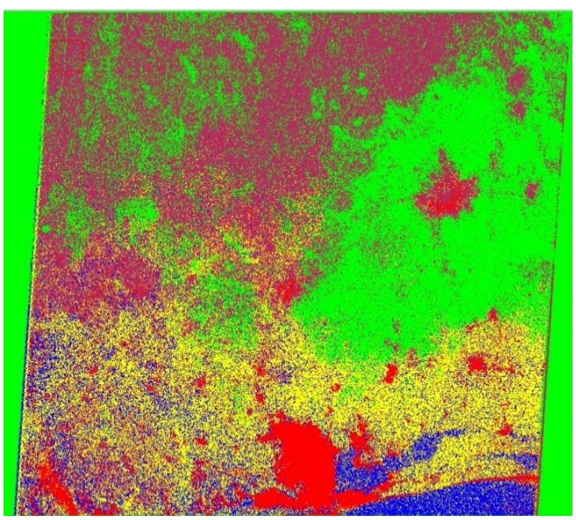
- Vegetation
- Water Body
- Built Up
- Mangroove
- Bare Ground

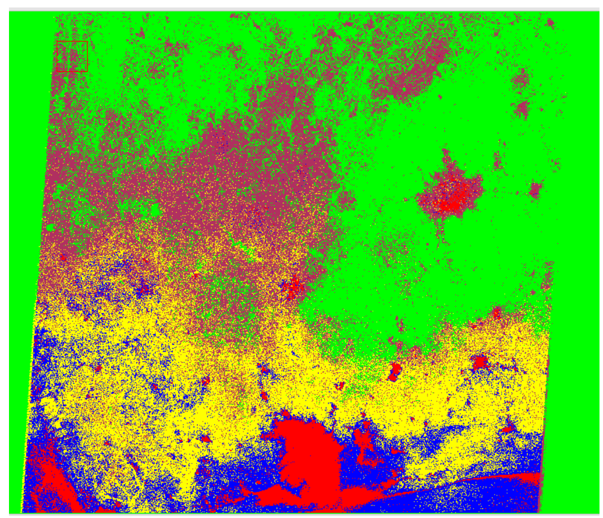




(a) True Composite

(c) Image Classified by Maximum Likelihood





(b) Image Classified by Mahalanobis

(d) Image Classified by Minimum Distance

Fig. 3(a – d): Result of image classification done with Larger-sized training site region (**CLASSIFICATION 2**)

Legend

- Vegetation
- Water Body
- Built Up
- Mangroove
- Bare Ground

Table 1(a): Summary of accuracy Level obtained From the Three (3) Classifiers when a small Training Site region was used (**CLASSIFICATION 1**) showing the Kappa co-efficient, Overall Accuracy and User accuracy (Per class).

	Minimal Training Site Specified (**CLASSIFICATION 1**)						
CLASSIFICATION TYPE / Accuracy Parameters	**Kappa Co-efficent**	**Overall Accuracy**	**Vegetation**	**Bare Ground**	**Mangroove**	**Built Up**	**Water**
Maximum Likelihood	0.57%	69.97%	1.03%	14.38%	2.18%	92.51%	92.30%
Mahalanobis	0.17%	45.15%	15.74%	21.36%	2.72%	58.54%	41.72%
Minimum Distance	0.81%	87.29%	97.57%	61.59%	26.89%	87.21%	99.06%

Table 1(b): Summary of accuracy Level obtained From the Three (3) Classifiers when a large Training Site region was used (**CLASSIFICATION 2**)) showing the Kappa co-efficient, Overall Accuracy and User accuracy (Per class).

	Increased Training Site Specified (**CLASSIFICATION 2**)						
CLASSIFICATION TYPE / Accuracy Parameters	**Kappa Co-efficent**	**Overall Accuracy**	**Vegetation**	**Bare Ground**	**Mangroove**	**Built Up**	**Water**
Maximum Likelihood	0.81%	87.34%	95.73%	51.05%	25.29%	88.20%	99.60%
Mahalanobis	0.79%	85.98%	97.58%	58.88%	21.12%	87.85%	98.07%
Minimum Distance	0.88%	91.86%	98.08%	75.42%	63.81%	88.50%	98.65%

DISCUSSION OF RESULTS

Visual examination of Figures 1(b – d) in comparison to Figure 1(a) reveals that the minimum distance classifier gave the closest result to the true ground situation when a small size training site is used for the classification. The next in accuracy being the maximum likelihood while the mahalanobis distance classifier gave the least visually appealing output. Similarly, visual examination of the results of classification 2 also follow similar trend.

These visually ascertainable results are further supported by the values obtained from the accuracy assessment results excerpts presented in tables 1 (a and b).

However, Tables 1 (a and b) justified the advantage of the use of the error matrix derived User accuracies over the conventional Kappa co-efficient and overall accuracy as the user is able to ascertain to a reasonable extent the confidence interval of the accuracy of a particular feature over other classes before using the image for further analysis.

For instance, in classification 1 and 2, although the overall accuracy and kappa co-efficient of maximum likelihood is more than that of mahalanobis distance classifier, the accuracy of the latter in classifying vegetation and bare ground exceeds that of the former. Therefore though the overall accuracy is lower, a user of such a classified image who is interested in vegetation or bare ground class would prefer to use the mahalanobis classifier rather than the maximum likelihood.

As it is seen from the user accuracy assessment that the accuracy of mahalanobis in classifying Vegetation and Bare Ground feature classes is consistently higher than that of the maximum likelihood in both classifications, it may be possible to further infer that the Mahalanobis distance is a better classifier for these classes than the Maximum likelihood. Further research is however recommended to validate this finding.

Finally, the summarized results presented above also shows that the accuracy of any classification technique is improved by large sized training sites therefore the "Larger the size of the training site, the better the classification Results"

CONCLUSIONS

From the discoveries made in this research, it can be affirmed that using kappa-coefficient and its overall accuracy alone as a means of evaluating accuracy measure of remote sensing image classification may not be absolutely reliable. Also, it has been identified that the larger the size of the training site, the better the resulting classified image obtained and that the mahalanobis classifier is better suited for vegetation and bare ground classes than the maximum likelihood classifier.
It is therefore recommended that image classification result assessment should be based on the use of confusion matrix results (Producer and User accuracy) rather than solely depending on the overall accuracy or the kappa co-efficient.

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APPENDIX (ERROR MATRIX)
(CLASSIFICATION 1)

(a) MAXIMUM LIKELIHOOD CLASSIFIER:

Overall Accuracy = (83870/119973) 69.9074%
Kappa Coefficient = 0.5670

Ground Truth (Percent) (**Confusion Matrix**)

	Ground Truth (Percent)				
Class	Vegetation	Mangroove	Built Up	Water	Bare Ground
Unclassified	0.00	0.00	0.00	0.00	0.00
Vegetation [G]	0.09	40.94	0.00	1.21	0.57
Mangroove [Ye]	99.91	14.13	0.00	0.00	0.00
Built Up [Red]	0.00	0.00	96.56	10.40	0.42
Water [Blue]	0.00	44.93	0.06	79.78	53.57
Bare Ground [Ma]	0.00	0.00	3.38	8.61	45.44
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Vegetation [G]	98.97	99.91	1924/1944	22231/22251
Mangroove [Ye]	97.82	85.87	22231/22726	3008/3503
Built Up [Red]	7.49	3.44	4123/55042	1816/52735
Water [Blue]	7.70	20.22	2634/34198	8001/39565
Bare Ground [Ma]	85.62	54.56	5191/6063	1047/1919

ACCURACY ASSESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Vegetation [G]	0.09	1.03	20/22251	20/1944
Mangroove [Ye]	14.13	2.18	495/3503	495/22726
Built Up [Red]	96.56	92.51	50919/52735	50919/55042
Water [Blue]	79.78	92.30	31564/39565	31564/34198
Bare Ground [Ma]	45.44	14.38	872/1919	872/6063

(b) MAHALANOBIS CLASSIFIER:

Overall Accuracy = (54163/119973) 45.1460%
Kappa Coefficient = 0.1681

Ground Truth (Percent) (**Confusion Matrix**)

Class	Water	Bare Ground	Mangroove	Built Up	Vegetation
Unclassified	0.00	0.00	0.00	0.00	0.00
Water [Blue]	3.71	69.15	20.44	0.01	0.00
Bare Ground [Ma]	0.30	30.12	0.03	3.81	0.00
Mangroove [Ye]	0.00	0.10	17.16	0.00	96.42
Built Up [Red]	90.35	0.47	4.60	96.18	0.00
Vegetation [G]	5.63	0.16	57.78	0.00	3.57
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Water [Blue]	58.28	96.29	2051/3519	38097/39565
Bare Ground [Ma]	78.64	69.88	2128/2706	1341/1919
Mangroove [Ye	97.28	82.84	21457/22058	2902/3503
Built Up [Red	41.46	3.82	35918/86639	2014/52735
Vegetation [G	84.26	96.43	4256/5051	21456/22251

ACCURACY ASSESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Water [Blue]	3.71	41.72	1468/39565	1468/3519
Bare Ground [Ma]	30.12	21.36	578/1919	578/2706
Mangroove [Ye]	17.16	2.72	601/3503	601/22058
Built Up [Red]	96.18	58.54	50721/52735	50721/86639
Vegetation [G]	3.57	15.74	795/22251	795/5051

(c) MINIMUM DISTANCE CLASSSIFIER

Overall Accuracy = (104726/119973) 87.2913%
Kappa Coefficient = 0.8097

Ground Truth (Percent) (**Confusion Matrix**)

Class	Vegetation	Water	Bare Ground	Mangroove	Built Up
Unclassified	0.00	0.00	0.00	0.00	0.00
Vegetation [G]	99.98	0.00	0.00	15.82	0.00
Water [Blue]	0.00	66.82	6.93	1.60	0.12
Bare Ground [Ma]	0.02	0.08	60.66	19.70	0.00
Mangroove [Ye]	0.00	15.09	0.94	62.89	0.00
Built Up [Red]	0.00	18.01	31.47	0.00	99.88
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Vegetation [G]	2.43	0.02	554/22801	4/22251
Water [Blue]	0.94	33.18	250/26689	13126/39565
Bare Ground [Ma]	38.41	39.34	726/1890	755/1919
Mangroove [Ye]	73.11	37.11	5989/8192	300/3503
Built Up [Red]	12.79	0.12	7728/60401	62/52735

ACCURACY ACCESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Vegetation [G]	99.98	97.57	22247/22251	22247/22801
Water [Blue]	66.82	99.06	26439/39565	26439/26689
Bare Ground [Ma]	60.66	61.59	1164/1919	1164/1890
Mangroove [Ye]	62.89	26.89	2203/3503	2203/8192
Built Up [Red]	99.88	87.21	52673/52735	52673/60401

(CLASSIFICATION 2)

(a) MAXIMUM LIKELIHOOD CLASSIFIER:

Overall Accuracy = (104786/119973) 87.3413%
Kappa Coefficient = 0.8113

Ground Truth (Percent) (**Confusion Matrix**)

Class	Built Up	Vegetation	Bare Ground	Mangroove	Water
Unclassified	0.00	0.00	0.00	0.00	0.00
Built Up [Red]	99.17	0.00	7.71	0.00	17.31

Vegetation [G]	0.00	99.23	0.16	28.06	0.00
Bare Ground [Ma]	0.75	0.77	91.56	17.98	1.24
Mangroove [Ye]	0.00	0.00	0.36	52.30	13.66
Water [Blue]	0.09	0.00	0.21	1.66	67.79
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Built Up [Red]	11.80	0.83	6996/59291	440/52735
Vegetation [G]	4.27	0.77	986/23066	171/22251
Bare Ground [Ma]	48.95	8.44	1685/3442	162/1919
Mangroove [Ye]	74.71	47.70	5413/7245	1671/3503
Water [Blue]	0.40	32.21	107/26929	12743/39565

ACCURACY ACCESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Built Up [Red]	99.17	88.20	52295/52735	52295/59291
Vegetation [G]	99.23	95.73	22080/22251	22080/23066
Bare Ground [Ma]	91.56	51.05	1757/1919	1757/3442
Mangroove [Ye]	52.30	25.29	1832/3503	1832/7245
Water [Blue]	67.79	99.60	26822/39565	26822/26929

(b) MAHALANOBIS CLASSIFIER:

Overall Accuracy = (103158/119973) 85.9843%
Kappa Coefficient = 0.7919

Ground Truth (Percent) (**Confusion Matrix**)

Class	Vegetation	Water	Bare Ground	Mangroove	Built Up
Unclassified	0.00	0.00	0.00	0.00	0.00
Vegetation [G]	99.05	0.00	0.05	15.56	0.00
Water [Blue]	0.06	63.08	0.05	12.30	0.09
Bare Ground [Ma]	0.86	0.64	89.68	15.90	0.38
Mangroove [Ye]	0.03	18.43	0.73	55.95	0.02
Built Up [Red	0.00	17.86	9.48	0.29	99.51
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Vegetation [G]	2.42	0.95	546/22586	211/22251
Water [Blue]	1.93	36.92	491/25449	14607/39565
Bare Ground [Ma]	41.12	10.32	1202/2923	198/1919
Mangroove [Ye]	78.88	44.05	7319/9279	1543/3503
Built Up [Red]	12.15	0.49	7257/59736	256/52735

ACCURACY ACCESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Vegetation [G]	99.05	97.58	22040/22251	22040/22586
Water [Blue]	63.08	98.07	24958/39565	24958/25449
Bare Ground [Ma]	89.68	58.88	1721/1919	1721/2923
Mangroove [Ye]	55.95	21.12	1960/3503	1960/9279
Built Up [Red]	99.51	87.85	52479/52735	52479/59736

(c) MINIMUM DISTANCE CLASSSIFIER

Overall Accuracy = (110210/119973) 91.8623%
Kappa Coefficient = 0.8767

Ground Truth (Percent) (**Confusion Matrix**)

Class	Vegetation	Bare Ground	Mangroove	Built Up	Water
Unclassified	0.00	0.00	0.00	0.00	0.00
Vegetation [G]	98.99	0.00	12.30	0.00	0.00
Bare Ground [Ma]	0.00	94.16	1.86	0.74	0.34
Mangroove [Ye]	1.01	1.62	76.62	0.00	3.20
Built Up [Red]	0.00	3.34	0.00	99.09	17.00
Water [Blue]	0.00	0.89	9.22	0.17	79.45
Total	100.00	100.00	100.00	100.00	100.00

PERCENTAGE ERROR

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Vegetation [G]	1.92	1.01	431/22458	224/22251
Bare Ground [Ma]	24.58	5.84	589/2396	112/1919
Mangroove [Ye]	36.19	23.38	1522/4206	819/3503
Built Up [Red]	11.50	0.91	6790/59046	479/52735
Water [Blue]	1.35	20.55	431/31867	8129/39565

ACCURACY ASSESSMENT

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Vegetation [G]	98.99	98.08	22027/22251	22027/22458
Bare Ground [Ma]	94.16	75.42	1807/1919	1807/2396
Mangroove [Ye]	76.62	63.81	2684/3503	2684/4206
Built Up [Red]	99.09	88.50	52256/52735	52256/59046
Water [Blue]	79.45	98.65	31436/39565	31436/31867