TECHNICAL REPORT: VALIDATION OF MANGROVE COVER MAPS FOR KENYA, TANZANIA, MOZAMBIQUE AND MADAGASCAR

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ABSTRACT: It is vital to monitor and identify mangroves types and spatial extent along the coastlines, due to their importance in coastal ecosystem and environmental protection (Muhammad and Waqar 2013). Although mangroves ecosystems provide a range of services, they are endangered globally, and hence there is a need of large-scale monitoring (Cho-Ricketts and Cherrington 2011). It was important after classification to verify that the land-cover classes in the produced land-cover map really correspond to classes on the surface of the earth. The most prefered approach was to conduct ground referencing where each pixel in the land-cover map was verified. This study found variying overall class accuracies from one country to another. Madagascar and Mozambique had the highest overall class accuracies, which meets and exceeds commonly used standards, indicating mangroves in Mozambique and Madagascar were mapped with a high level of accuracy (86% and 84% overall class accuracy). On the otherhand, the cloud variation on the images significantly reduced the classification accuracy mainly for Kenya and Tanzania (69% and 77% respectively overall class accuracy).The KHAT statistics for Kenya, Tanzania, Mozambique and Madagascar were 0.34, 0.54, 0.64, and 0.7 respectively. This indicates that the accuracy of validation data for Kenya, Tanzania, Mozambique and Madagascar mangrove cover maps were approximately 34%, 54%, 64% and 70% respectively better than what would have been achieved by pure chance. Medium resolution Landsat may underestimate mangroves in areas where relatively small and narrower coastal features exist (Kirui et al. 2011).

Key words: *Mangrove, Kenya, Tanzania, Mozambique, Madagascar,Landsat, Accuracy, KHAT statistic*

INTRODUCTION

SERVIR-Eastern and Southern Africa was tasked to map and quantify sea-grasses and mangrove cover in Kenya, Madagascar, Mozambique and Tanzania using medium resolution imagery (LANDSAT) and high resolution imagery (Worldview/FORMSAT). The products of this project were mearnt to contribute to the development of coastal and marine ecosystems geospatial products and database, which would ultimately be transferred to key Governmental and Community-Based Organizations involved in the management of coastal and marine resources. It was important after classification to verify that the land-cover classes in the produced land-cover map really correspond to classes on the surface of the earth. The most prefered approach was to conduct ground

referencing where each pixel in the land-cover map was verified. From March - June 2015, field surveys to validate the mangrove cover estimates were conducted along Kenya, Tanzania, Mozambique and Madagascar coastlines resulting in the collection of data from some **258** individual random sites (Kenya - 98 points, Tanzania - 24 points, Mozambique - 42 points, Madagascar - 94 ponts). The objective of the field work was to 'ground truth' mangrove cover maps for Kenya, Tanzania, Mozambique and Madagascar.

METHOLOGY

Verification is a key phase in terms of the generation of data and information products from remotely sensed data. Accuracy assessment allows one to both determine whether the data achieves a predetermined minimum acceptable level of accuracy and to determine the uncertainty in the data produced. At each location, based on the Landsat 7 & 8 mangrove cover derived maps, randomly selected mangrove sites were surveyed and randomly generated non-mangrove sites were surveyed. Due to the scale of the imagery used in creating the cover map (30m x 30m pixels), the surveys had to incorporate sufficient distance between data points at each site.This was in accordance with the methodology proposed by ICFI (2009). There was no local maps with known accurancy or sufficient field data availlable to assess relative accuracy. Hence, we based our estimation of classification accuracy on independent and systematic method for selecting validation points. We used random points separated by 200 metres within the random sampling blocks. Due to time and logistical limitations, we assessed the areas we did not collect validation points from by visual interpretation of high-resolution images (Digital Globe) in Google Earth software. We only used the areas identified as mangroves on the landcover map or in Google Earth. In total, some 258 surveys were conducted across the sampling blocks visited. Surveys were conducted at the randomly selected mangrove sites, using the hand-held GPS device (Kauffman and Donato 2012; Kirui et al. 2011).

Figure 1: Field Work at Gazi with the help of KEMFRI (Kenya Marine and Fisheries Research Institute) staff- Kenyan Coast

Calculation of Classification Accuracy

Error in the geometric correction applied to the image and in GPS positioning may have resulted in some correctly classified mangrove pixels being mapped to locations which are actually non mangrove *in situ* (this would be particularly prevalent along the boundaries between the two habitats i.e mangrove and non-mangrove classes). A method was needed which quantifies these classification errors by estimating how many mangrove pixels are in reality non mangrove, how many non mangrove pixels are mangrove; hence the reliability, or accuracy of the classification. There are several complementary methods of conducting this assessment including error matrices, user and producer accurancies.

RESULTS

Kenya

The ground truthing exercise in Kenya was conducted in some areas including:Vanga, Gazi,Tana, Makongeni, Mombasa (Mkupe), Kilifi, Mtwapa, Takaungu and Mwazaro. The field data points (34 sites) which fell within clouds and shadows were excluded in the creation of the error matrix. The ground truth-based validation determined an overall class accuracy of 69% for the Landsat 7 ETM+ satelite data.

Table 1: Presents the overall error matrix - Kenya

	User Validation Dataset (Landsat 8 Ground Surveys)				
Producer Classification	**Classes**	**Mangrove**	**Non Mangrove**	**Total**	**User Accuracy**
Dataset (Landsat 7 mangrove	Mangrove	**34**	20	54	63%
	Non	0	**10**	10	100%

cover map)	Mangrove				
	Total	34	30	**64**	-
	Producer Accuracy	100%	33%	-	**Overall Accuracy 69%**

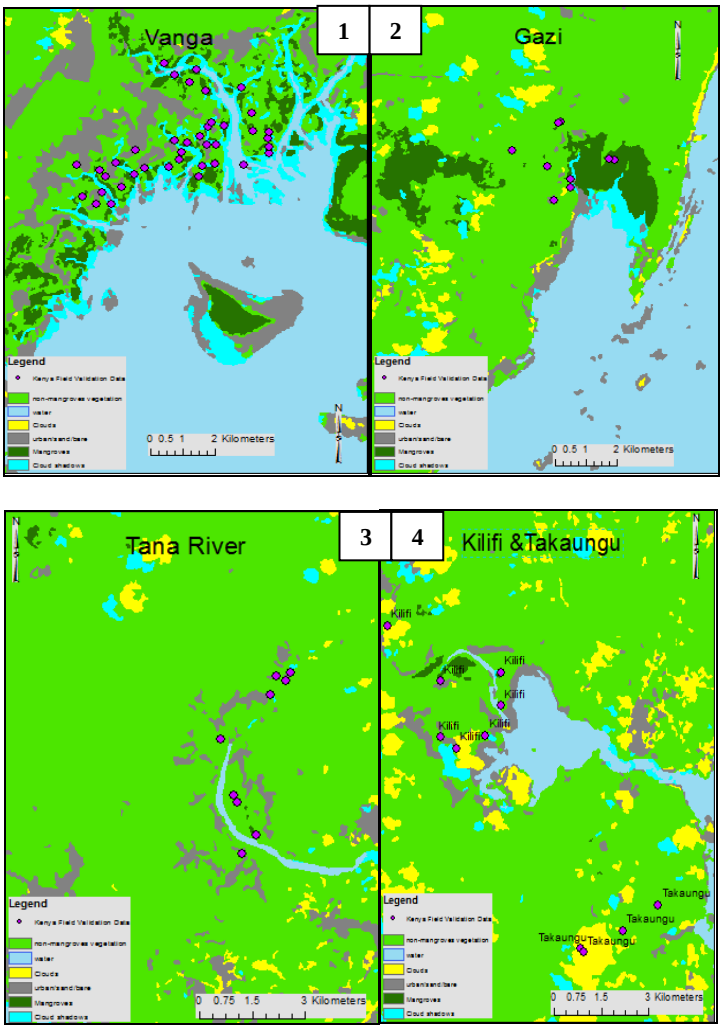

Figure 2: Location of mangrove surveying blocks (1)Vanga, (2) Gazi, (3)Tana River, (4) Kilifi - Takaungu- Kenya

Tanzania

The ground truthing exercise in Tanzania was conducted in some areas including: Kunduchi, Bagamayo, Kaole, Kikale, Mlingotini, Kiganboni, and Kijichi . The ground truth-based validation determined an overall class accuracy of 77% for the Landsat 8 OLI satelite data.

Figure 3: Field Assitant fron TAFIRI collecting data in Rufuji and Dar Es Salaam respectively

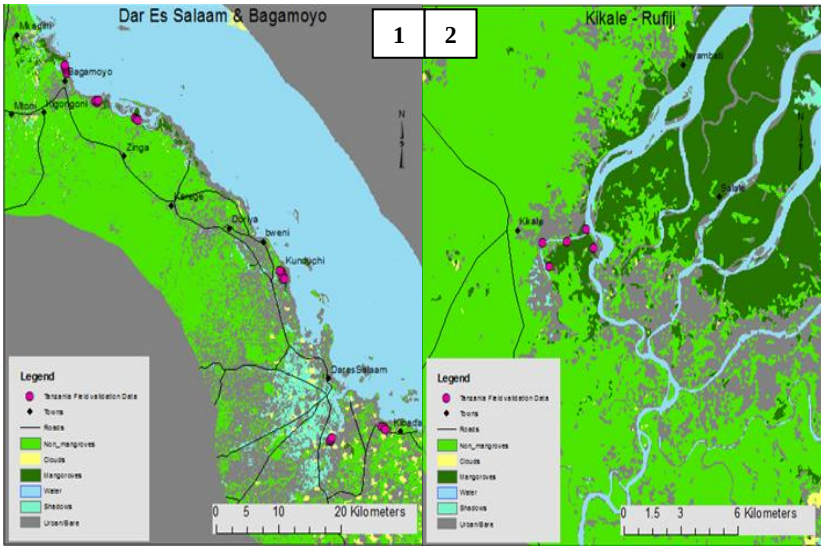

Figure 4: Location of mangrove surveying blocks (Dar Es Saalam 1, Kisiju - 2) - Tanzania

Table 2: Presents the overall error matrix - Tanzania

		User Validation Dataset (Landsat 7 Ground Surveys)			
Producer Classification Dataset (Landsat 8 mangrove cover map)	**Classes**	**Mangrove**	**Non Mangrove**	**Total**	**User Accuracy**
	Mangrove	**16**	**8**	**24**	**67%**
	Non Mangrove	**0**	**10**	**10**	**100%**
	Total	**16**	**18**	**34**	**-**
	Producer Accuracy	**100%**	**55%**	**-**	**Overall Accuracy 77%**

Mozambique

The ground truthing exercise in Mozambique was conducted in some areas including: Inhambane, Morrumbene, Lindela, Limpopo, Maputo and Macaneta. The ground truth-based validation determined an overall class accuracy of 84% for the Landsat 8 OLI satelite data.

Figure 5: Field work at Macaneta in Mozambique with assistance from University of Eduardo Mondlande staff

Table 3: Presents the overall error matrix - Mozambique

	User Validation Dataset (Landsat 8 Ground Surveys)				
Producer Classification Dataset (Landsat 7 mangrove cover map)	**Classes**	**Mangrove**	**Non Mangrove**	**Total**	**User Accuracy**
	Mangrove	**10**	1	11	91%
	Non Mangrove	2	**5**	7	71%
	Total	12	6	**18**	-
	Producer Accuracy	83%	83%	-	**Overall Accuracy 84%**

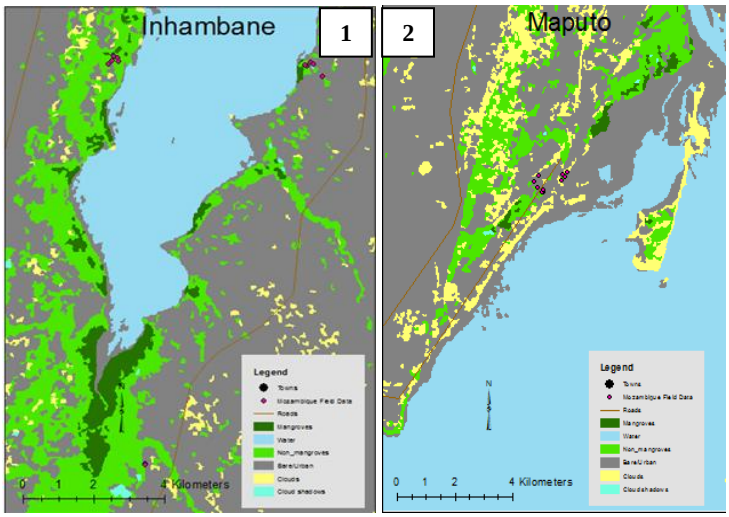

Figure 6: Location of mangrove surveying blocks (1)Inhambane, (2)Maputo- Mozambique

Madagascar

The ground truthing exercise in Madagascar was conducted mainly in Ambaro bay some of the specific sites included: Atenina, Ampapamena, Famaly, Ambilobe, Ambaja, and Akivanja. The ground truth-based validation determined an overall accuracy of 86% for the Landsat 8 OLI satelite data.

Figure 7: Field work in Madagascar

Table 4: Presents the overall error matrix - Madagascar

		User Validation Dataset (Landsat 8 Ground Surveys)			
Producer Classification Dataset (Landsat 7 mangrove cover map)	**Classes**	**Mangrove**	**Non Mangrove**	**Total**	**User Accuracy**
	Mangrove	**49**	4	53	92.0%
	Non Mangrove	9	**32**	41	78.0%
	Total	58	36	**94**	
	Producer Accuracy	84.%	88%	-	**Overall Accuracy 86.2%**

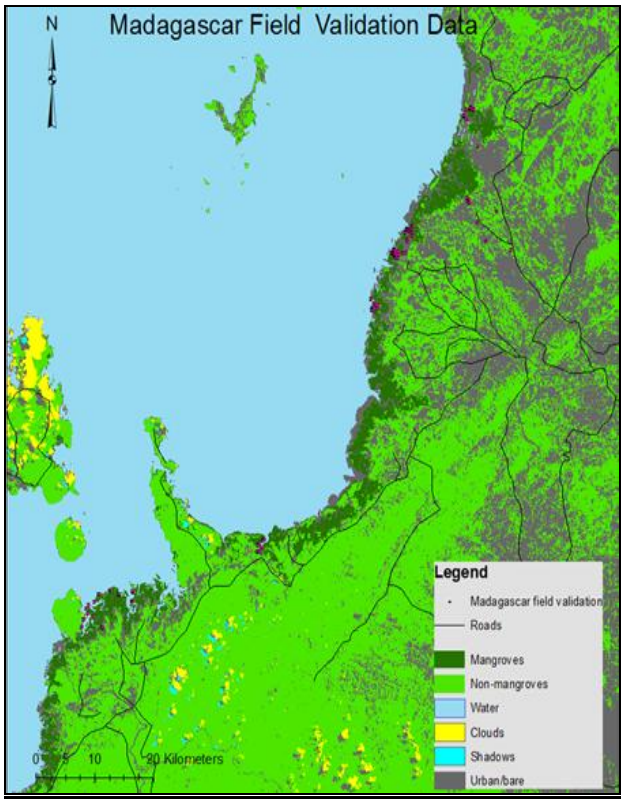

Figure 8: Location of mangrove surveying blocks (Ambaro Bay)-Madagascar

KHAT/ The Cohen's Kappa For Reliability

Random assignment is known to result in an averagely good classification result, and hence validation of remotely sensed data should include estimates of k (also known as

KHAT or the Cohen's Kappa statistic) , this serves as an indicator of the extent to which the proportional correct values of an error matrix are due to "true agreement" versus "chance agreement". To measure the observed agreement in the confusion matrix intuitively despite the fact that there is always the problem of random agreement, there is a need to calculate KHAT statistic. KHAT statistic/Cohen's aims at taking away agreement by chance or random agreement out of the equation.

$$k^{\wedge} = \frac{\texttt{observedaccuracy-chanceagreement}}{\texttt{1-chanceagreement}}$$

$$k^{\wedge} = \frac{N \sum_{i=1}^{r} xii - \sum_{i=1}^{r} (x_{i+} * x+i)}{N^2 - \sum_{i=1}^{r} (x_{i+} * x+i)}$$

Where: xii = No. of rows in the error matrix, r = No. of observations in row i and column i (on the major diagonal), $x_{i}+$ = Total of observations in row(shown as marginal total to right of the matrix), $x+i$ = total of observations in colunm (shown as marginal total at bottom of the matrix), N = total number of observations included in matrix

Figure 9: The calculation for KHAT/ Cohen's Kappa Statistic : Source:(Cho-Ricketts and Cherrington 2011)

Example of KHAT Calculation from Kenya Field Validation Data (Error matrix)

See Table. 1 above.

- Observed agreement (OA)
- Agreement by chance (AC) (Agreement by chance positive and Agreement by chance negative)
- OA = (34+10)/64 = 0.6875
- AC (positive) = (34/64)*(54/64) = 0.53125*0.84375 = 0.448242
- AC (Negative) = (30/64)*(10/64) = 0.46875*0.15625 = 0.073242
- AC (positive) + AC (Negative) = 0.448242 + 0.073242 = 0.521484
- Cohen's coeffient (k) = (OA-AC)/(1-AC) , to standardized the coefficeint = (0.6875 - 0.521484)/(1-0.521484)

- **k = 0.35**

Table 5: KHAT Statistic and Overall Classes Accuracy

Country	KHAT/Cohen's statistic	% KHAT/Cohen's statistic	Overall Accuracy	% Overall Accuracy
Kenya	0.34	34%	0.69	69%
Tanzania	0.54	54%	0.77	77%
Mozambique	0.64	64%	0.84	84%
Madagascar	0.71	71%	0.86	86%

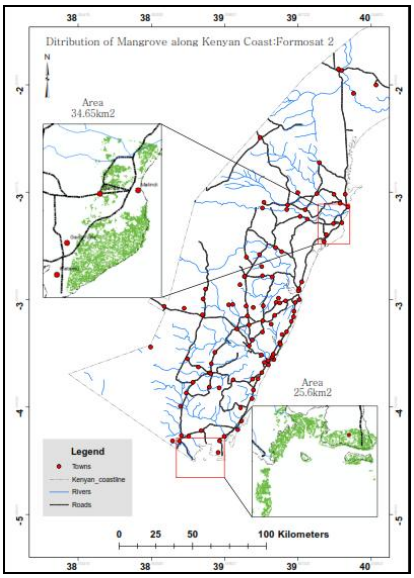

Figure 10: Cover Classification Using FORMOSAT 2 - Vanga & Malindi - Kenya

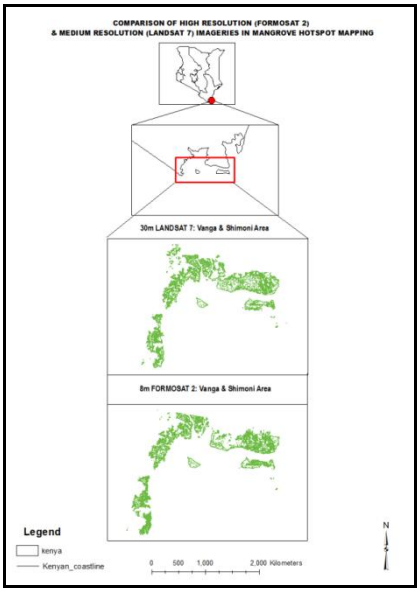

Figure 11: A map showing mangrove cover of Shimoni and Vanga areas estimated from LANDSAT 7 ETM+ & FORMOSAT- 2 imageries

Comparison Analysis – Sii Island: Formosat 2, Worldview 2, Landsat 8

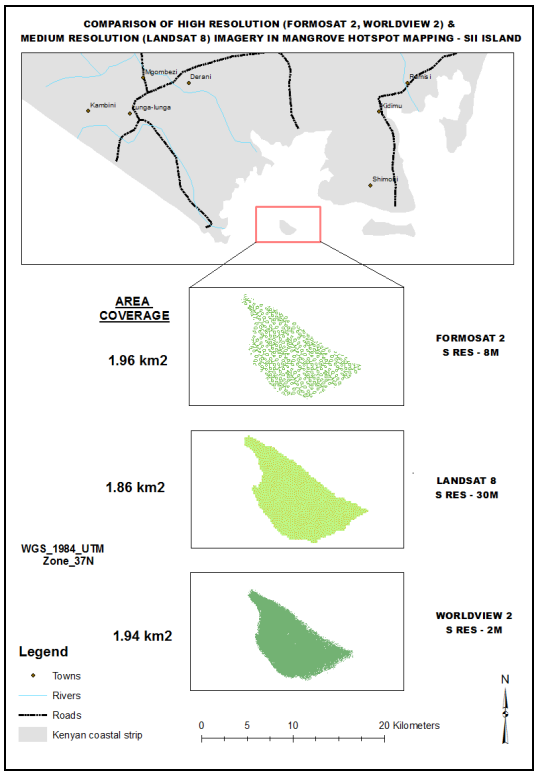

Figure 12: Satellite Imagery Resolution Comparison Analyses

DISCUSSION

Accuracy of each class was expressed as a matrix showing errors of commission and omission. This was derived from the field data points and extracted points from the classification map. Overall classification accuracy and KHAT statistic of each country data was computed. Overall map accuracy was computed by dividing the total number of correctly classified pixels by the total number of reference pixels in the error matrix. Overall accuracy uses only the main diagonal elements of the error matrix. The accuracy of individual categories is computed by dividing the corresponding row or the corresponding column. When the number of correct pixels in a category is divided by the total number pixels in the corresponding row (i.e. the total number pixels that were classified in that category), the result is an accuracy measure called “user’s accuracy” and is a measure of commission error. “User’s accuracy”, or reliability, is indicative of the probability that a pixel classified on the map actually represent that category on the ground. On the other hand, when the correct number of pixels in a category is divided by the total number of pixels in the corresponding column (i.e. the total number of pixels for that category in the reference data) the result is called “producer’s accuracy”. Producer’s accuracy indicates the probability of reference pixels being correctly classified and is really a measure of omission error. The overal accurancies of mangrove cover validation attained was generally very good, within the limits of U.S. Geological Survey's suggested threshold of 85% for Madagascar and Mozambique (86.2% and 84.5 % respectively). The user and producer accurancies were also the high for both mangroves and no-mangroves for Madagascar and Mozambique (**Table 3** &**Table 4** repectively). On the otherhand, the accurancy was slightly lower for Kenya and Tanzania but still in acceptable range of 69% and 77% respectively (**Table 1 & 2**). Besides, examining the different accuracy statistics, the Cohen's statistic produced also indicated the quality of the outcome. The KHAT statistic is estimated to supplement the overall class accuracy statistic, because the overall accuracy serves as an indicator of the extent to which the percentage correct values of an error matrix are due to "true" agreement against "chance" agreement. The KHAT statistic for mangrove cover maps for Kenya, Tanzania, Mozambique and Madagascar were: 0.34, 0.54, 0.64 and 0.7 respectively (**Table 5)**. The qualitative interpretations of KHAT statitics (Cho-Ricketts and Cherrington 2011), indicate that KHAT statistc exceeding 0.6 show "significant

agreement," the values for Mozambique and Madagascar fell within the limit. Though Kenya and Tanzania data are below the threshold. The KHAT statistic for Kenya, Tanzania, Mozambique and Madagascar (0.34, 0.54, 0.64, and 0.7 respectively). This shows that validaton data accuracy for Kenya, Tanzania, Mozambique and Madagascar cover maps were approximately 34%, 54%, 64% and 70% respectively better than what would have been achieved by pure chance. The lower levels of accurancies could be attributed to the variation of clouds on images of the areas surveyed **Figures 13, 14 & 15** below. The areas with dwarf mangroves - interspersed with water - might appear more similar to water than other classes of mangrove whose canopies are mostly closed and which would not reflect much water, thereby reducing the accurancies (Smith 2013).

Comparison Analysis: LANDSAT, Worldview-2 and FORMOSAT

The results derived from mangrove cover statistics showed that LANDSAT imagery estimated above ground biomass at 65.58km^2 while FORMOSAT- 2 identified 41.93 km^2 of mangrove cover for the same area. However, the total area classified as mangrove could not be directly compared between LANDSAT 7 and FORMOSAT- 2 imageries due to variations in the areas covered by clouds Figure 11. Further classification of a smaller but cloud free area (Sii Island) using a LANDSAT 8 image acquired on 7th September 2014, Worldview-2 and a FORMOSAT- 2 image acquired on 29th June 2014 produced mangrove cover of 1.86 km^2, 1.94 km^2 and 1.96 km^2 respectively Figure 12. While the area values are similar, it is important to underscore the complimentary value added to the results by much higher resolution and refined FORMOSAT- 2 and Worldview-2 grids, which can enhance area and boundary delineations, features that are quite important for ecological change detection and monitoring.

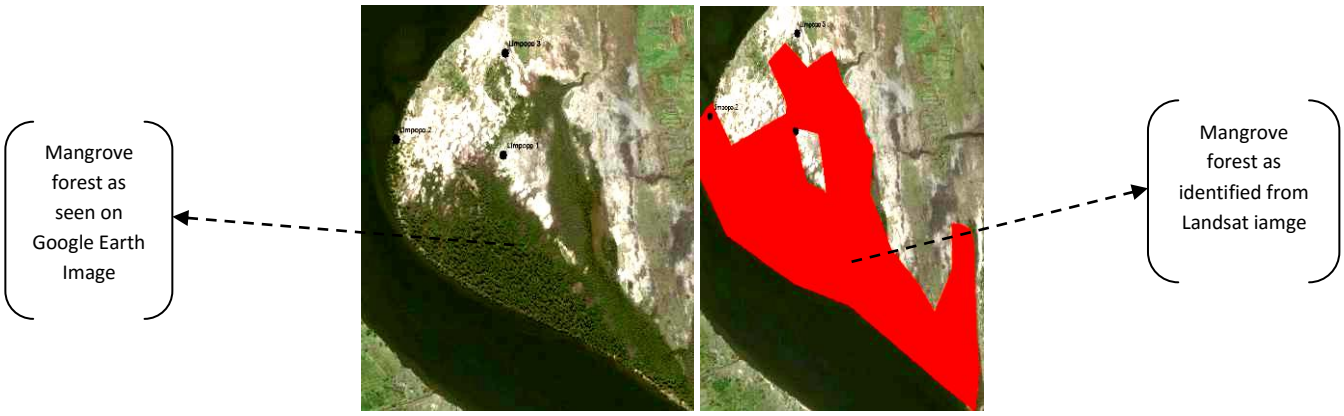

Figure 13: Mangrove area around river Limpopo accurately identified through classification

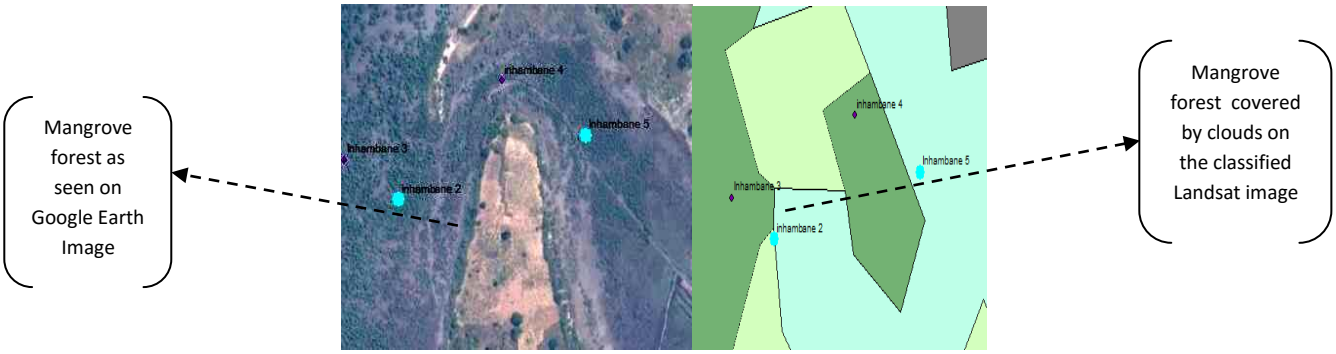

Figure 14: A mangrove area around in Inhambane covered by clouds, reducing the accuracy - Mozambique

Figure 15: A mangrove area around in Maputo covered by clouds, reducing the accuracy - Mozambique

CONCLUSION

Extensive field effort to validate mangrove cover map executed between the months of March and June 2015. Landsat 8 and 7 were used in producing the first cover maps, most image scenes were derived during the dry months (January, March and August) of the year. The study found variying overall accuracy from one country to another. Madagascar and Mozambique had the highest overall accuracy, which meets and exceeds commonly used standards, indicating mangroves in Mozambique and Madagascar were mapped with a high level of accuracy (86% and 84% overall class accuracy). The KHAT statistics for Mozambique and Madagascar were 0.64 and 0.7 respectively, an acceptable range, this shows how good the maps were compared to 'chance agreement', the figures show 'substantial agreement'. On the otherhand, the cloud variation on the images significantly reduced the classification accuracy mainly for Kenya and Tanzania (69% and 77% respectively overall class accuracy), hence poor KHAT statistic (0.34 and 0.54 respectively). The KHAT statistic for Kenya, Tanzania, Mozambique and Madagascar were 0.34, 0.54, 0.64, and 0.7 respectively. This shows that data accuracy for Kenya, Tanzania, Mozambique and Madagascar cover maps were approximately 34%, 54%, 64% and 70% respectively better than what would have been achieved by pure chance. The lower levels of accuracies could be attributed to the variation of clouds on images of the areas surveyed. The areas with dwarf mangroves - interspersed with water - might appear more similar to water than other classes of mangrove whose canopies are mostly closed and which would not reflect much water, thereby reducing the accuracies. The elimination of data that fell within the clouds reduced the data available for estimating the accuracy statistics.

APPENDIX

Table 6: Kenya Validation Data

Location	Latitude	Longitude	Landuse
Gazi	-4.423778	39.506167	Non_mangroves
Gazi	-4.413500	39.504222	Non_mangroves
Gazi	-4.399722	39.508222	Non_mangroves
Gazi	-4.400028	39.507611	Non_mangroves
Fuhamuni	-4.408639	39.493694	Non_mangroves
Fuhamuni	-4.492722	39.426778	Non_mangroves
Fuhamuni	-4.505611	39.426167	Non_mangroves

Mwazaro	-4.599917	39.391444	Non_mangroves
Ramisi	-4.534167	39.400417	Non_mangroves
Ramisi	-4.537361	39.401222	Non_mangroves
Tana	-2.519200	40.509800	Mangroves
Tana	-2.516700	40.476300	Mangroves
Tana	-2.519500	40.471100	Mangroves
Tana	-2.558300	40.356700	Mangroves
Tana	-2.568300	40.335200	Mangroves
Tana	-2.568300	40.354300	Mangroves
Tana	-2.571700	40.325400	Mangroves
Tana	-2.624800	40.275500	Mangroves
Gazi	-4.417306	39.511028	Mangroves
Gazi	-4.419917	39.511000	Mangroves
Kibuyuni	-4.643306	39.330861	Mangroves
Kibuyuni	-4.643583	39.330167	Mangroves
Makongeni	-4.411611	39.524111	Mangroves
Makongeni	-4.411139	39.522417	Mangroves
Mwazaro	-4.601694	39.394000	Mangroves
Mwache	-4.009167	39.572306	Mangroves
Mwache	-4.009639	39.570944	Mangroves
Kilifi	-3.600208	39.778806	Mangroves
Kilifi	-3.809028	39.809028	Mangroves
Kilifi	-3.620889	39.811139	Mangroves
Kilifi	-3.614611	39.793806	Mangroves
Kilifi	-3.612194	39.811083	Mangroves
Kilifi	-3.629083	39.793944	Mangroves
Kilifi	-3.631889	39.798417	Mangroves
Kilifi	-3.628583	39.806694	Mangroves
Takaungu	-3.672333	39.855667	Mangroves
Takaungu	-3.679000	39.845667	Mangroves
Takaungu	-3.683611	39.833611	Mangroves
-Takaungu	-3.684556	39.834556	Mangroves
Takaungu	-3.699333	39.966000	Mangroves
Mtwapa	-3.950583	39.703639	Mangroves
Mtwapa	-3.945806	39.707389	Mangroves
Mtwapa	-3.937194	39.702389	Mangroves
Mtwapa	-3.935639	39.701556	Mangroves
Mtwapa	-3.921000	39.698333	Mangroves
Mtwapa	-3.905750	39.714639	Mangroves
Mtwapa	-3.904778	39.712444	Mangroves
Mtwapa	-3.909472	39.710889	Mangroves
Mtwapa	-3.903611	39.716083	Mangroves
Vanga	-4.630061	39.239394	Mangroves
Vanga	-4.630119	39.243614	Mangroves
Vanga	-4.626506	39.241011	Mangroves

Vanga	-4.627750	39.235472	Mangroves
Vanga	-4.619569	39.240472	Mangroves
Vanga	-4.621475	39.242169	Mangroves
Vanga	-4.618086	39.233958	Mangroves
Vanga	-4.624708	39.246553	Mangroves
Vanga	-4.620881	39.250086	Mangroves
Vanga	-4.617278	39.244892	Mangroves
Vanga	-4.613358	39.250622	Mangroves
Vanga	-4.618853	39.253081	Mangroves
Vanga	-4.616228	39.262744	Mangroves
Vanga	-4.614069	39.263411	Mangroves
Vanga	-4.611219	39.265172	Mangroves
Vanga	-4.610381	39.261475	Mangroves
Vanga	-4.617933	39.281083	Mangroves
Vanga	-4.608997	39.268550	Mangroves
Vanga	-4.621531	39.268458	Mangroves
Vanga	-4.618197	39.269403	Mangroves
Vanga	-4.617519	39.272975	Mangroves
Vanga	-4.611806	39.273297	Mangroves
Vanga	-4.611806	39.270694	Mangroves
Vanga	-4.606022	39.275375	Mangroves
Vanga	-4.606097	39.270994	Mangroves
Vanga	-4.604906	39.272053	Mangroves
Vanga	-4.595036	39.270347	Mangroves
Vanga	-4.592542	39.265856	Mangroves
Vanga	-4.588703	39.267661	Mangroves
Vanga	-4.590375	39.261675	Mangroves
Vanga	-4.586825	39.258458	Mangroves
Vanga	-4.601886	39.283225	Mangroves
Vanga	-4.607586	39.283472	Mangroves
Vanga	-4.594253	39.280258	Mangroves
Vanga	-4.609672	39.287942	Mangroves
Vanga	-4.614342	39.288244	Mangroves
Vanga	-4.612447	39.288150	Mangroves
Vanga	-4.607861	39.288008	Mangroves
Vanga	-4.618528	39.259811	Mangroves

Table 7: Tanzania Validation Data

Location	Latitude	Longitude	Land_use
Bagamoyo	-6.42419460000	38.90268026000	Mangroves
Bagamoyo	-6.41965178000	38.90154292000	Mangroves
Bagamoyo	-6.41733427000	38.89970519000	Mangroves
Bagamoyo	-6.41401662000	38.89935139000	Mangroves

Kaole	-6.45856317000	38.94478935000	Mangroves
Kaole	-6.45970956000	38.94644955000	Mangroves
Kaole	-6.45734034000	38.94566643000	Mangroves
Kaole	-6.45730404000	38.94862189000	Mangroves
Kigamboni	-6.85886585000	39.36148267000	Mangroves
Kigamboni	-6.85996145000	39.36430930000	Mangroves
Kigamboni	-6.86170950000	39.36612826000	Mangroves
Kikale	-7.86171824000	39.21904673000	Mangroves
Kikale	-7.85261792000	39.21573831000	Mangroves
Kikale	-7.85213311000	39.22733786000	Mangroves
Kikale	-7.84754670000	39.23639115000	Mangroves
Kikale	-7.85470141000	39.23985120000	Mangroves
Kunduchi	-6.67193407000	39.21717555000	Mangroves
Kunduchi	-6.67420205000	39.21660759000	Mangroves
Kunduchi	-6.67695299000	39.21904086000	Mangroves
Tafiri	-6.66659086000	39.21324385000	Mangroves
Kijichi	-6.87578673000	39.28564573000	Mangroves
Kijichi	-6.87460447000	39.28656028000	Mangroves
Kijichi	-6.87283287000	39.28807849000	Mangroves
Mlingotini	-6.47936094000	39.00222517000	Mangroves
Mlingotini	-6.48032988000	39.00493705000	Mangroves
Mlingotini	-6.48206829000	39.00578831000	Mangroves

Table 8:Mozambique Validation Data

Location	Latitude	Longitude	Landuse
Gilo	-23.52240996000	35.23402995000	Non Mangroves
Ihambane	-23.87015224000	35.38049265000	Mangroves
Ihambene	-23.86979752000	35.38036139000	Mangroves
inhambane	-23.92166818000	35.38982498000	Mangroves
Inhambane	-23.92138462000	35.38929348000	Mangroves
inhambane	-23.92082420000	35.39082670000	Mangroves
Inhambane	-23.92121178000	35.39164485000	Mangroves
Limpopo	-25.16051506000	33.50482489000	Mangroves
Limpopo	-25.15810912000	33.50879607000	Mangroves
Limpopp	-25.16095888000	33.50874452000	Mangroves
lindela	-23.91902033000	35.33566648000	Mangroves
Lindela	-23.91768929000	35.33622530000	Mangroves
Lindela	-23.91835749000	35.33712057000	Mangroves
Macaneta	-25.76533483000	32.73468850000	Mangroves
Maputo	-25.90757422000	32.65548790000	Mangroves
Maputo	-25.91181505000	32.64515360000	Mangroves
Maputo	-25.91004211000	32.64388315000	Mangroves
Maputo	-25.90834829000	32.64539751000	Mangroves
Maputo	-25.90892890000	32.65439498000	Mangroves
Maputo	-25.90846530000	32.65398603000	Mangroves

Maputo	-25.91017513000	32.65323954000	Mangroves
Maputo	-25.91349067000	32.64701094000	Mangroves
Maputo	-25.91338900000	32.64641231000	Mangroves
Maputo	-25.91258325000	32.64709393000	Mangroves
Morrumbe	-23.66602776000	35.35495902000	Mangroves
Morrumbene	-23.66625826000	35.35433256000	Mangroves
Limpopo	-25.05667157000	33.60858028000	Non Mangroves
Inhambane	-24.02594727000	35.34173800000	Non Mangroves
Limpopo	-25.15051846000	33.51497102000	Non Mangroves
Maputo	-25.77226549000	32.73701901000	Non Mangroves
Maputo	-25.76497190000	32.73713627000	Non Mangroves
Maputo	-25.73848785000	32.72772901000	Non Mangroves
Maputo	-25.73501464000	32.68373575000	Non Mangroves
Limpopo	-25.15447170000	33.52067423000	Non Mangroves
Ihambane	-23.91925268000	35.33740665000	Non Mangroves
Inhambane	-23.92446807000	35.39403529000	Non Mangroves
Inhambane	-24.04828520000	35.31907987000	Non Mangroves
Inhambane	-24.04282616000	35.31342418000	Non Mangroves
Inhambane	-23.91991032000	35.33455906000	Non Mangroves
Morrumbene	-23.66599624000	35.35416132000	Non Mangroves
Morrumbene	-23.66661097000	35.35297235000	Non Mangroves
Inhambane	-24.02624834000	35.34182777000	Non Mangroves

Table 9: Madagascar Validation Data

Name	Latitude	Longitude	Landuse
Antsahabe	-12.878170	48.950150	Mangroves
Antsahabe	-12.878173	48.950226	Mangroves
Antsahabe	-12.878169	48.950221	Mangroves
Ampasivelo	-13.141733	48.812899	Non_Mangroves
Ampasivelo	-13.141729	48.812906	Non_Mangroves
Antafiamilameva	-13.546821	48.449301	Mangroves
Antafiamilameva	-13.546860	48.449285	Mangroves
Babere	-13.570144	48.387850	Mangroves
AmpikahiaB	-13.538940	48.428504	Mangroves
AntafiamilamevaA	-13.546611	48.449274	Mangroves
AntafiamilamevaB	-13.546829	48.449295	Mangroves
AntafiamilamevaC	-13.547585	48.449161	Mangroves
AntafiamilamevaD	-13.535302	48.450352	Non_Mangroves
AnkatakaA	-13.534060	48.450034	Mangroves
AnkatakaB	-13.533454	48.449567	Mangroves
Tambohoni tromba	-13.559552	48.377622	Non_Mangroves
Maroatrandra	-13.573264	48.374269	Non_Mangroves
Ankonko matsoraka	-13.565439	48.380367	Mangroves
Ambatomarerano	-13.582724	48.372118	Non_Mangroves
Antsahampano port	-13.583879	48.402579	Mangroves
Antsahampano	-13.583316	48.404549	Non_Mangroves
Ambario mipkey	-13.554386	48.381587	Non_Mangroves
Marojohy	-13.549363	48.389770	Mangroves
Farafaka mivorivoryA	-13.539518	48.396299	Non_Mangroves
Farafaka mivorivoryB	-13.539631	48.397859	Mangroves
Marovovo	-13.068017	48.839944	Non_Mangroves
Maroakoho	-13.534178	48.414607	Mangroves

AmpikahiaA	-13.538283	48.429005	Mangroves
Ampapamina_1	-13.474640	48.641741	Mangroves
Ampapamina-10	-13.459136	48.650149	Mangroves
Ampapamiana-11	-13.464643	48.643286	Mangroves
Ampapamina-12	-13.465136	48.643094	Mangroves
Ampapamiana-2	-13.474795	48.641923	Mangroves
Ampapamina-3	-13.472847	48.644091	Mangroves
Ampapamina-4	-13.472857	48.644805	Mangroves
Ampapamina-5	-13.468070	48.647614	Mangroves
Ampapamina-6	-13.467300	48.647710	Mangroves
Ampapamina-7	-13.457370	48.652027	Mangroves
Ampapamina-8	-13.458001	48.651625	Mangroves
Ampapamina-9	-13.458608	48.650454	Mangroves
Ambavanankaran	-12.888944	48.941099	Mangroves
AmbavanankarnR	-12.888362	48.941419	Mangroves
Ampahaka	-13.048156	48.867668	Mangroves
Ampanasna	-13.027111	48.967797	Non_Mangroves
Ampandriampan	-13.035506	48.865999	Mangroves
Ampanoara Ch	-12.999322	48.951804	Non_Mangroves
Ampapamena	-12.927860	48.963664	Non_Mangroves
Ampasiuel2 RIV	-13.147240	48.815253	Non_Mangroves
Ampasiuelo 5R	-13.139948	48.810150	Non_Mangroves
Ampasivelo R4	-13.142623	48.816372	Mangroves
Ampasivelo Riv	-13.148048	48.813559	Non_Mangroves
Ampasivelo4R	-13.141540	48.812604	Non_Mangroves
Ampasy anteni2	-13.040225	48.857591	Mangroves
Ampasy Antenin	-13.039778	48.858405	Non_Mangroves
Ampotsehy	-13.051235	48.981900	Non_Mangroves
Andavanemboka	-13.045259	48.855828	Mangroves
AndavanembokaC	-13.041021	48.858883	Non_Mangroves
andavanemboko1	-13.042459	48.862087	Mangroves
Andavanemboko2	-13.045296	48.866971	Mangroves
Andranofotsy	-13.002664	48.953739	Non_Mangroves
Anjaviala	-12.996785	48.951999	Non_Mangroves
Anjeviala1	-12.994411	48.950393	Non_Mangroves
Anjiha	-13.040345	48.864649	Mangroves
Ankiuanja	-12.875637	48.952185	Non_Mangroves
Ankiuanja MN	-12.878481	48.955264	Non_Mangroves
Ankivanja 1	-12.879671	48.955762	Non_Mangroves
Antafiambotry	-13.147091	48.809064	Non_Mangroves
Antafiambotry1	-13.148409	48.808244	Mangroves
Antafiambotry3	-13.149109	48.808140	Mangroves
Antenina 1	-13.071555	48.857221	Non_Mangroves
Antenina Ambav	-13.070482	48.844437	Mangroves
Antenina Riv	-13.068114	48.839997	Mangroves
Antenina10	-13.053235	48.859021	Non_Mangroves
Antenina9	-13.056752	48.859984	Non_Mangroves
Antsabaraona1	-13.078671	48.842202	Mangroves
Antsabaraona4	-13.072019	48.835657	Mangroves
Antsabaraona5	-13.072658	48.836561	Mangroves
Antsabaraona9	-13.072263	48.840299	Mangroves
Antsahabaraon3	-13.074008	48.838319	Mangroves
Antsahabaraona	-13.079207	48.844923	Mangroves
Antsahabe 1	-12.878170	48.950221	Mangroves
Antsahabe 2	-12.877468	48.950632	Mangroves
Antsahabe Cha	-12.880810	48.944080	Mangroves
antsahabolono	-13.036539	48.866155	Non_Mangroves
Antsahabraona2	-13.075979	48.841611	Non_Mangroves
Antsarabarao6	-13.074573	48.839652	Mangroves
Antsarabaraon7	-13.072482	48.839899	Mangroves
Antsarabaraon8	-13.072295	48.840289	Mangroves
Antsarabe Non_Mangroves	-13.062022	49.020999	Non_Mangroves
Antsarabe2	-13.012043	48.997367	Non_Mangroves

Non_Mangroves			
belaza	-13.074645	48.846120	Mangroves
Belaza1	-13.072499	48.852869	Non_Mangroves
Entrance Sos	-12.892904	48.946243	Non_Mangroves
Famaly	-13.134363	48.805582	Non_Mangroves

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