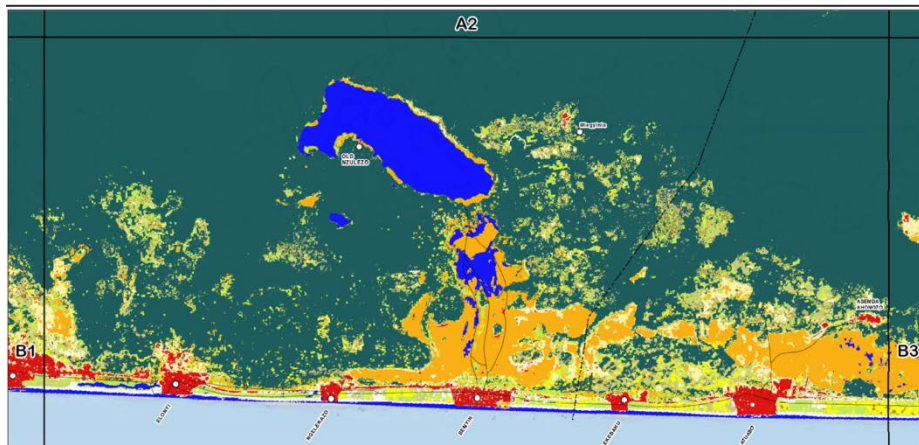




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# Quantifying a Decade of Land Cover Change in Ghana's Amanzule Region, 2002 – 2012



Y.Q. Wang', Christopher Damon', Glenn Archetto, Justice Nana Inkoom, Donald Robadue Jr. , Hilary Stevens, and Kofi Agbogah

October, 2013

## Hen Mpoano

THE  
UNIVERSITY  
OF RHODE ISLAND  
GRADUATE SCHOOL  
OF OCEANOGRAPHY



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For more information on the Integrated Coastal and Fisheries Governance project, contact: Coastal Resources Center, University of Rhode Island, Narragansett Bay Campus, 220 South Ferry Road, Narragansett, Rhode Island 02882, USA. Brian Crawford, Director International Programs at [brian@crc.uri.edu](mailto:brian@crc.uri.edu); Tel: 401-874-6224; Fax: 401-874-6920.

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Sustainametrix: <http://www.sustainametrix.com>

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\*Contacts: [yqwang@uri.edu](mailto:yqwang@uri.edu); [cdamon@edc.uri.edu](mailto:cdamon@edc.uri.edu), Department of Natural Resources Science, University of Rhode Island, Kingston, RI 02881, USA

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## Table of Contents

Study Location .....	1
Land Cover Change Detection.....	1
Data Preparation.....	1
Detecting Change.....	3
Results and Discussion .....	4
Re-Examination .....	4
Reducing Clutter .....	6
Conclusion .....	8
Resources .....	9
Appendix A:.....	10
Appendix B:.....	12

## List of Figures

Figure 1: Map of the Amanzule wetland complex in Ghana's Western Region.....	1
Figure 2: Collapsed classification scheme used to highlight areas of change. ....	2
Figure 3: The change detection process using matrices to represent the input and output raster datasets. Areas of change have been highlighted in red in the final output.....	3
Figure 4: Change matrix where all persistent classes have been set to "0" isolating locations where change has occurred. ....	3
Figure 5 Amanzule collage displaying land cover change between 2002 and 2012. (a) Generalized, 30m land cover map of the Amanzule study area; (b) Amanzule land cover condensed to 5 classes prior to performing the change analysis; (c) Results displaying all areas where change was detected. Colors indicate what classes the land cover was converted to; and (d) Areas of change > 2 hectares in size. Letters indicate the primary types of change that were detected.....	5

## Study Location



**Figure 1: Map of the Amanzule wetland complex in Ghana's Western Region.**

The Amanzule is a coastal wetland complex in Ghana's Western Region (Figure 1) near the border with neighboring Côte d'Ivoire. Even with its close proximity to the coast, the wetland is largely a freshwater system except along its southeastern terminus where the outlet parallels the coast before finally emptying into the sea near Azulewanu. The

ecosystem is composed of several wetland categories including peat, swamp and mangrove forests and holds Ghana's only known peat swamp forest and the country's

largest intact swamp forest (GhanaWestCoast.com).

Despite its ecological significance, the area is not without environmental pressures. An upland diversion of the Bosoko River in 2001 led to a lowering of water levels, reduced freshwater fish catches and a change in the downstream species composition (Mckeown and Ntiri, 2005). In addition, there has been a rapid expansion in the development of the offshore oil and gas fields, and the Amanzule region has been identified as a prime terminus for pipelines extending from the Tano Deepwater and West Cape Three Points development blocks.

## Land Cover Change Detection

The change detection analysis was an attempt to quantify how the land cover had changed in the Amanzule Region between 2002 and 2013. This project leveraged work from an earlier study to develop a baseline land cover map for Ghana's Western Region as part of the *Hen Mpoano* Project. *Hen Mpoano*, or "Our Coast, Our Future" was a three year, USAID-funded endeavor lead by the University of Rhode Island's Coastal Resources Center to develop adaptation strategies for coastal communities (Wang et al., 2012). The 2002 land cover map of the region was developed from Landsat TM data with a 30m pixel size, while the 2013 land cover mapping was developed using RapidEye multispectral imagery with a 5m pixel size.

## Data Preparation

In preparation for the change analysis, it was necessary to reformat both the TM and RapidEye classifications to match in both pixel size and spatial extent in order to compute change on a pixel-by-pixel basis. This process varied for each of the source data types.

- I. *TM Preparation*: The classified Landsat image was modified slightly from its original 28.5m pixel size to a 30m pixel size, and the extent was trimmed to match the RapidEye imagery. In order to preserve the original classification values, a

“nearest neighbor” resampling method was used, thereby shifting pixels in to alignment without modifying the original classification results.

- II. *RapidEye Preparation:* Because change detection was computed at the pixel level, it was necessary to generalize the 5m RapidEye data to a 30m pixel resolution. To accomplish this, the data were resampled using a majority filter, allowing a good representation of land cover without unduly compromising the fidelity of the original 5m data.
- III. *Collapsing the classification scheme:* With both datasets now perfectly aligned in both extent and resolution, computing change is possible. However, the fifteen different categories of land cover type used for the classification would result in a confusing picture, displaying both distinct transformations (forest to developed) as well as the more subtle (grassland-forest to shrubland-grassland) changes.

Original Classification Scheme		Condensed Classification	
Broadleaved forest regularly flooded	Aquatic vegetation	[1]	
Broadleaved forest permanently flooded			
Artificial areas	Artificial and bare areas	[2]	
Bare areas			
Rainfed croplands	Cultivated/managed/ herbaceous	[3]	
Mosaic croplands/vegetation			
Mosaic vegetation/croplands			
Closed to open grassland			
Closed to open shrubland			
Sparse vegetation			
Closed to open broadleaved evergreen	Woody vegetation	[4]	
Open broadleaved deciduous			
Mosaic forest – shrubland/grassland			
Mosaic grassland/forest – shrubland			
Water	Water	[5]	

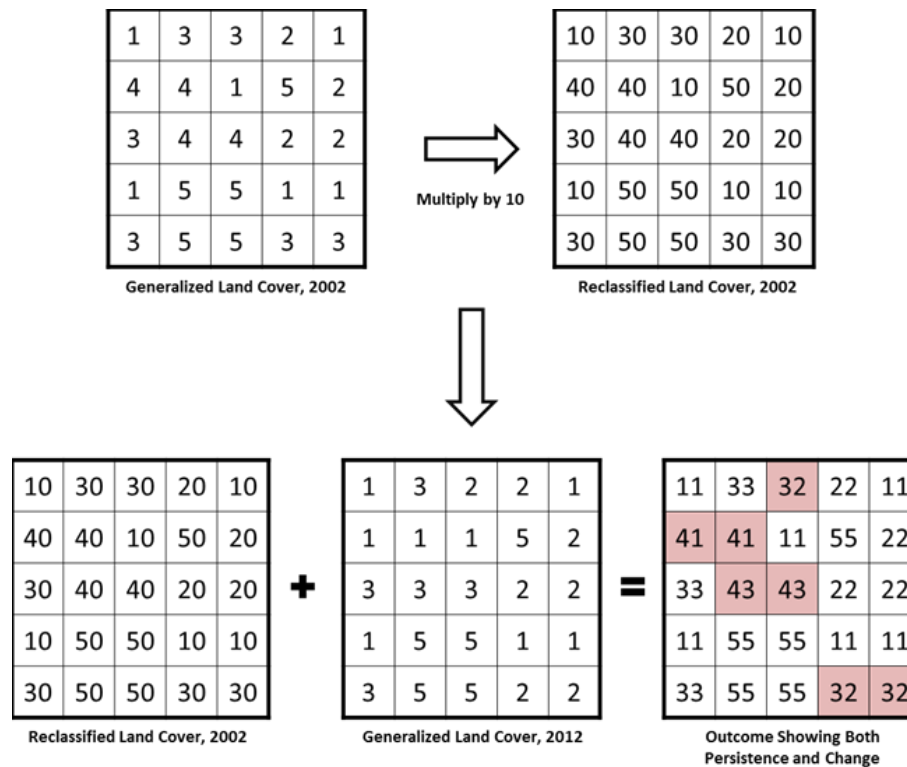
Because inter-category variation can be heavily influenced both by image quality and sensor type, these classes of change were deemed far less important than the macro-changes occurring across the landscape. These large-scale differences have a direct impact on the goods and services a landscape can provide, and would include such modifications as forest being converted into agricultural lands or developed areas. Figure 2 displays how the original fifteen land cover categories were collapsed for each dataset into five macro-classes used for the change detection. Definitions for each land cover category are

**Figure 2: Collapsed classification scheme used to highlight areas of change.**

provided in Appendix A.

## Detecting Change

Change detection was a straightforward comparative analysis that employed a simple mathematical operation on each pair of pixels. Figure 3 describes this process using matrices that represent the inputs and outputs of the operation.



**Figure 3: The change detection process using matrices to represent the input and output raster datasets. Areas of change have been highlighted in red in the final output.**

At the start, both the 2002 and 2012 datasets are composed of values ranging from 1 to 5, representing the five general land cover classes. To begin, one of the two data sets is multiplied by ten to allow differentiation between the two inputs. For this work we chose to multiply the oldest land cover dataset by 10 before proceeding, and the reason for doing so will become apparent in the results.

0	0	32	0	0
41	41	0	0	0
0	43	43	0	0
0	0	0	0	0
0	0	0	32	32

**Figure 4: Change matrix where all persistent classes have been set to "0" isolating locations where change has occurred.**

Simply adding the two data files together results in a new matrix of values where each digit represents both the starting and ending land cover types. Upon closer examination, two different pieces of information can be extracted from the outcome: persistence, where the starting and ending land cover types are the same; and change, where the cover types differ. For example, using the numbering scheme from Figure 3, a value of "44" indicates that that location was classified as "Woody Vegetation" in the 2002 and also in 2012. There has been no change, so at this location the land cover (Woody Vegetation) has persisted through time. On the other hand, a value of "43" indicates that the location was classified as "Woody Vegetation" in 2002 but "Cultivated/Managed" land in 2012. Setting all of the persistent pixels to either "0" or "No

Data,” isolates only the locations that have changed classes during the study period and separates these areas for further investigation (Figure 4).

## **Results and Discussion**

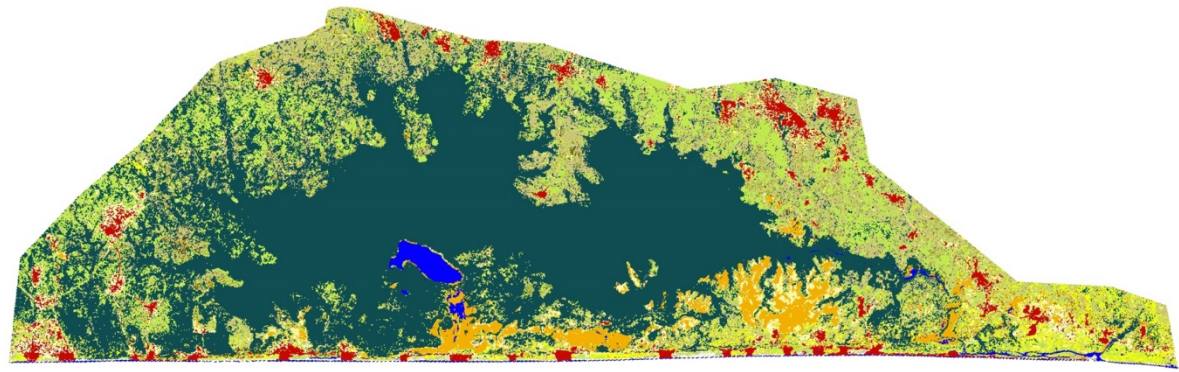
A step-wise collage showing land cover change in the Amanzule Region is displayed in Figure 5. Panels 5 a/b display the Amanzule land cover prior to the change analysis in both the original and condensed classification schemes, while panels 5 c/d exhibit the post-detection results.

Over the decade span between the 2002 and 2012 classifications, it might be expected that certain macro-scale changes would be reflected in the landscape; developed and cropland areas would tend to expand over time, and that growth would be reflected in a reduction of forested areas, grasslands, or both. In addition, it would be perfectly reasonable to hypothesize that these changes would be greatest near the towns/villages and decrease as one moved farther afield from the population centers. However for this work, neither of these assumptions were demonstrated to be valid. Of particular note was the complete lack of spatial definition for areas where land cover change was detected — there were simply no readily identifiable patterns in either the type of change detected or the locations where change was thought to have occurred. These results (Figure 5c) indicate that change has happened universally throughout the study area, apart from the dense, regularly to permanently flooded broadleaved forest. While change surely has occurred, these initial results simply do not reflect ground conditions (May, 2013) observed during field work to collect image validation points.

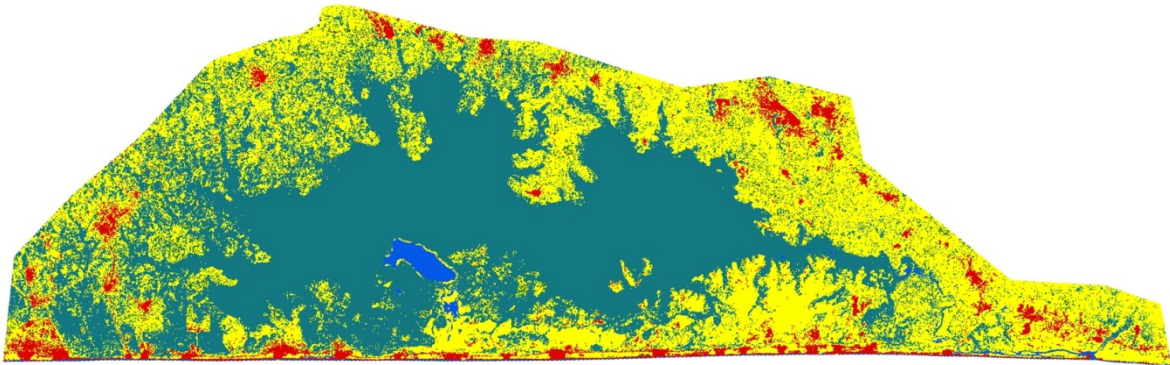
### **Re-Examination**

In an attempt to understand these results, it was necessary to revisit the Wang et al. (2012) study that developed the 2002 land cover map used as the baseline map for this work. From this, three primary factors emerged as the most likely causes for the widespread disparity between the 2002 and 2012 classifications.

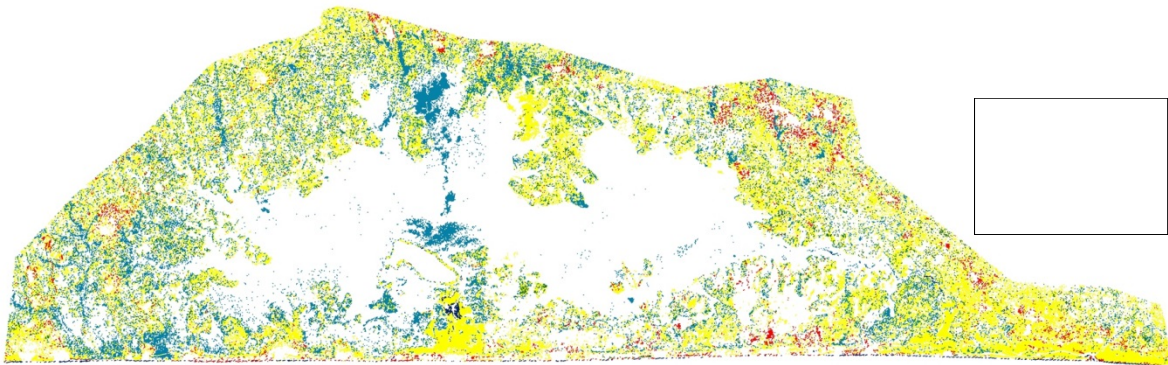
The first, and most important, was the poor quality of the LandsatTM imagery used for the baseline land cover study. Although the images selected for the study were the best available at no cost, they were heavily influenced by haze and cloud cover. Aerosol impacts are common in equatorial regions and have the net effect of altering spectral signatures and degrading the ability to differentiate between similar spectral



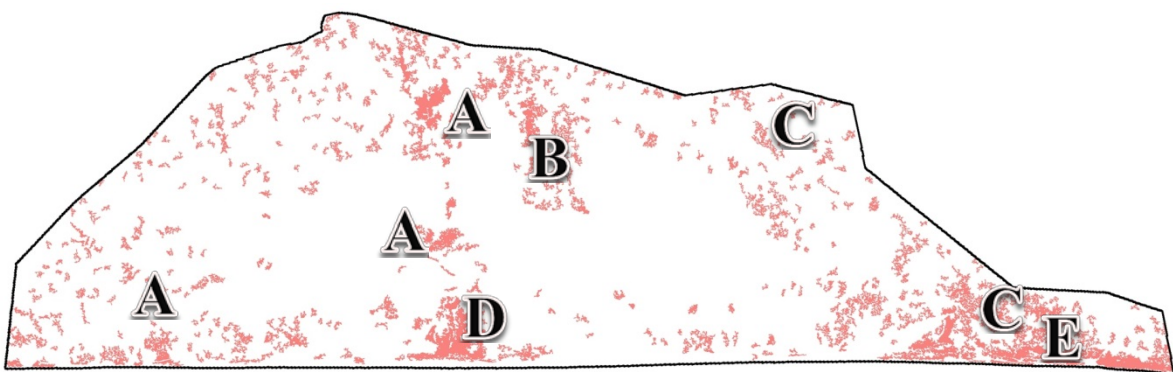
(a)



(b)



(c)



(d)

**Figure 5 Amanzule collage displaying land cover change between 2002 and 2012. (a) Generalized, 30m land cover map of the Amanzule study area; (b) Amanzule land cover condensed to 5 classes prior to performing the change analysis; (c) Results displaying all areas where change was detected. Colors indicate what classes the land cover was converted to; and (d) Areas of change > 2 hectares in size. Letters indicate the primary types of change that were detected.**



classes (Kerr, 2003). Although steps were taken to mitigate these effects, difficulties remained in the ability to accurately separate adjacent land cover types in highly mosaicked environments, such as those found throughout the Amanzule (Wang et al., 2012). The second factor, was the study location itself. The Amanzule region is located in the southwestern corner of the Landsat composite used in 2012. Coincidentally, this was also the portion of the Landsat imagery that was both highly mosaicked and heavily influenced by optical interference from haze and clouds. The final factor affecting the results was the size disparity between the two study areas -- 449,202 ha in 2012 vs. 36,507 ha for this work. By focusing on a much smaller region for this study, any classification errors from the 2012 Landsat work were distributed over a much smaller space, thus having a more noticeable impact.

While distilling the number of land cover classes used for the change detection mitigated minor spectral differences between the Landsat and RapidEye imagery, the methodology was unable to account for major classification shifts; such as from forest classes to mosaicked vegetation classes. Based on the combination of these three factors, it became apparent that it would be impossible to quantify land cover change between 2002 and 2012 with any real accuracy, even at the macro level.

### **Reducing Clutter**

Believing that the overall methodology was sound, the results were revisited to see if it was possible to interpret any patterns to the change being recorded. The apparent systematic errors introduced by poor image clarity led to widespread change being recorded across the entire study area (Figure 5c). To reduce “salt-and-pepper” pixel clutter, only contiguous blocks of changed pixels within each of the five land cover classes were retained. These zones of change were further subset by excluding all areas less than two hectares in size, leaving the largest, most prominent zones for further investigation. As shown in Figure 5d, this greatly reduced the amount of area to review and allowed five primary types of alteration to be detected that describe much of the pseudo-change identified between 2002 and 2012. Table 1 describes the principal transitions.

**Table 1: Primary types of land cover change that were recorded between 2002 and 2012.**

<b>Zones of Change</b>	<b>Type of Change Recorded</b>	<b>Description</b>	<b>2012 Implications</b>
Zone A	To aquatic vegetation	Occurs both at the wetland margins and in the interior. The greatest influence was observed in the western half of the study area where the haze in the Landsat imagery was most pronounced.	Better definition of freshwater wetlands and inland drainage areas.
Zone B	To cultivated / managed / herbaceous	A mixture of different forest classes that were converted to mosaic vegetation/croplands.	Influenced by both the subjective nature of the land cover classes and the similarity of adjacent land cover types. Overall, an improved characterization.
Zone C	To cultivated / managed / herbaceous	Locations near population centers where areas of bare/sparse vegetation or mosaic forest/grassland/shrubland are converted to one of the mosaic cropland classes.	It would be reasonable to expect these transitions as population centers expand outward, but it is unclear whether these differences reflect true change or are simply the result of a better classification.
Zone D	To cultivated / managed / herbaceous	Bare and sparsely vegetated areas transformed to grasslands. These zones are most prominent along the southern margin of the study area where inland wetland areas abut sandy coastal soils.	These locations are temporarily flooded during the rainy season with sheet flow from the interior. Depending on the time of year or the density of the grasses, these zones can easily be mistaken for bare to sparse vegetation or water. An improvement in the delineation of this cover type.
Zone E	To cultivated / managed / herbaceous	Most pronounced in the southeastern corner of the study area where broadleaved, permanently flooded areas (mangroves) were converted to cropland classes.	These zones generally do not represent true transformations. Landscape fragmentation and the cultivation of broadleaved crops right to the wetland borders could be adding to spectral confusion. These types of changes could also be influenced by the different number of spectral bands available for the analysis; 7 for Landsat vs. 5 for RapidEye. Additional field validation and/or a different classification procedure is recommended for accurate mangrove delineation.

## **Conclusion**

This work sought to quantify land cover change in the Amanzule Region of western Ghana from 2002 – 2012. A classified Landsat 30m image was used to represent 2002 ground conditions while a classified RapidEye 5m image represented 2012 conditions. Both images were validated using field observations at the time of classification. Prior to performing the change detection, the classified RapidEye image was generalized to a 30m resolution to match Landsat, and the images were spatially aligned to facilitate the pixel-based analysis.

Poor image quality of the 2002 Landsat imagery made it impossible to deduce any true land cover changes, however five primary types of change were noted. While a reliable estimate of land cover change was not possible, the classified land cover map developed from the RapidEye imagery represents a much improved land cover classification for the Amanzule, and should be considered the new baseline for future work in this area.

## Resources

Ghana West Coast. “Amanzule”. <http://ghanawestcoast.com>.

Kerr, J.T. and M. Ostrovsky, 2003. From space to species: ecological applications for remote sensing. *Trends in Ecology and Evolution* **18** (6).

Mckeown, J.P and E. Ntiri. 2005. “Conflict in the diversion of the Bosoko river in the Amanzule Lake”. In A. Engel and B. Korf. Negotiation and mediation techniques for natural resource management. DFID/FAO Livelihood Support Programme. Rome, FAO.

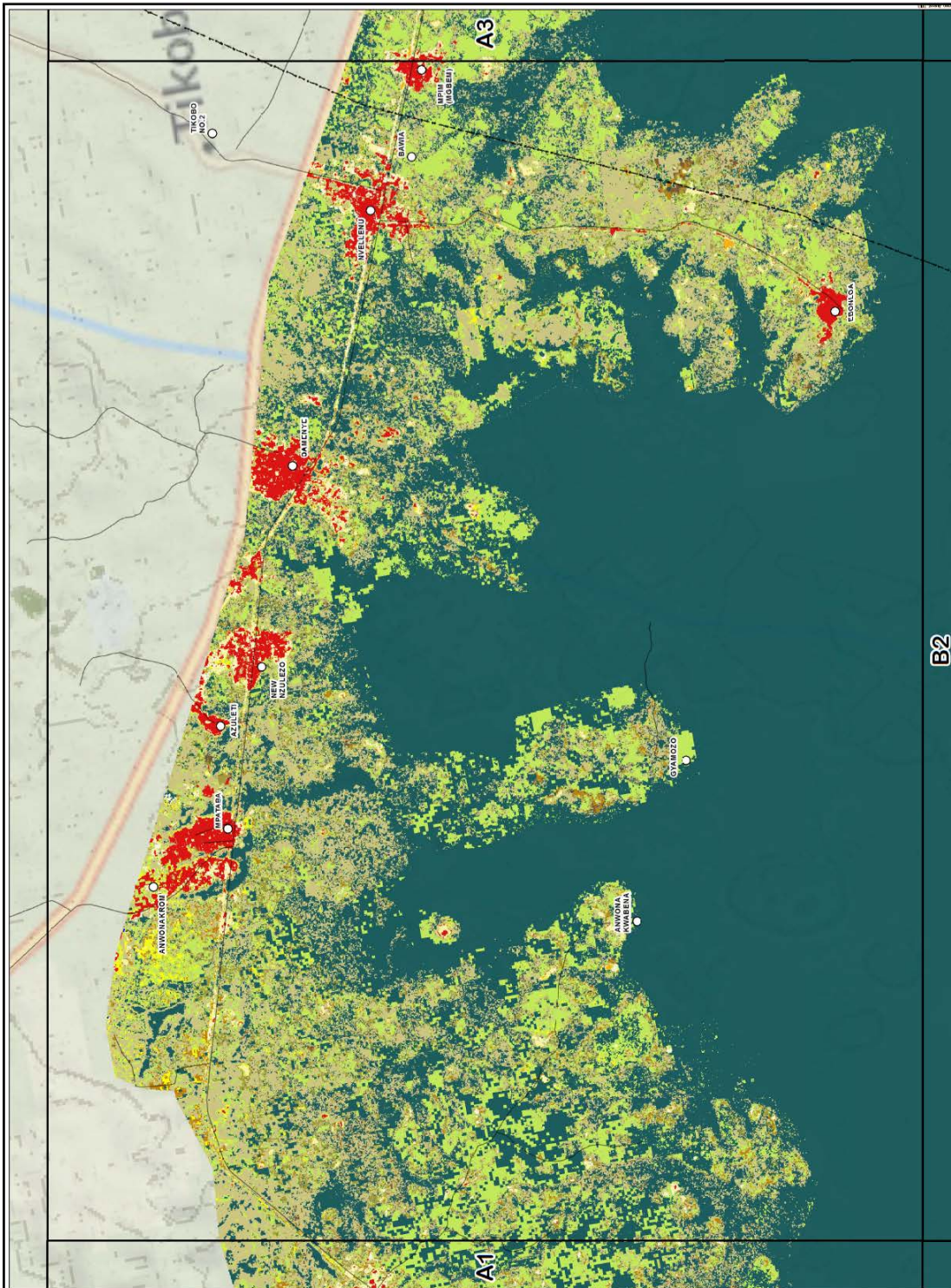
Wang, Y.Q., C. Damon, G. Archetto, D. Robadue, and M. Fenn. 2012. Land cover mapping of the greater Cape Three Points area using Landsat imagery. USAID and Coastal Resources Center – University of Rhode Island. Cooperative Agreement # 641-A-00-09-00036-00. Report, 18pp.

## Appendix A:

Land cover classes and descriptions used for the Amanzule land cover change detection project

Class Name	Class #	Class Description
Rainfed Croplands	1	Crops whose establishment and development are completely determined by rainfall.
Mosaic Croplands/Vegetation	2	A mapping unit which contains 50-70% cropland and 20-50 percent vegetative cover (grassland/shrubland/forest)
Mosaic Vegetation/Croplands	3	A mapping unit which contains 50-70% vegetative cover (grassland/shrubland/forest) and 20-50 cropland.
Closed to Open Broadleaved Evergreen or Semi-Deciduous Forest	4	A class representing 100-40% of the cover within a mapping unit which is comprised of broadleaved evergreen or semi-deciduous forest. The crowns can form an even or uneven canopy layer.
Open Broadleaved Deciduous Forest	5	Between 70-60 and 40 percent of a mapping unit is covered by broadleaved deciduous forest. The crowns of the canopy are not usually interlocking. The distance between crowns can range from very small up to twice the average diameter of the crown.
Mosaic Forest – Shrubland/Grassland	6	A mixed mapping unit which consists of 50-70% forest and 50-20% shrubland or grassland.
Mosaic Grassland/Forest – Shrubland	7	A mixed mapping unit which consists of 50-70% grassland or forest and 20-50% shrubland.
Closed to Open Shrubland	8	Shrubland which covers 100 to 40% of a mapping unit. Shrubland is defined as woody vegetation smaller than 5 meters in height.
Closed to Open Grassland	9	Grassland which covers 100 to 40% of a mapping unit. Grassland is defined as herbaceous cover which is 3 to .03 meters in height.
Sparse Vegetation	10	A mapping unit which contains 20-10% to 1% vegetative cover.
Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish water)	11	Broadleaved forest covering 100-40% of the mapping unit which is flooded for during a particular season with fresh or brackish water.
Closed Broadleaved Forest Permanently Flooded (saline-brackish water)	12	Broadleaved forest cover 100-70% of the mapping unit which is permanently flooded with saline or brackish water.
Artificial Areas	13	Cover resulting from human activities such as urban development, extraction or deposition of materials.
Bare Areas	14	A class representing areas which are not covered by vegetation or artificial cover. Can be comprised of rocky or sandy areas.
Water Bodies	15	Areas covered by natural water bodies such as ocean, lakes, ponds, rivers or streams.





**Classification Scheme**

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish)
  - Closed Broadleaved Forest Permanently Flooded (brackish-saline)
- Artificial and Bare Areas**
  - Artificial Areas
  - Bare Areas
- Cultivated Areas and Managed Lands**
  - Rainfed Croplands
  - Mosaic Croplands/Vegetation
  - Mosaic Vegetation/Cropland
- Herbaceous Vegetation**
  - Closed to Open Grassland
- Shrub Vegetation**
  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreen/ Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies

Projection: UTM  
Scale: 1:25,000  
Zone: 30N  
Datum: WGS84  
1 cm = 0.25 km

Kilometers  
0 0.5 1

**Data Sources and Processing**  
Land cover was derived using RapidEye Level 1B satellite images at 5m resolution from 2010 and 2011.  
The land cover categories and definitions were adopted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. The initial classification was performed in May, 2013 using stratified classification techniques, and revised in July, 2013 after field verification. All data were verified by the Ghana Forestry Commission, Ghana Forestry Research Institute, and the Terrestrial Remote Sensing and Environmental Data Center.  
The cell size for these data are 5 meters and are primarily for planning purposes. These data are not intended for detailed site-level image acquisition and provide a regional assessment from which future analyses may be derived.

### 2012 Land Cover for Western Ghana's Amanzule Region

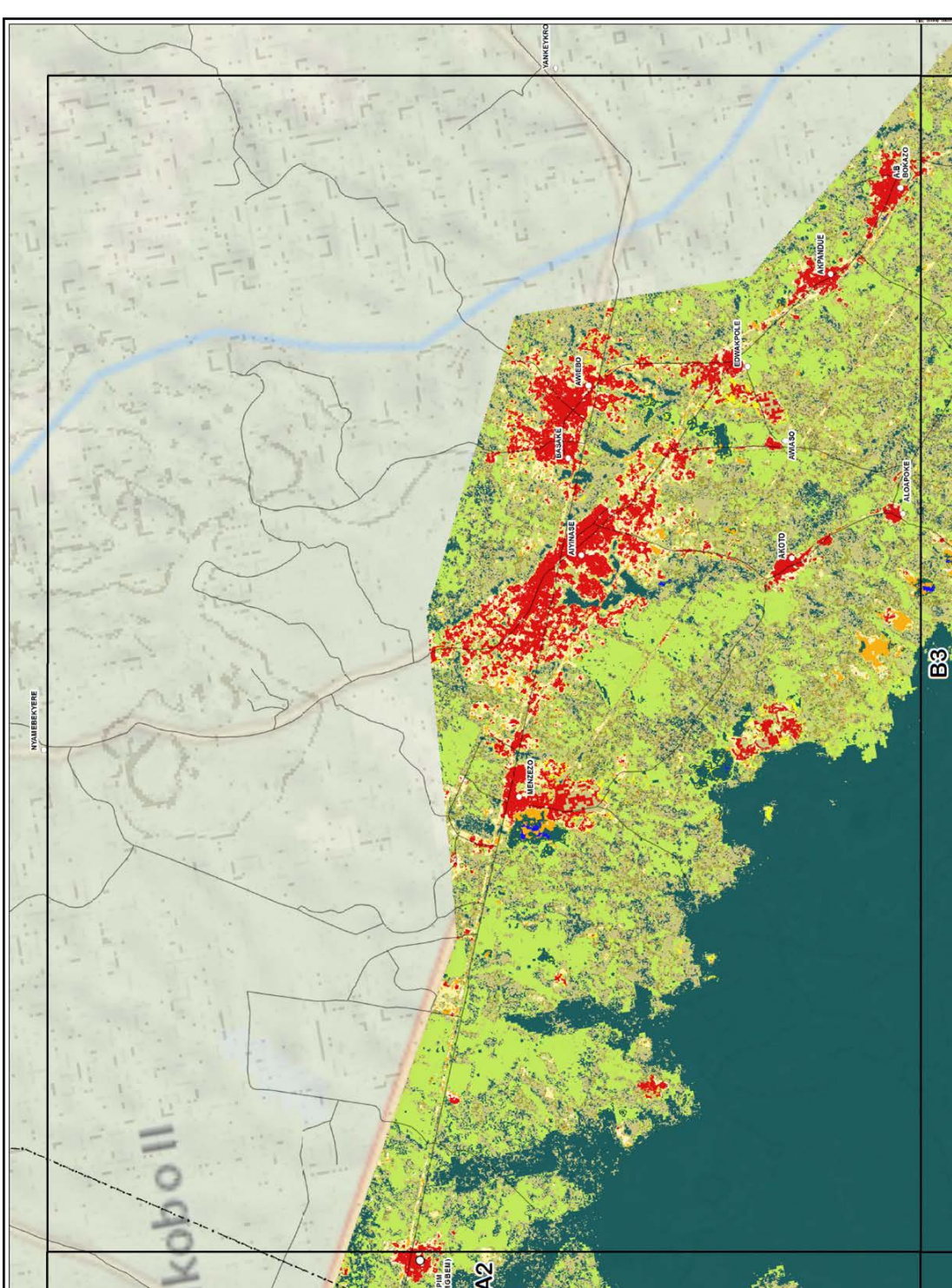
LAND COVER COLOR CODE	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL
[Green]	1,055	43	4.0
[Light Green]	5,275	969	17.4
[Yellow-Green]	4,912	1,441	29.3
[Yellow]	---	---	---
[Orange]	---	---	---
[Red]	---	---	---
[Dark Green]	---	---	---
[Blue]	---	---	---
[Light Blue]	---	---	---
[Dark Blue]	---	---	---
[White]	---	---	---
[Grey]	---	---	---
[Black]	---	---	---

LAND COVER COLOR CODE	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL
[Green]	18,483	5,002	27.3
[Light Green]	---	---	---
[Yellow-Green]	---	---	---
[Yellow]	---	---	---
[Orange]	---	---	---
[Red]	---	---	---
[Dark Green]	---	---	---
[Blue]	---	---	---
[Light Blue]	---	---	---
[Dark Blue]	---	---	---
[White]	---	---	---
[Grey]	---	---	---
[Black]	---	---	---



**MAP A2**



**Classification Scheme**

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish)
  - Closed Broadleaved Forest Permanently Flooded (brackish-saline)
- Artificial and Bare Areas**
  - Artificial Areas
  - Bare Areas
- Cultivated Areas and Managed Lands**
  - Rainfed Croplands
  - Mosaic Croplands/Vegetation
  - Mosaic Vegetation/Cropland
- Herbaceous Vegetation**
  - Closed to Open Grassland
- Shrub Vegetation**
  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreen or Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies

Projection: UTM  
Scale: 1:25,000  
Zone: 30N  
Datum: WGS84  
1 cm = 0.25 km

Kilometers  
0 0.5 1

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Center for Aquaculture and Fisheries Systems Development and Management

### 2012 Land Cover for Western Ghana's Amanzule Region

LAND COVER COLOR CODE	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL	
			LAND COVER	AREA IN MAP
	1,055	36	3.4	...
	5,575	1,144	20.5	7.5
	4,912	976	19.9	24.3
	...	...	...	...
	...	...	...	...
	...	...	...	...
	18,483	1,000	9.1	...
	...	...	...	...
	1,219	296	24.3	...
	740	50	6.7	...
	...	...	...	...
	1,175	188	16.0	...

**Data Sources and Processing:**  
Land cover was derived using RapidEye Level 1B satellite images at 5m resolution from 2010 and 2011.

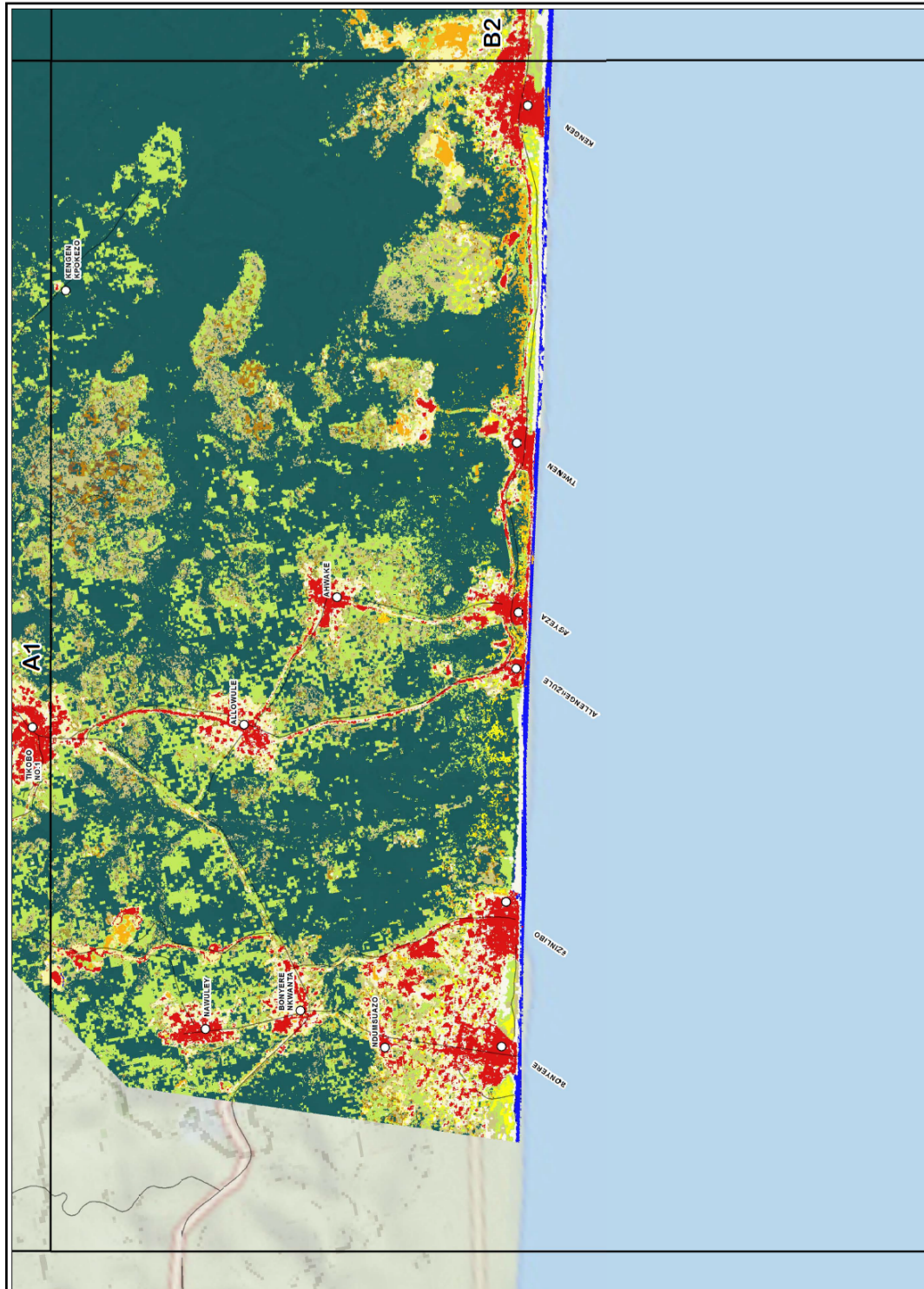
The land cover categories and definitions were adopted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. The initial classification was performed in May, 2013, using the LCCS software. The final classification was performed in May, 2013, using the LCCS software. The processing and mapping were conducted at the University of Rhode Island's Laboratory for Terrestrial Remote Sensing and Environmental Data Center.

The cell size for these data are 5 meters and are primarily for planning purposes. These data display conditions at the time of image acquisition and provide a regional assessment from which future analyses may be derived.



### Classification Scheme

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish)
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  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreen/Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies



USAID  
U.S. Agency for International Development

WorldFish  
World Bank

## 2012 Land Cover for Western Ghana's Amanzule Region

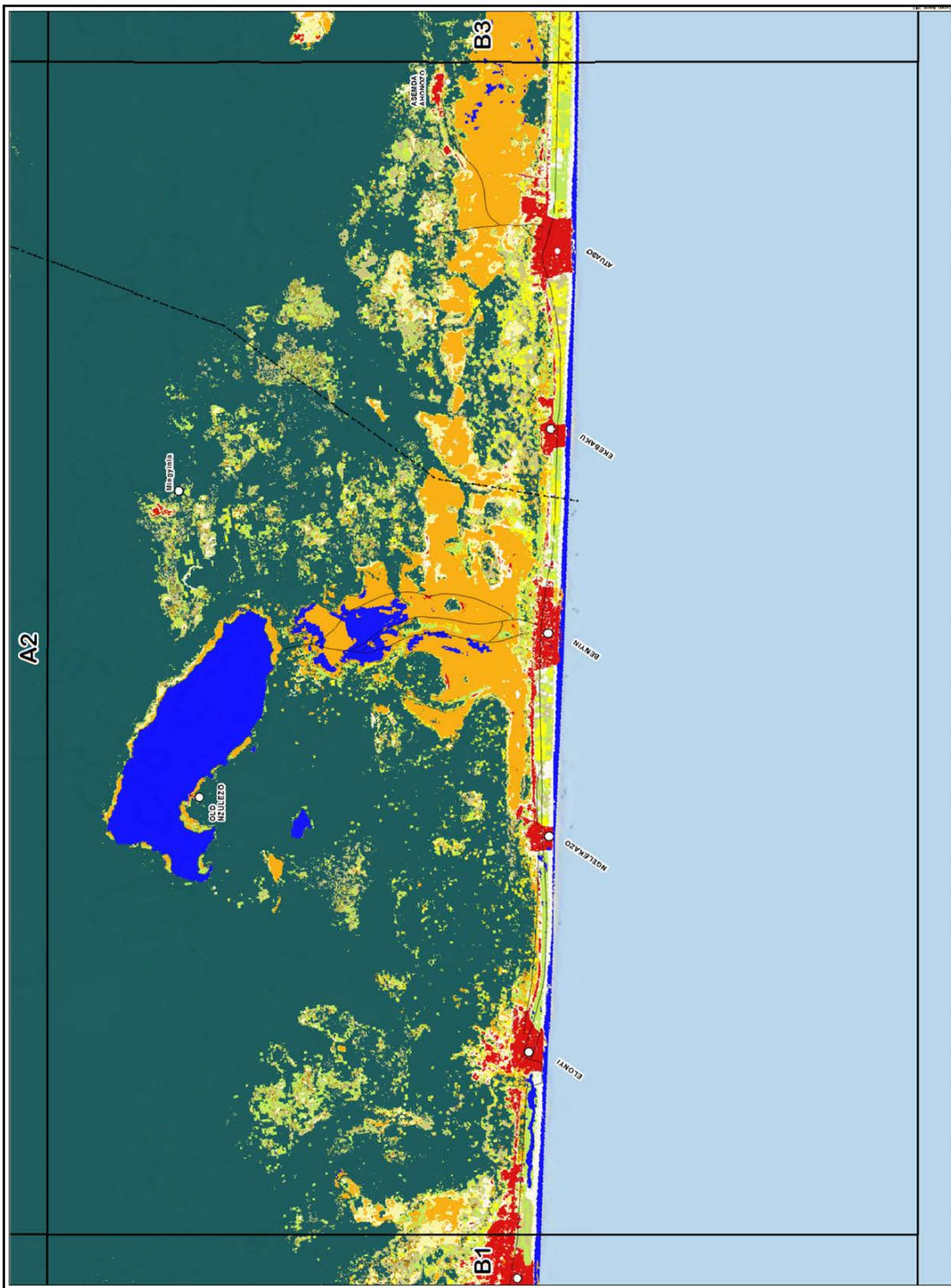
LAND COVER COLOR CODE	TOTAL AREA (ha)		AREA IN MAP (ha)		PERCENT OF TOTAL	
	Actual	Map	Actual	Map	Actual	Map
[Green]	1,055	79	878	84	9.5	14.8
[Light Green]	5,575	803	503	81	16.2	29.2
[Yellow]	4,912	381	94	11	12.0	25.0
[Dark Green]	---	---	1,425	49	3.5	---
[Blue]	---	---	1,175	170	14.5	---

**Data Sources and Processing:**  
Land cover was derived using RapidEye Level 18 satellite images at 5m resolution from 2010 and 2011.

The land cover categories and definitions were adopted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. The initial classification was performed in May, 2013 using the RapidEye Level 18 satellite images. The classification was then refined using ground truth data, processing and mapping were conducted at the University of Rhode Island's Laboratory for Terrestrial Remote Sensing and Environmental Data Center.

The cell size for these data are 5 meters and are primarily for planning purposes. These data display conditions at the time of image acquisition and provide a regional assessment from which future analyses may be derived.

MAP B1



**Classification Scheme**

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish)
  - Closed Broadleaved Forest Permanently Flooded (brackish-saline)
- Artificial and Bare Areas**
  - Artificial Areas
  - Bare Areas
- Cultivated Areas and Managed Lands**
  - Rainfed Croplands
  - Mosaic Croplands/Vegetation
  - Mosaic Vegetation/Cropland
- Herbaceous Vegetation**
  - Closed to Open Grassland
- Shrub Vegetation**
  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreenor Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies

Projection: UTM  
 Units: Meters  
 Scale: 1:25,000  
 Zone: 30QDS84  
 Datum: WGS84  
 1 cm = 0.25 km  
 Kilometers 0 0.5 1

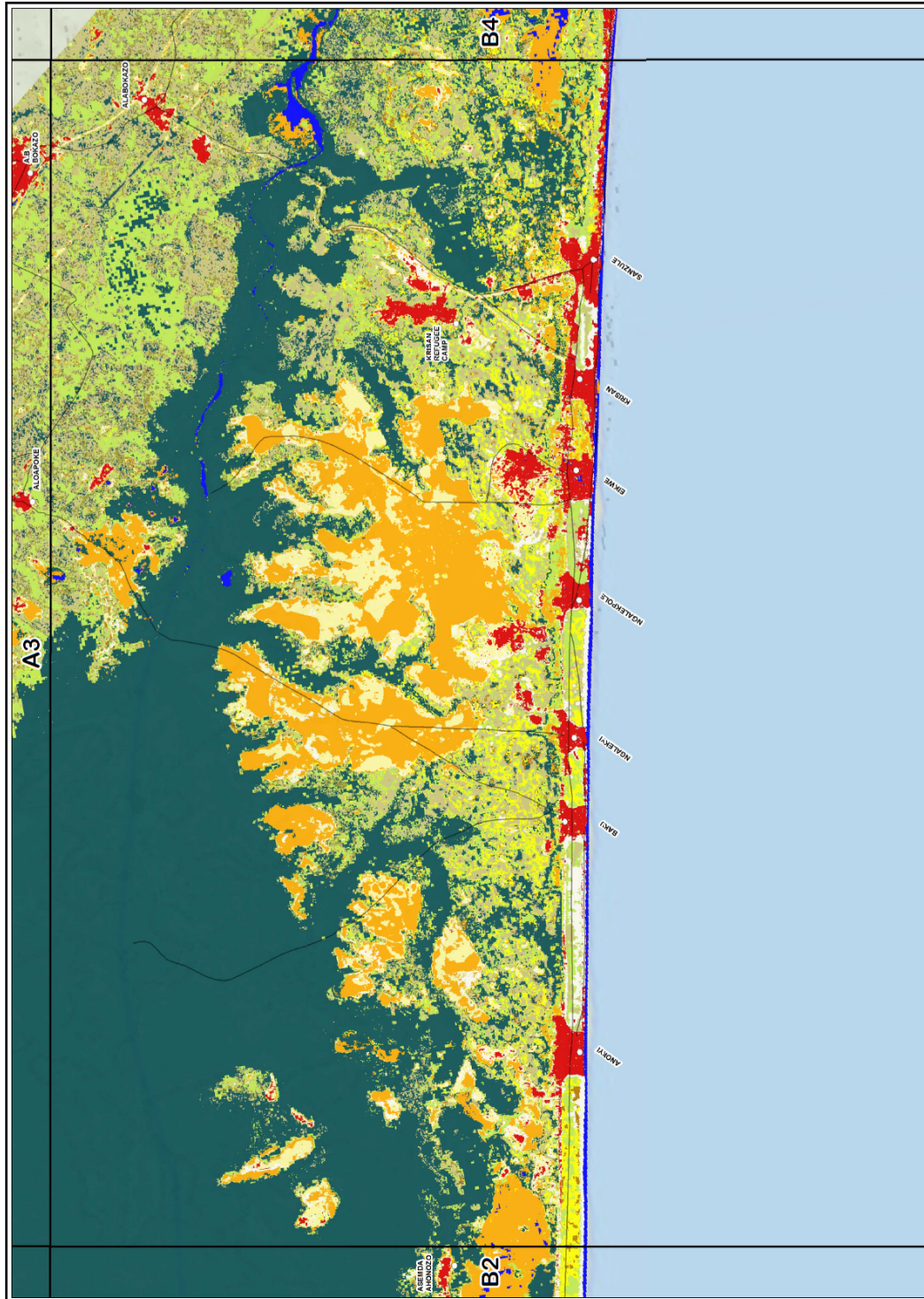
**Data Sources and Processing:**  
 Land cover was derived using RapidEye Level 1B satellite images at 5m resolution from 2010 and 2012.  
 The land cover categories and definitions were adopted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. Air photos were acquired in May, 2010 and used for ground truthing and validation. The land cover classification was performed using the Random Forest machine learning algorithm. All data processing and mapping were conducted at the University of Rhode Island's Laboratory for Terrestrial Remote Sensing and Environmental Data Center.  
 The cell size for these data are 5 meters and are primarily for planning purposes. These data display conditions at the time of image acquisition and provide a regional assessment from which future analyses may be derived.

### 2012 Land Cover for Western Ghana's Amanzule Region

LAND COVER SCHEME	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL
1055	1,055	120	11.3
5275	5,275	332	6.0
4912	4,912	220	4.5
18483	18,483	4,123	22.3
1219	1,219	109	8.9
740	740	126	17.0
1425	1,425	461	32.3
1175	1,175	110	9.4



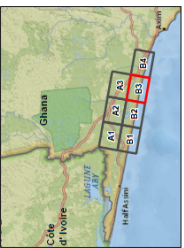
MAP B2



**Classification Scheme**

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest: Regularly Flooded (fresh-brackish)
  - Closed Broadleaved Forest: Permanently Flooded (brackish-saline)
- Artificial and Bare Areas**
  - Artificial Areas
  - Bare Areas
- Cultivated Areas and Managed Lands**
  - Rainfed Croplands
  - Mosaic Croplands/Vegetation
  - Mosaic Vegetation/Cropland
- Herbaceous Vegetation**
  - Closed to Open Grassland
- Shrub Vegetation**
  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreen/Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies

Projection: UTM  
 Units: Meters  
 Scale: 1:25,000  
 Zone: 30N  
 Datum: WGS84  
 1 cm = 0.25 km

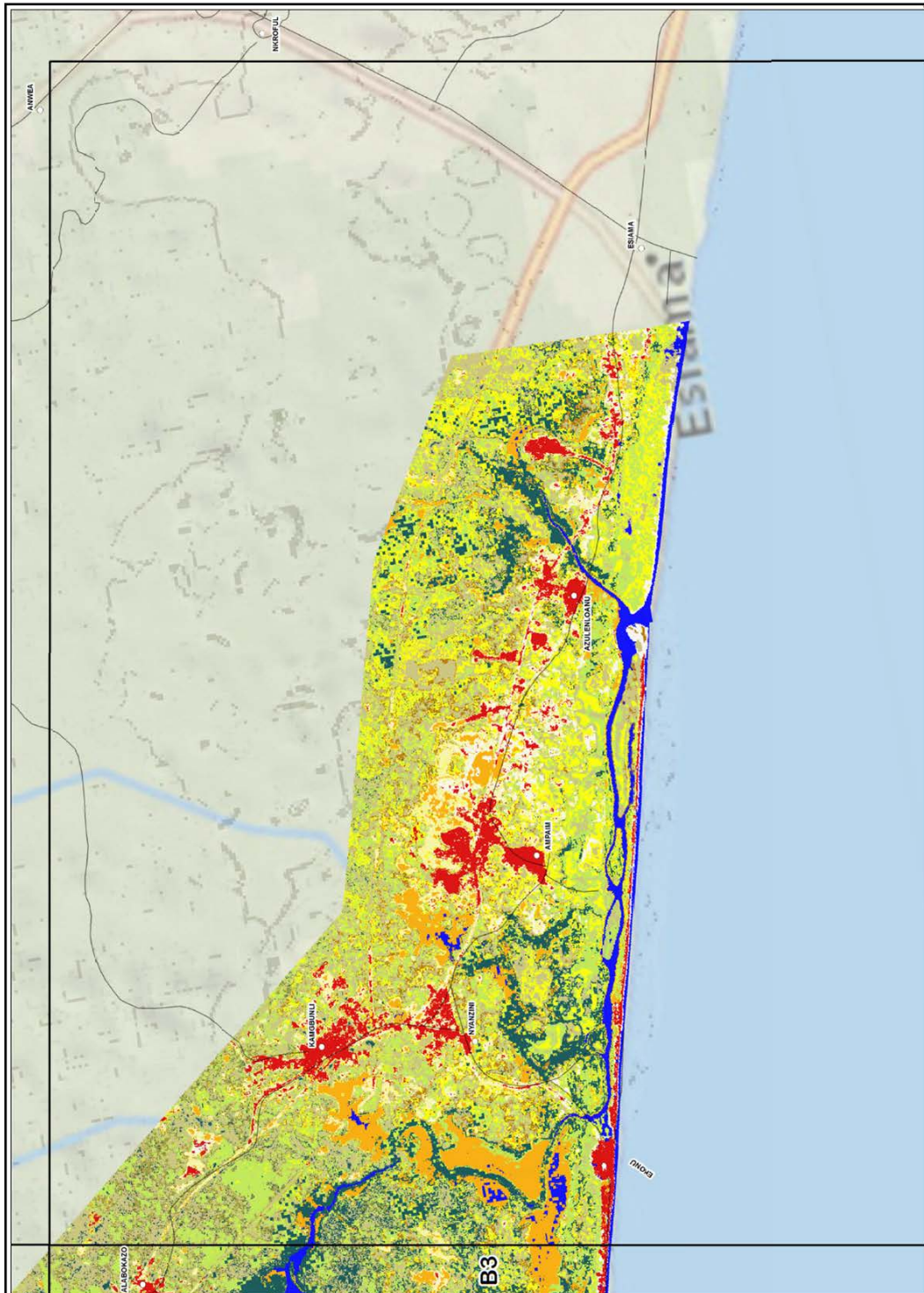


**2012 Land Cover for Western Ghana's Amanzule Region**

LAND COVER COLOR CODE	TOTAL AREA (HA)	AREA IN MAP (HA)	PERCENT OF TOTAL	LAND COVER COLOR CODE	TOTAL AREA (HA)	AREA IN MAP (HA)	PERCENT OF TOTAL
[Green]	1,035	251	23.8	[Red]	18,483	2,848	15.4
[Light Green]	5,575	763	13.7	[Dark Green]	---	---	---
[Yellow]	4,912	794	16.2	[Light Blue]	1,119	182	14.9
[Dark Green]	---	---	---	[White]	740	166	22.5
[Dark Green]	---	---	---	[White]	1,175	327	27.8

**Data Sources and Processing:**  
 This cover was derived using RapidEye Level 1B satellite images at 5m resolution from 2010 and 2012. The land cover categories and definitions were adapted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. The initial classification was performed in May 2013 using stratified classification techniques, and refined in July 2013 after field verification. All data processing and mapping were conducted at the University of Rhode Island's Laboratory for Terrestrial Remote Sensing and Environmental Data Center.  
 The cell size for these data is 5 meters and are primarily for planning purposes. These data display conditions at the time of image acquisition and provide a regional assessment from which future analyses may be derived.

**MAP B3**



**Classification Scheme**

- Aquatic Vegetation**
  - Closed to Open Broadleaved Forest Regularly Flooded (fresh-brackish)
  - Closed Broadleaved Forest Regularly Flooded (brackish-saline)
- Artificial and Bare Areas**
  - Artificial Areas
  - Bare Areas
- Cultivated Areas and Managed Lands**
  - Rainfed Croplands
  - Mosaic Croplands/Vegetation
  - Mosaic Vegetation/Cropland
- Herbaceous Vegetation**
  - Closed to Open Grassland
- Shrub Vegetation**
  - Closed to Open Shrubland
- Sparse Vegetation**
  - Sparse Vegetation
- Woody Vegetation**
  - Closed to Open Broadleaved Evergreen/ Semideciduous Forest
  - Open Broadleaved Deciduous Forest
  - Mosaic Forest - Shrubland/Grassland
  - Mosaic Grassland/Forest - Shrubland
- Waterbodies**
  - Water Bodies

Projection: UTM  
Scale: 1:25,000  
Zone: 30N  
Datum: WGS84  
1 cm = 0.25 km



**2012 Land Cover for Western Ghana's Amanzule Region**

LAND COVER COLOR CODE	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL	LAND COVER COLOR CODE	TOTAL AREA (ha)	AREA IN MAP (ha)	PERCENT OF TOTAL
	1,055	488	46.3		18,483	270	1.5
	5,575	606	10.9		---	---	---
	4,912	982	11.8		1,219	173	14.2
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**Data Sources and Processing**  
Land cover was derived using RapidEye Level 1B satellite images at 5m resolution from 2010 and 2011.

The land cover categories and definitions were adopted from the Land Cover Classification System (LCCS) developed by FAO and UNEP. The initial classification was performed in May, 2013 using RapidEye Level 1B satellite images. The classification was refined through a series of processing and mapping were conducted at the University of Rhode Island's Laboratory for Terrestrial Remote Sensing and Environmental Data Center.

The cell size for these data are 5 meters and are primarily for planning purposes. These data display conditions at the time of image acquisition and provide a regional assessment from which future analyses may be derived.

**MAP B4**