Abu Dhabi Global Environmental Data Initiative (AGEDI)

Abu Dhabi Blue Carbon Demonstration Project

Spatial Data Assessment Report

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Executive Summary

The Abu Dhabi Blue Carbon Demonstration Project, commissioned by the Abu Dhabi Global Environmental Data Initiative (AGEDI) on behalf of the Environment Agency – Abu Dhabi (EAD) aims to improve the understanding of carbon sequestration and other services that coastal and marine Blue Carbon ecosystems provide within Abu Dhabi Emirate. A field based ground-truthing and ecosystem validation assessment, led by UNEP World Conservation Monitoring Centre (WCMC), was undertaken to both assess the existing extent of these ecosystems, and provide the tools and training for future assessments.

Ecosystem layers provided by EAD were derived from several datasets compiled in 2000 and subsequently updated and enhanced through stakeholder workshops conducted in 2012-2013. Field verifications during the project covered 20 sampling areas and a total of 155 ground-truthing sites and were undertaken to assess the true extent of Blue Carbon ecosystems in Abu Dhabi. Whilst focus was on the "traditional" Blue Carbon ecosystems of mangroves, salt marsh (intertidal) and (subtidal) seagrass meadows, algal mats and coastal sabkha were also sampled as potential Blue Carbon ecosystems as the project assessed the ability of these to both sequester and store carbon. In total, the extent of mangroves (51), salt marshes (25), algal mats (10), seagrass beds (34) and coastal sabkhas (18) was recorded to provide an indication of the accuracy of the extent of these mapped ecosystems. Within this sample range, four types of field sites were distinguished: randomly generated points, discrete sites and linear transect points as well as carbon sampling points.

Based on the accuracy assessment, coastal sabkha (83% accurate), seagrasses (77% accurate to approximately 3.5 metres depth) and mangroves (71% accurate) were mapped relatively precisely. Salt marsh habitats were however often misclassified (35% accurate) as mangroves, due to the very similar spectral signature given off by these habitats on satellite imagery. Algal mats (38% accurate) were also often misclassified as sabkha or salt marsh which may reflect the natural succession of habitats over time, the imagery being from 2000 and the field-based sampling taking place 12 years later. The overall accuracy of the maps was 40%. It is suggested that the significant time gap between the mapping and the sampling is the main contributor to the discrepancy in remote and field based observations. There is therefore a need to validate existing maps through field analysis. Such an exercise would be supported through the development of *The Abu Dhabi Blue Carbon Mapping Toolkit* which consists of:

1) Online Assessment Tool (public facing) allowing users to visualise the extent of the blue carbon ecosystems of Abu Dhabi through a mapping interface;

2) Online Validation Tool (pre-approved and registered users only) to remotely validate and edit the various habitat layers;

3) Offline Validation Tool (pre-approved and registered users only) to validate and edit *in situ,* the various habitat layers.

The aim of the *Abu Dhabi Blue Carbon Mapping Toolkit* is to enhance the spatial accuracy of the maps and further define habitat characteristics on state, species composition and condition, as well as to provide an online assessment tool for carbon in an area of interest. The Mapping Toolkit in combination with the capacity building delivered with EAD scientists throughout the project aims to ensure the longevity of the assessment and encourage ongoing updates to capture change over time.

Based on the most recent updates to the habitat layers, the total extent of blue carbon ecosystems in Abu Dhabi is 188,000 ha (1,880 km^2) (0.28% of the total area of the Abu Dhabi Emirate). Of the various Blue Carbon and potential Blue Carbon ecosystems, seagrasses are the most abundant in Abu Dhabi and extend over 158,000 ha (1,580 km^2). As the seagrass layer is currently based upon the amalgamation of remote sensing imagery to 3.5 m and local expert knowledge, the actual extent of seagrass is expected to be an underestimate, particularly at deeper depths.

Combining these spatial results with those obtained from the carbon baseline assessment, seagrasses in Abu Dhabi are calculated to store an estimated 30 million tonnes of carbon dioxide equivalent (CO_2 equivalent) within the soil and biomass. Mangrove area is estimated at approximately 14’000 ha (140 km^2), storing 5 million tonnes of CO_2 equivalent; Salt marsh area is estimated at 4’800 ha (48 km^2) and stores a total of 1.2 million tonnes of CO_2 equivalent; Algal mats extended over 10,930 ha (109.3 km^2) and were found to contain the highest carbon stock per unit area (130 Mg/ha^{-1} (13,000 Mg/km^2)), contributing to nearly 5.2 million tonnes of CO_2 equivalent. As a result of the carbon baseline assessment coastal sabkhas have been identified as an associated Blue Carbon ecosystem as, although they do not actively sequester carbon, they do cap buried former Blue Carbon soil deposits and therefore prevent the release of stored carbon. For this reason and the relatively small sabkha sampling number, appropriate for a Demonstration Project, sabkha has not been included as a dedicated Blue Carbon ecosystem within the Abu Dhabi Blue Carbon Mapping Toolkit. It is however represented in the Toolkit and has been attributed a carbon value of zero (0) along with an explanation to the user of the above.

It is recognised that an ecosystem reclassification is currently being undertaken by EAD and that this will greatly enhance the spatial accuracy and associated carbon stock estimates. Key recommendations for areas of focus based on the outcomes of the *Abu Dhabi Blue Carbon Demonstration Project* include:

- A renewed effort to map seagrass as their extent is likely to be significantly underestimated, particularly at deeper depths, and;

- Additional sampling of sabkha and algal mats to improve the understanding of their contribution to carbon storage and the potential carbon lost when they are converted.

1 Introduction

1.1 Project Context

"Blue Carbon" refers to the ability of coastal vegetation to sequester carbon. Focus is on quantifying carbon stocks in "traditional" Blue Carbon ecosystems of mangroves, salt marsh (intertidal) and seagrass meadows (subtidal). Algal mats and coastal sabkha were also sampled as potential Blue Carbon ecosystems as the project assessed the ability of these to both sequester and store carbon. When these ecosystems are destroyed, buried carbon can be released into the atmosphere as carbon dioxide, contributing to global warming.

As a result of the carbon baseline assessment coastal sabkha has been identified as an associated Blue Carbon ecosystem as, although they do not actively sequester carbon, they do cap buried former Blue Carbon soil deposits and therefore prevent the release of stored carbon. For this reason and the relatively small sabkha sampling number, appropriate for a Demonstration Project, sabkha has not been included as a dedicated Blue Carbon ecosystem within the Abu Dhabi Blue Carbon Mapping Toolkit. It is however represented in the Toolkit and has been attributed a carbon value of zero (0) along with an explanation to the user of the above.

In addition to their climate related benefits, Blue Carbon ecosystems provide highly valuable *Ecosystem Services* to coastal communities. They protect shorelines, support coastal tourism, and provide nursery grounds for fish and habitats for a wide range of species. They also have significant cultural and social value. The conservation and restoration of Blue Carbon ecosystems can be supported by funds generated through 'Payment for Ecosystem Services' schemes such as carbon offsets.

The Abu Dhabi Blue Carbon Demonstration Project aims to improve our understanding of carbon sequestration and the other services that coastal and marine Blue Carbon ecosystems provide. The project will enhance local capacity to measure and monitor carbon in coastal ecosystems, and to manage associated data. It will also identify options for the incorporation of these values into policy and management, with the intention of supporting sustainable ecosystem use and the preservation of their services for future generations.

1.2 International Context

The Blue Carbon concept has strengthened interest in the management and conservation of coastal marine ecosystems, supporting climate change mitigation efforts. However, there are still gaps in our understanding of Blue Carbon, and incentives are needed to ensure more sustainable environmental management practices.

The experience and knowledge gained from the project will help guide other Blue carbon projects and international efforts, such as the Global Environment Facility's (GEF) Blue Forests Project, of which Environment Agency – Abu Dhabi (EAD) are a partner. It will help develop Blue Carbon science and data management through the production of tools and the testing of methodologies that can be utilized and up-scaled to the international arena and will enhance international Blue Carbon cooperation and training.

1.3 Project Setting

In just over 40 years, Abu Dhabi has evolved from a small fishing community to the largest and most populated of the seven Emirates of the United Arab Emirates (UAE). With the vision and direction from His Highness the late Sheikh Zayed Bin Sultan Al Nahyan, the environment has become an intrinsic part of the heritage and traditions of the people of the UAE.

This national affinity to the sea has led to the initiation of the Abu Dhabi blue carbon Demonstration project in order to explore the values which coastal ecosystems provide the UAE, and to help preserve our environmental and cultural heritage. The project, commissioned by the Abu Dhabi Global Environmental Data Initiative (AGEDI) on behalf of Environment Agency – Abu Dhabi (EAD) will run until the end of 2013.

1.4 Project Structure

The project is comprised of five components:

1) A **carbon baseline assessment** that will estimate the stocks of carbon for coastal ecosystems, and rate of carbon sequestration associated with mangrove afforestation;

2) A **geographic assessment** that will map Abu Dhabi's Blue carbon ecosystems and provide a carbon analysis tool to support informed decision making (subject of this report);

3) An **ecosystem services assessment** that will investigate the goods and services beyond carbon sequestration that Blue carbon Ecosystems provide Abu Dhabi with;

4) A **policy component** that will identify the most suitable options for incorporating Blue carbon and Ecosystem Services in Abu Dhabi's policy and governance frameworks; and

5) A **blue carbon and ecosystem services finance feasibility assessment** that will pull together the findings of each component to recommend the most feasible policy and market options for implementing blue carbon projects in Abu Dhabi.

1.5 The Geographic Team

The UNEP World Conservation Monitoring Centre (WCMC, the Centre) has undertaken the geographic assessment component of the Abu Dhabi Blue Carbon Demonstration Project. UNEP-WCMC is the specialist biodiversity assessment arm of the United Nations Environment Programme. The Centre has been in operation for over 30 years, combining scientific research with policy advice and the development of decision-support tools. To do this, UNEP-WCMC sources, verifies and collates data on biodiversity and ecosystem services; interpret and analyse information to provide comprehensive assessments and policy advice; and make the results available in appropriate forms for national and international level decision-makers and businesses.

The work was conducted by the Marine Assessment and Decision Support Programme (MADS), led by Jan-Willem van Bochove, Programme Officer, with overall oversight provided by Dr. Damon Stanwell-Smith, the Head of the MADS programme. As part of this component, a small team of field specialists conducted a three-week accuracy assessment of the Blue Carbon ecosystems of Abu Dhabi. This element was led by Robert Irving, a consultant contracted to lead the fieldwork. The fieldwork was supported by Kerstin Brauneder and Kamila Janiak, specialists in geology and marine science respectively.

1.6 The Abu Dhabi Blue Carbon Mapping Toolkit ("The Mapping Toolkit")

The Mapping Toolkit was designed to support the geographic component of the *Abu Dhabi Blue Carbon Demonstration Project* and allow for the validation and updating of Blue Carbon ecosystems through integrated online (web-based) and offline (tablet-based) technology. During the project the Mapping Toolkit was used to map and validate Blue Carbon ecosystems throughout the fieldwork. Capacity building undertaken throughout the project aims to ensure that this continues post project. More information on using The Mapping Toolkit to support ecosystem validation can be found in Section 5.

1.7 Report objectives and outline

This report describes the accuracy of the baseline spatial data provided by EAD and included within The Mapping Toolkit as assessed through *in situ* and remote validations, as well as providing an estimate of the overall extent of Blue Carbon ecosystems in Abu Dhabi, and the associated carbon stocks held. This data underpins both the online validation and data analysis tools, as well as the offline tablet-based technology. As the information presented in The Toolkit may be used to inform decisions relating to environmental and coastal zone management, it is critical that the quality of the underlying data is understood. The spatial data assessment is also referred to as *ground-truthing* or *accuracy assessment*. It includes:

Section 1: Introduction – Setting the context of the *Abu Dhabi Blue Carbon Demonstration Project* and in particular the Geographic component;

Section 2: Background information - Background information on the origin of the baseline spatial datasets used within The Mapping Toolkit

Section 3: Undertaking the Spatial Data Assessment - A brief review of good-practice in spatial dataset assessments methodology and classification used for the fieldwork, including an overview of field work and the location of field sites;

Section 4: Spatial Data Assessment Results – Results of spatial data assessment and discussion of the validity of assessment results based on statistical analysis;

Section 5: Spatial Data Assessment Outcomes – Outcomes of the assessment, emphasising data gaps identified and the potential of the Abu Dhabi Blue Carbon Mapping Toolkit to enhance existing ecosystem maps;

Section 6: Conclusions – implications for Abu Dhabi and the future of Blue Carbon spatial data.

2 Background information

2.1 Background on source data layers

2.1.1 Overview of source data layers

In November of 2012, EAD provided UNEP-WCMC with spatial data on five blue carbon habitats of Abu Dhabi: Salt marsh, Seagrass, Sabkha, Mangroves and Algal mat. This was contained within two ArcGIS Shapefiles:

- ***UAE_Ecological_Habitat***: an integrated habitat proxy map produced by Hyder Consulting on behalf of EAD in 2012 (Holness, 2012). The classification scheme distinguishes 39 mutually exclusive inland, coastal and marine habitats. Of these, four blue carbon habitats were retained: salt marsh, coastal sabkha, seagrass and algal mats. Habitat extents were initially derived from satellite imagery from the year 2000.

- ***Mangrove_Update_2012:*** contains the extent of mangrove habitats in Abu Dhabi for2012. This dataset was produced based on a review of the extent of mangroves within UAE_Ecological_Habitat data layer using a combination of an unsupervised classification of Quickbird (2006) imagery with a manual on-screen digitization of RapidEye (2012) imagery.

The report refers to each dataset by the name of its ArcGIS shapefile. An overview of source layers provided by EAD that constitute the baseline spatial data of The Tool is illustrated in **Figure 1.**

Figure 1: Overview of source layers provided by EAD that constitute the baseline spatial data of The Abu Dhabi Blue Carbon Mapping Tool

Mangroves 2012

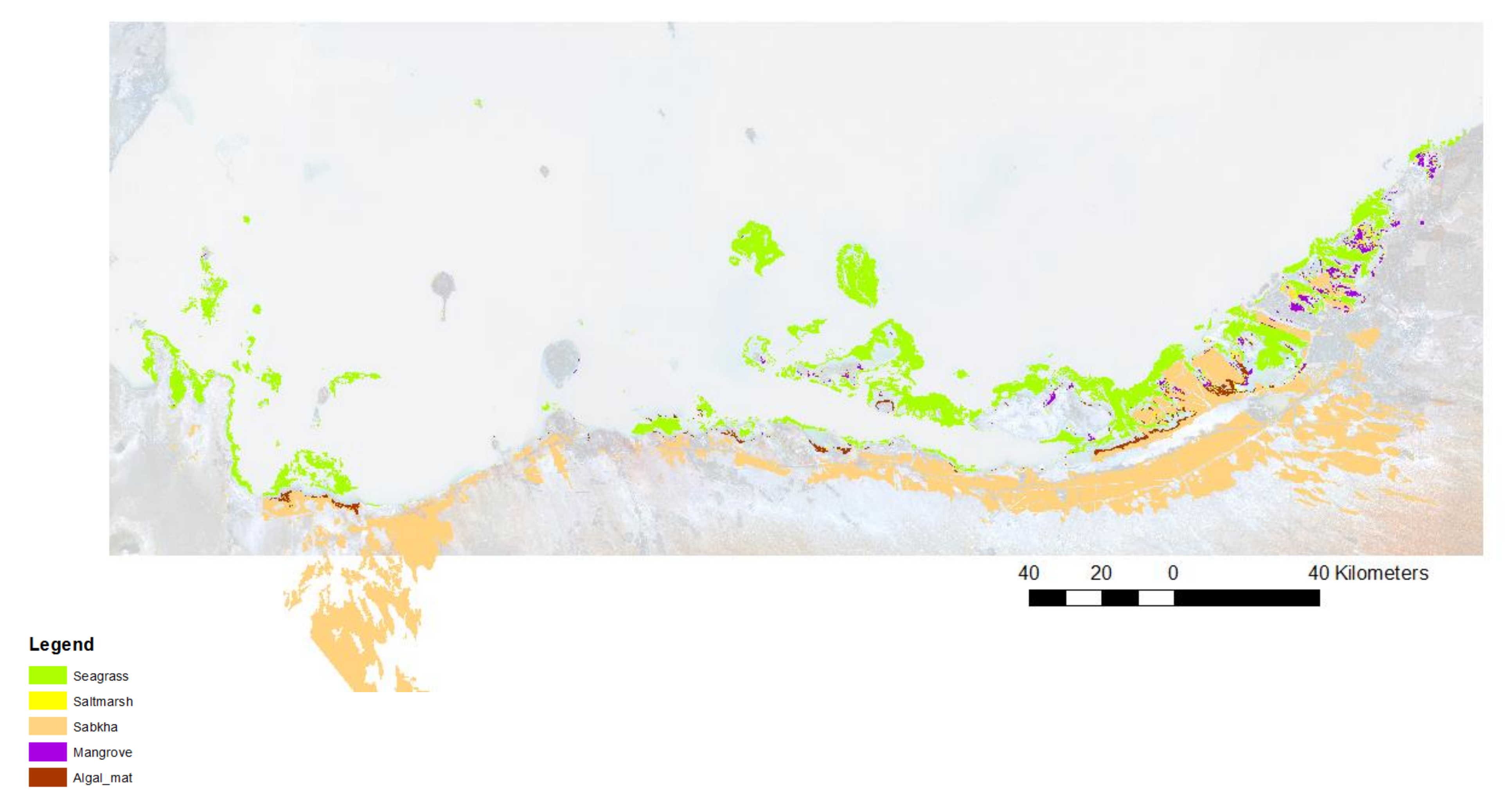
Source: Mangrove_update_2012
Method: Image classification derived from Quickbird 2006. Visual interpretation, refining and onscreen digitization based on RapidEye 2012 imagery (1m resolution)

Saltmarsh, Algal Mat, Seagrass, Sabkha

Source: UAE_Ecological_Habitat, Integrated Habitat Proxy Map produced by Hyder Consulting on behalf of EAD (2012)
Method: Collation of pre-existing datasets and consultation with experts. Majority of data derived from the Coastal Resources Atlas for Abu Dhabi (2010) based on classification of Landsat 2000 imagery (30m resolution)

RapidEye Satellite Image 2012

Source: EAD
Specifications: Bands 1, 2 , 3



SOURCE: RapidEye (2012), Habitat data: "UAE_Habitat_Layers". "Mangrove_Update_2012"
Provided by Environment Agency – Abu Dhabi

Abu Dhabi Blue Carbon Demonstration Project

Figure 2

Map of the five Blue Carbon habitat source layers

2.1.2 UAE_Ecological_Habitat (2000): Origin, age and resolution of source data

The integrated ecosystem map *"UAE_Ecological_Habitat"* was derived from several datasets compiled in 2012, and subsequently updated and enhanced through stakeholder workshops held in 2012 as part of the *Local, National Regional Biodiversity Assessment Project*. Data was derived from 12 different capture sources, as distinguished by their shapefile attributes. This is illustrated in Table 1.

Table 1: Percentage of total polygons of *UAE_Ecological_Habitat (2012)* derived from different capture sources (as recorded within metadata)

Capture Sources	% of total polygons
Data supplied by: EAD, CMRECS	81.67
Data created from: Abu Dhabi Soils and Vegetation GIS Data	6.26
Digitised using The National Atlas of UAE (Geology Map) 1993	3.95
Automated polygons from Union process in ArcGIS	3.75
Data Supplied by John Burt, NYU Abu Dhabi, July 2012	1.76
Derived from GEBCO Contours	1.33
Data created from: Northern Emirates Soil and Vegetation GIS Data	0.94
Derived from surrounding polygons	0.20
Data supplied by: UNEP WCMS (*sic*)	0.07
Data created from: The National Atlas of UAE (Geology Map) 1993	0.05
Derived from satellite imagery	0.01
Polygon amended based on discussion with Dick Hornby	0.01

As outlined in Table 1, the majority of polygons are imported from a habitat map derived from EAD's Coastal Resources Atlas for Abu Dhabi (launched online in 2010), enhanced with data from EAD's soil and vegetation survey for Abu Dhabi and the Northern Emirates (carried out in 2006-2009).

The datasets for algal mats, salt marsh and seagrass/macro-algal beds included in The Mapping Toolkit are also primarily derived from EAD's Coastal Resources Atlas for Abu Dhabi, which follows the Coastal and Marine Resources and Ecosystem Habitat Classification System. The extent of these ecosystems is noted in Table 2.

Table 2: Percentage of marine polygons in UAE_Ecological_Habitat derived from the EAD, CMRECS methodology.

Habitat	Polygons derived from EAD, CMRECS	Total	% of total
Algal mat	959	1008	95.1
Salt marsh	1485	1527	97.2
Seagrass / macro-algal beds*	3819	3824	99.9
Mangroves	1458	2286	63.7
Coastal Sabkha	11	631	1.7

* Note: This base layer classified seagrass/macro-algal beds as one habitat category, however Blue Carbon field surveys concluded seagrass as dominant, interspersed with some macro-algal beds.

CMRECS was a project completed by *Applied Science Associates* on behalf of EAD in 2010, for which the final report[1] was not available at the time. Information on the remote sensing methodology, underlying the generation of the Blue Carbon habitat extents was therefore based on The Marine Habitat Workshop (June 28th, 2012), as well as reports produced by Hyder Consulting (AGEDI, 2012a, 2012b, 2012c; Holness, 2012; Parr, 2012a, 2012b). These indicate:

- The CMRECS data is derived from an unsupervised[2] classification by remote sensing of Landsat Enhanced Thematic Mapper imagery, with a 30m resolution;

- The CMRECS data represents the extent of Clue Carbon ecosystems in the year 2000 (as understood in direct communication with EAD). This was however subsequently updated to include areas of modified coastline, as suggested by a statement in issue 10 of the *Decision Table of the Marine Habitat Workshop* (AGEDI, 2012b): "*The CMRECS data reflects the habitat distribution as well as the modified coast from imagery obtained in 2010*".

2.1.3 Mangrove_Update (2012): Origin, age and resolution of source data

The mangrove data sets, sourced from Mangrove_Update_2012 were derived from a combination of an unsupervised classification of Quickbird (2006) imagery of 2m resolution, enhanced by manual on-screen digitization of RapidEye (2012) imagery of 1m resolution.

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[1] *Applied Science Associates 2010 Coastal and Marine Resources and Ecosystem Habitat Classification System*. Unpublished Report for Environment Agency - Abu Dhabi.

[2] **Unsupervised classification**: Classification seeking to group together cases by their relative spectral similarity, without the user specifying how to classify any portion of the image.

Polygons outlining the extent of mangrove ecosystems within *Mangrove_update_2012* are not mutually exclusive with *UAE_Ecological_Habitats* and spatial overlap between mangroves and other ecosystems does occur in places. This is as a result of the reclassification of some of the mangrove areas in further updates. While the total area of mangroves in the 2000 dataset was 155 km^2, the newly mapped area presented 141 km^2 of mangroves. The discrepancy between these two datasets is likely to be a result of the rapidly changing coastline of Abu Dhabi between 2000 and 2012. Should this be the case, the dramatic loss of 26% of the Emirates mangroves in 12 years has significant environmental management implications.

2.1.4 Classification scheme used in source data

Remotely sensed data forms the basis of the majority of the ecosystem information used within The Mapping Toolkit. Thematic habitat mapping was based on an imagery classification, either classified through computer aided techniques (UAE_Ecological_Habitat) or visual interpretation (Mangrove_update_2012).

The classification scheme used for Blue Carbon ecosystems in the source maps are listed in Table 3, and more information can be found in Holness (2012) report. The classification is a compilation of definitions from Brown & Boer (2004), Feulner (1998), CMRECS (2010) and results from the workshop on marine habitats (AGEDI, 2012b).

Table 3: Description of Blue Carbon ecosystems in the classification scheme used in the Abu Dhabi Blue Carbon Mapping Toolkit source maps

Ecosystem group: Coastal sabkha
Ecosystem type: Coastal sabkha Salt encrusted substrate close to the coast covering wide expanses. Coastal sabkha is devoid of vegetation due to the salinity of the substrate, although halophytes may occur where there is a thin carpeting of sand on the surface (Brown & Boer, 2004).
Ecosystem group: Intertidal
Ecosystem type: Algal Mats Sheltered low-angle intertidal areas typically composed of unconsolidated sediment (sand or mud) with extensive cover of algal or microbial mats (CMRECS, 2010)
Ecosystem type: Mangroves Intertidal areas dominated by true mangroves and associates (CMRECS, 2010)
Ecosystem type: Salt marsh Intertidal areas dominated by emergency halophytic herbaceous vegetation and shrubs (CMRECS, 2010)
Ecosystem group: Shallow marine water habitats
Ecosystem type: Seagrass / Marco-algal beds Subtidal benthic substrates, generally compose of unconsolidated sediments, and characterised by greater than 10% cover of rooted vascular seagrass species (CMRECS, 2010)

2.2 Background on Accuracy Assessments

2.2.1 Overview of the Accuracy Assessment approach

The spatial data was assessed by performing an accuracy assessment, specifically, a *quantitative assessment of thematic accuracy*. Thematic accuracy assesses the degree to which the classification of polygons on the map (map classification) conforms to observations on the ground (field classification), in order to identify common confusions or omissions of classes.

Thematic accuracy assessments involve the collection and comparison of two kinds of data for each sampling site:

1) **Map data** - *The ecosystem class label of the accuracy assessment site, which is derived from the map being assessed (in this case the UAE_Ecological_Habitat and Mangroves_2012 data).*

2) **Ground data** - *The ecosystem class label of the accuracy assessment site, which is derived from data collected in the field. These are assumed to be correct, however the use of the term ground-truth is discouraged as the ground data may also be subject to interpretation errors by the field staff.*

Three basic stages are involved in an accuracy assessment.

1) ***Sampling strategy*** designed to determine the number of samples to be collected, the distribution of samples across thematic map classes and the size of the sampling parcels (section 3.1);

2) ***Field work*** undertaken to collect ground data (section 3.2);

3) ***Map data and ground data*** compared using an error matrix (section 4.1), including an analysis of the statistical significance of differences (section 4.3).

Good-practice rules for thematic accuracy assessments include (Congalton & Krass (2008), Foody (2002)):

1) Using the same minimum mapping unit in the field as was used during the creation of the map (section 3.1.1);

2) Using the same classification scheme in the field as was used during the creation of the map. This is of particular relevance in the case of mixed ecosystems commonly found in Abu Dhabi (section 3.1.3);

3) Collect the validation field data at the same time, or as soon as possible after the creation of the map.

It is acknowledged that the challenge of completing successful accuracy assessments lies in balancing statistical validity with practical application (Congalton & Green, 2008). Although changes to the planned fieldwork sampling strategy due to weather conditions and logistical challenges may decrease the confidence level of the accuracy of outputs, for the purposes of this Demonstration project, this is considered as acceptable and lessons learnt for future applications both within Abu Dhabi and elsewhere.

2.2.2 The Accuracy Assessment Error matrix

An error matrix is a useful and widely recognised way to present comparisons from the ground data to the habitat map data (Figure 3). It is a square array of numbers set out in rows and columns which express the field classification label, relative to the map classification label. The classifications located in the columns are the ground data verified by observation and assumed to be correct. The classifications located in the rows are the associated habitat map data which are being assessed for accuracy.

Figure 3: Example error matrix

		Mangroves	Salt marsh	Seagrass	*No. of samples*	User accuracy
Classified in habitat map as:	**Mangrove**	**46**	2	2	50	92%
	Salt marsh	10	**37**	3	50	74%
	Seagrass	5	1	**44**	50	88%
	No. ground truthed points:	61	40	49	**150**	**Overall accuracy**
	Producer accuracy:	75%	93%	90%		**84.67%**

Error matrices are very effective representations of map accuracy because the individual accuracies of each map category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the map. A commission error occurs when an area is included as an incorrect category. An omission error occurs when an area is excluded from the category to which it belongs. Every error on the map is therefore an omission from the correct category and a commission to an incorrect category. In addition to clearly showing errors of omission and commission, the error matrix can be used to assess overall accuracy, as well as producer's accuracy, and user's accuracy (**Figure 3**):

1) **Overall accuracy** is the sum of the major diagonal (i.e. the correctly classified sample units) divided by the total number of sample units in the error matrix. It is the percentage of cases correctly allocated and represents the overall thematic accuracy of the classification. This value is the most commonly reported accuracy assessment statistics. In our example, the overall accuracy is 84.67%;

2) **Producer's and user's accuracies** are ways of representing individual category accuracies as opposed to the overall classification accuracy. Each diagonal element is divided by the column total to yield a producer's accuracy and by the row total to yield a user's accuracy. This approach ensures that any issue with accuracy can be addressed at source.

    a. **The producer's accuracy** (exclusion error) indicates how well the map classified a particular ecosystem, e.g. the percentage of times that substrate known to be seagrass was correctly interpreted as seagrass. In our example, the producer accuracy for mangroves is 46/61 = 75%;

    b. **The user's accuracy** (inclusion error) indicates how often map polygons of a certain type were classified correctly, e.g. the percentage of times that a polygon classified as seagrass was actually seagrass. In our example, the user accuracy for salt marsh is 37/50 = 74%.

3 Undertaking the Spatial Data Assessment

3.1 Sampling strategy

3.1.1 Size of sampling parcel and Minimum Mapping Unit (MMU)

The sampling parcel is the area surveyed by the field sampling team, and over which the ecosystem is classified for the accuracy assessment. The Minimum Mapping Unit (MMU) is a feature of the source map; it is the smallest size areal entity to be mapped as a discrete entity and can be understood as the smallest feature on a map that was reliably mapped (Knight & Lunetta, 2003).

A sampling parcel equal to the MMU is selected is recommended (Congalton & Green (2008)). The MMU is usually defined within the initial mapping protocol; however this information was not available. A sampling parcel size of 30 x 30m was therefore selected for the field work, based on the assumption that the MMU is equal to one pixel of the imagery used to generate the map (e.g. a nominal resolution of 30 x 30m in the case of Landsat ETM imagery). For methodological consistency in the field, 30 x 30m sampling parcels were also used for validating the mangrove 2012 layer, which is based on imagery with a nominal resolution of 3 x 3m.

3.1.2 Field classification scheme

Ecosystems encountered during the fieldwork were identified according to the classification scheme used within the source maps (**Table 3**). A new "anthropogenic" class was created in the field in order to designate areas that had undergone land use change i.e. developed (e.g. a highway construction site) since the creation of the habitat map. The sampling teams familiarised itself with these in advance to ensure consensus while labelling the ground data separately. A sample fieldsheet is included within Appendix A.

3.1.3 Classification protocol for mixed ecosystems

The classification scheme is mutually exclusive, requiring that a single reference label be attributed per sample site. Classification schemes rules therefore impose discrete boundaries on continuous conditions, which can be problematic when sampling teams are faced with mixed habitats. In the majority of cases, the classification was unambiguous, with a particular habitat undoubtedly covering the majority of the sampling parcel. Out of the 148 sampling sites, 12 sites or an equivalent of 8% of sites were ambiguous and classified as mixed.

The classification of mixed ecosystems is particularly vulnerable to observer variability (Congalton & Green, 2008). To minimize the impacts of observer variability, the assessment of mixed ecosystems was undertaken after the field work and a set of decision rules defined. Ideally, the decision rules used in the attribution of the field class would be the same as those used in the initial satellite imagery analysis. In the absence of information relating to these, a new set of decision rules were created:

1) If one of the ecosystem classes observed is the same class on the map, that class is selected (bias towards higher accuracy). The dominant of the two classes observed in the field was selected;

2) If the observed dominant ecosystem class was misclassified on the map, the observed class was selected over the mapped class.

3.2 Data collection

3.2.1 Parameters recorded

The parameters recorded in the field to classify individual parcels during post-field analysis included:

1) Percentage of habitat(s) in a 30 x 30m parcel;

2) Percentage cover categorised into four categories: sparse (<20%), moderate (20%-50%), dense (50%-80%) and very dense (>80%);

3) For mangroves, a visual estimate of percentage cover by the canopy (e.g. surface area covered by mangrove canopy, rather than trunk diameter);

4) Photographs towards 4 cardinal directions (north, east, south, west).

Parameters were recorded onto fieldsheets and transferred onto Excel spreadsheets the same day. Appendix A provides a sample fieldsheet. Where possible, data parameters were also recorded through the offline validation tool (tablet-based iOS). An Excel database was used to bring together all the field data and was used for further analysis and mapping of the ground-truthing and validation data.

3.2.2 Location of sampling area and field sites

Samples were collected between January 15th and January 28th, 2013. 20 sampling areas were visited during this period, covering just over 2% of the total area of Abu Dhabi's coastal ecosystems. Within this, the aim was to select representative sites to visit, making sure to include all of the relevant Blue Carbon ecosystems in a variety of situations (i.e. as large areas covering single ‘uniform’ ecosystems or as smaller areas of mixed ones). A total of 194 field sites were assessed, of which 155 were suitable for ground truthing (**Table 5**). Sites not suitable for ground-truthing included those which were restricted due to physical boundaries, logistical limitations, required permission outside EAD’s jurisdiction to access, or which were not accessible safely due to weather conditions.

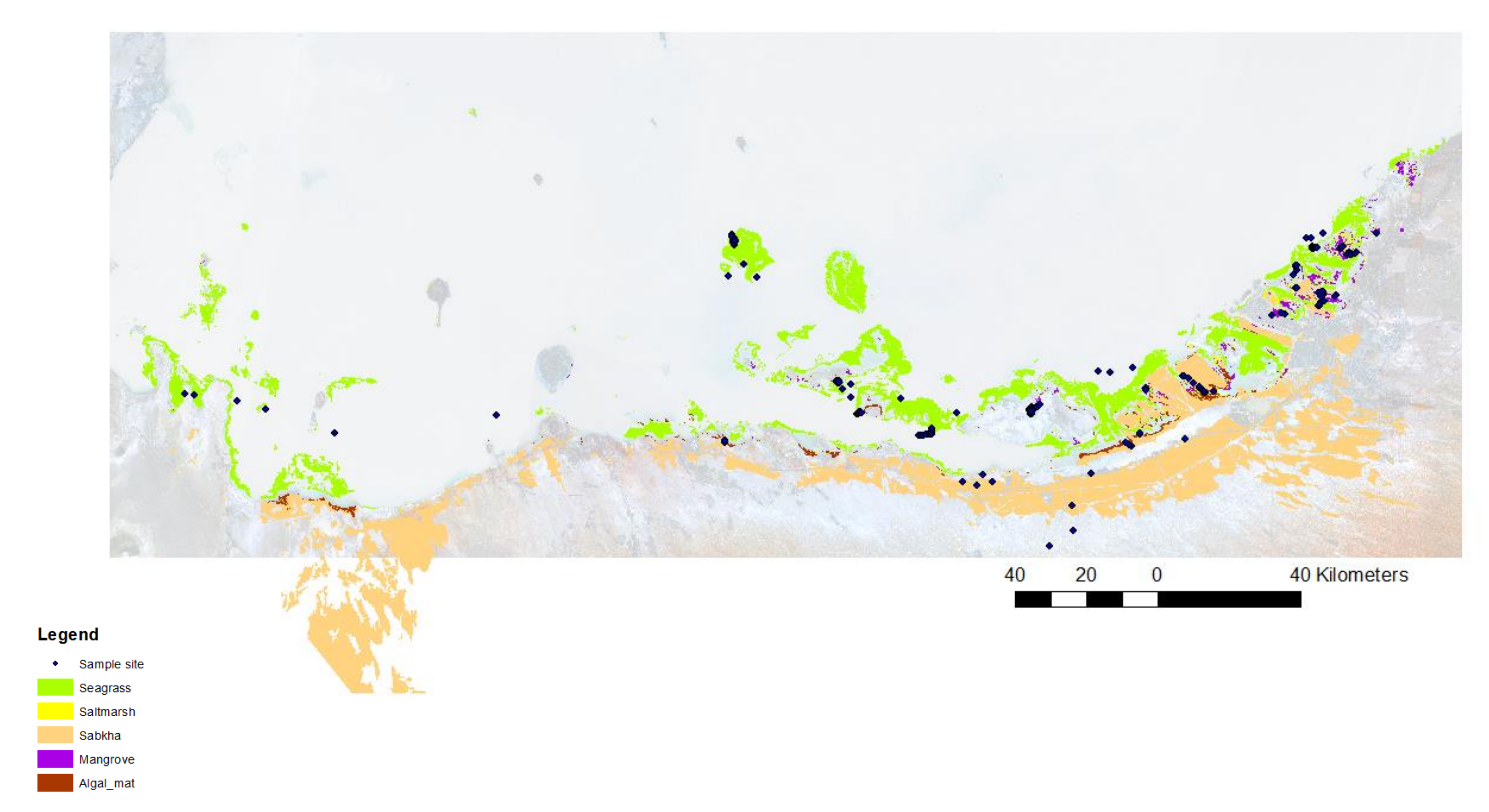
Within this sample, four types of field sites were distinguished:

1) **Randomly generated sites**: Points generated through a GIS-based random sampling scheme across one or several ecosystems polygons (42/155 points);

2) **Discrete sites**: Individual points of interest (21/155 points);

3) **Transect points**: Points collected along a linear transect across one of several habitats (41/155 points);

4) **Carbon sample points:** Points where a carbon core sample was taken. As several carbon samples were taken along a transect in very close proximity to each other, a single coordinate was calculated as a median location within the subset (51/155 point).



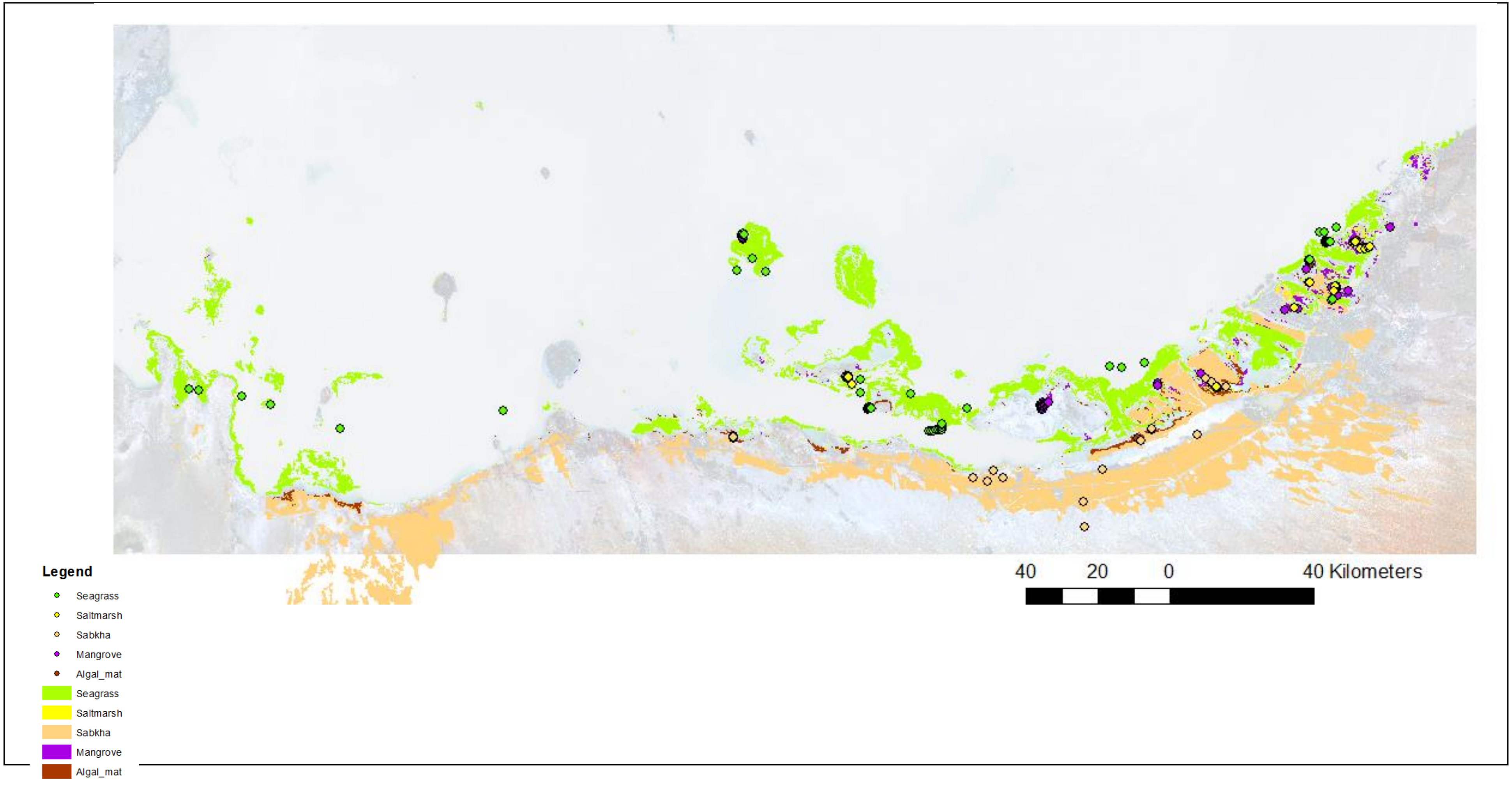
SOURCE: RapidEye (2012), Habitat data: “UAE_Habitat_Layers”. “Mangrove_Update_2012”

Provided by Environment Agency – Abu Dhabi

*Non blue carbon *sites were only sampled in the case where Blue Carbon ecosystems were expected*

Figure 4

Distribution of all 155 sampling points in the study area, including non-Blue Carbon habitats*



SOURCE: RapidEye (2012), Habitat data: "UAE_Habitat_Layers". "Mangrove_Update_2012"

Provided by Environment Agency – Abu Dhabi

Abu Dhabi Blue Carbon Demonstration Project

Figure 5

Distribution of 138 Blue Carbon habitat sampling points in the study area

4 Spatial Data Assessment Results

4.1 Error matrix

The ground data was collated within a GIS point layer, which was spatially joined to the source maps in order to identify the map classification for each point. Results of this comparison are presented in the error matrix (Table 4). Any ambiguous points were evaluated using high-resolution imagery in Google Earth (mostly 2013 Digital Globe Imagery) and photographs taken in the field, using the tablet-based (iOS) Validation Tool.

Table 4: Error matrix for Blue Carbon ecosystems

MAP DATA	GROUND DATA: Mangroves	Salt marsh	Algal mats	Coastal sabkha	Seagrass[1]	Shallow water[2]	Coral reef	Tidal flats[3]	Sand[4]	Dunes[5]	Sand sheets[6]	Rocky platforms	Island	> 15m depth	Anthropogenic	SUM	User accuracy (%)
Mangroves	25	8	1	0	0	0	0	0	1	0	0	0	0	0	0	35	**71**
Salt marsh	7	6	1	0	0	0	0	0	3	0	0	0	0	0	0	17	**35**
Algal mats	2	7	8	3	0	0	0	0	1	0	0	0	0	0	0	21	**38**
Coastal sabkha	2	0	0	10	0	0	0	0	0	0	0	0	0	0	0	12	**83**
Seagrass[1]	0	0	0	0	10	2	1	0	0	0	0	0	0	0	0	13	**77**
Shallow water[2]	3	1	0	0	20	2	2	0	0	0	0	0	0	0	0	28	**Classes not targeted**
Coral Reef	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	
Tidal flats[3]	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
Sand[4]	0	0	0	4	0	0	0	0	1	0	0	0	0	0	1	6	
Dunes[5]	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	
Sand sheets[6]	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	
Rocky Platform	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Island	6	2	0	0	0	0	0	0	2	0	0	0	0	0	0	10	
> 15m depth	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3	
No eq. class	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
SUM	51	25	10	18	34	4	3	0	8	1	0	0	0	0	1	**155**	
Producer accuracy (%)	**49**	**24**	**80**	**56**	**29**	**Classes not targeted**										**Overall accuracy (%): 40%**	

[1] *Seagrass / macro-algal beds*
[2] *other shallow water (>15m), with no seagrass*
[3] *i.e. mud and salt flats, no algal mats*
[4] *Sand (Island / Coastal plains, sand sheets and dunes)*
[5] *Sand sheets, dunes and mega-dunes*
[6] *Sand sheets and dunes with distinct shrub cover or dwarf shrub cover*

Producer[3] and user[4] accuracies were only calculated for the ecosystems of interest under the Abu Dhabi Blue Carbon Demonstration Project. This is to differentiate between classes that were targeted, as opposed to classes that were merely intersected. Furthermore, targeted classes have a higher sample number and are therefore more representative.

4.1.1 *Individual class accuracy*

Based on the results from the error matrix, the following conclusions can be drawn:

1) Relatively high user accuracies (>70%) are recorded for mangroves, seagrass and coastal sabkha habitats. This indicates that outputs based on these ecosystems have a good degree of accuracy;

2) Relatively low user accuracies (<40%) are recorded for salt marsh and algal mats. As a result, caution should be taken when using this class data to infer carbon estimates;

3) Seagrasses have lower producer accuracy (29%) than user accuracy (77%). This indicates that although seagrass habitats were usually correctly mapped, there were many areas where seagrasses were observed in the field but were not mapped as such. This is likely to be due to the limited survey depth of around 3.5 at which seagrasses could be mapped from satellite imagery, and indicates that seagrass extent is probably underestimated on the current extent maps. Algal mats have higher producer accuracy (80%) than user accuracy (38%). This indicates that when algal mats were identified in the field, they were classified correctly on the map as well. However, there was a low probability that areas labelled as algal mats on the map were actually observed to be algal mats. This indicates that there is a high degree of misclassification of algal mats, most likely due to confusion with other habitats such as salt marsh. Therefore, algal mats may be over represented in the current maps.

4) User accuracy increased from 52% to 71% during the reclassification of mangroves between the 2000 habitat map and the updated, 2012 mangrove habitat maps, indicating that further visual interpretation of the mangrove class maps has enhanced the accuracy.

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[3] **User accuracy**: probability that an area labelled as a particular ecosystem on the map is really this habitat in the field

[4] **Producer accuracy**: probability that a ecosystem identified in the field is classified as such on the map

4.2 Interpretation of results

4.2.1 Mixed classes commonly observed in the field

Several kinds of mixed ecosystems were commonly observed in the field:

1) **Mixed salt marsh and mangroves** : Most commonly observed with a sparse density of both salt marsh and mangroves (**Figure 6**);

2) **Mixed salt marsh and algal mat**: Salt marsh density ranges from sparse to moderate. The distribution of algal mats is not continuous between salt marsh vegetation, but occurs in large patches while the rest of the area is occupied by large sand patches (**Figure 6**);

3) **Mixed sand and salt marsh**

Non Blue Carbon ecosystem classes were encountered in several cases, leading to a negative validation. Where one of these classes was encountered, it was identified according to the same classification scheme as outlined in (CMRECS, 2010). These were: coral reef (3), tidal mudflat (1), salt flat (1), sand (11), dunes (1), man-made structure (1).

Figure 6

Mixed classes of ecosystem observed. Mangrove and salt marsh (left) and salt marsh and algal mat (right)

4.2.2 *Potential class misinterpretation*

When assessing the ecosystem classes that were most commonly misinterpreted, some common trends can be highlighted. The lowest user and producer accuracy were recorded for the 'shallow water' ecosystem class. This is likely to be caused by confusion with unidentified seagrass and can be due to either natural, seasonal variation in seagrass cover or mis-classification with other marine ecosystems, particularly the '*shallow_water'* class.

The *Mangrove _2012* layer shows regular confusion with the salt marsh class and vice versa. This is probably due to the fact that they give off a very similar spectral signature in the imagery-based (Landsat) habitat classification. Finally, areas classified as algal mats on the map were often found to be salt marshes in the field. This may again represent confusion in spectral signature and lead to an overestimate of total algal mat extent.

4.3 Spatial data validity and statistical analysis of results

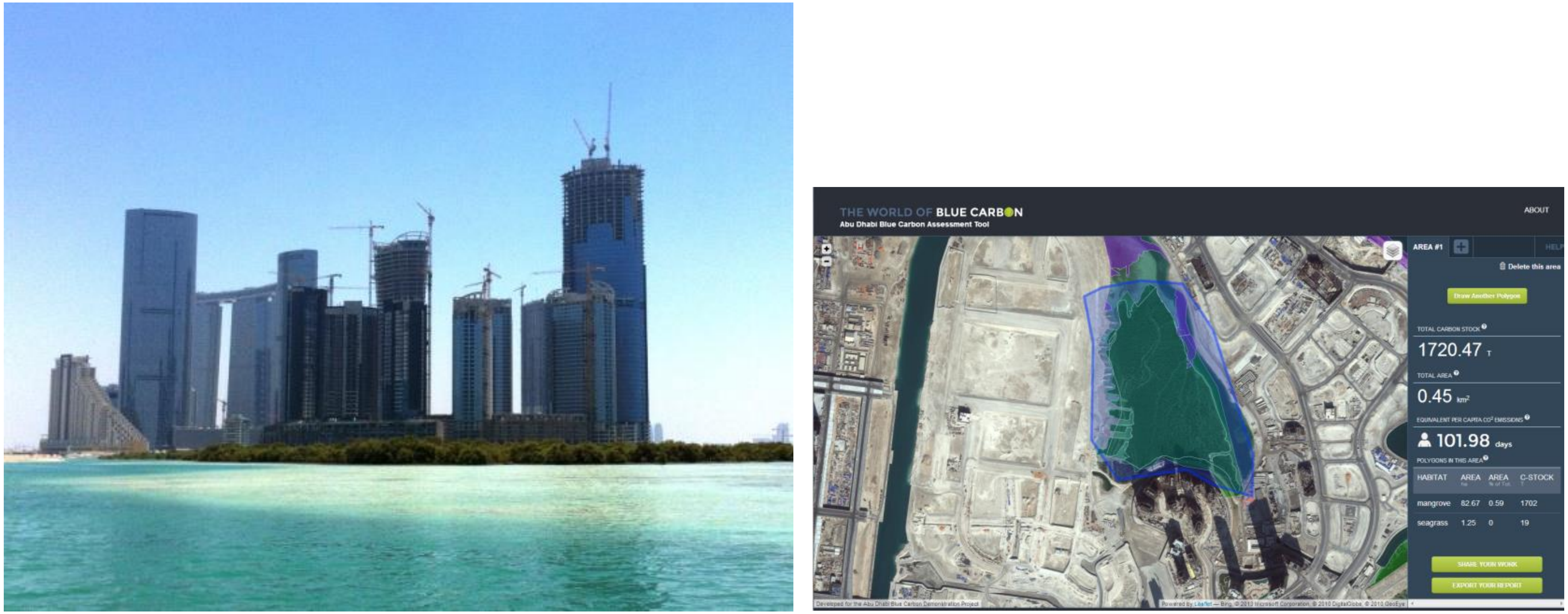
The results presented here provide an indication of the overall accuracy and highlight areas where further validation work is recommended. However, given the limited number of sampling sites, across a limited coastal range, any conclusions about the accuracy of the maps should be reserved until further such work has been conducted. This note of caution is all the more relevant as the ecosystem layers were derived from imagery from the year 2000. Although further enhancement of the data has since been undertaken, it can be expected that large areas have not been addressed and ecosystem extents have changed due to the high rate of coastal development in Abu Dhabi. Information on the decision rules for the ecosystem classification may determine the uncertainty on mixed classes of ecosystems, and provide higher accuracy results.

5 Spatial Data Assessment Outcomes

This section provides a summary of the key findings of the geographic ecosystem assessment, based on the updated ecosystem layers used in The Abu Dhabi Blue Carbon Mapping Toolkit. These layers can be continually enhanced through The Mapping Toolkit to ensure that the best available data is used to support assessments of carbon stock through the Online Assessment Tool. The latest ecosystem information and associated carbon stock data can be found at http://bluecarbon.unep-wcmc.org.

5.1 Blue Carbon Ecosystem extent data

The Toolkit has been used to update ecosystem extent data based on the UAE_Ecological_Habitat data as well as the Mangrove_2012 data, provided by EAD. Updates have been based on field-based validations using the Offline Validation Tool, as well as satellite imagery based observations using the Online Validation Tool. For example, seagrass and salt marsh around Al Reem Island were updated to reflect the development and resulting ecosystem loss in this area (**Figure 7**).



Abu Dhabi Blue Carbon Demonstration Project

Figure 7

Assessing Blue Carbon resources in a rapidly changing environment: Development of Al Reem Island (left), and the same area of interest portrayed on the Blue Carbon Assessment Tool with the associated carbon stock of its mangrove (green) and seagrass (purple) habitats (right)

Seagrass provide the largest area of Blue Carbon ecosystems in Abu Dhabi, and are currently estimated to be nearly 160,000 ha (1,600 km^2). This value is likely to be an underestimate as seagrasses were measured to only 3.5 m below sea level, but carbon baseline team members found seagrasses to be widespread beyond 10 m, and even at 14 m. Following the validation effort, mangrove extent is currently estimated to be 14,000 ha (140 km^2). This includes areas that have been reforested, as well as mangrove plantation sites. Associated median carbon estimates for mangroves are highly variable. Salt marsh coverage was estimated to be approximately 4,770 ha (48 km^2). This value is lower than the UAE_Ecological_Habitat layer, mainly as a result of salt marsh losses around Abu Dhabi City since the layer was produced. Additionally, mixed ecosystems consisting of both mangrove and salt marsh were found to be common, but were generally classified as mangrove. This bias in classification may lead to an underestimation of salt marsh cover in some places. Algal mats, although only representing a relatively low extent of 10,930 ha (109 km^2), had the highest carbon content of all the five ecosystems. Finally, coastal sabkha has been left out of further analysis on carbon stocks as although they do cap buried former Blue Carbon soil deposits and therefore prevent the release of stored carbon, they are not considered to actively sequester carbon. The extent of coastal sabkha is currently estimated to be 390,000 ha (3,900 km^2).

The changes to ecosystem extent are reflected in the latest version of The Mapping Toolkit and current estimates are presented in Table 5. Carbon stock median values are derived from carbon sampling results from the carbon baseline assessment and are presented as median values. This was then used to derive the total estimated carbon stock values as well as the approximate total potential CO_2 equivalent emissions for each ecosystem.

Table 5: Blue Carbon ecosystem extent and associated carbon stock estimates

Ecosystem	Extent (ha)	Median C (Mg/ha^{-1})	Total C (Mg)	Total C0$_2$ (Mg)
Algal mat	10,930	129.6	1,416,729	5,194,674
Mangrove	14,117	98.3	1,387,576	5,087,778
Salt marsh	4,770	69.2	329,840	1,209,412
Seagrass	158,262	51.6	8,169,516	29,954,893
Total	**188,079**		**11,303,661**	**41,446,758**

5.2 Data outputs

The results from the geographic component ground truthing sampling sites will be provided to AGEDI/EAD as geo-referenced Excel database. A central database where all ecosystem data and corresponding carbon values are stored in vector format in CartoDB, a cloud based geospatially enabled PostgreSQL database. Further information on the use of the Abu Dhabi Blue Carbon Mapping Toolkit is included within the *Online Geographic Data Tool – Specifications* document. The most recent spatial layers can be downloaded directly from the Mapping Toolkit as shapefiles for each of the Blue Carbon ecosystems. It is recommended that EAD/AGEDI periodically download versions of all the data from the administration interface in order to develop a catalogue of historic versions on the data. This is considered a valuable tool in itself to illustrate ecosystem change over time.

At the end of the project, the ecosystem basemap will be provided by UNEP-WCMC in both a geodatabase and shapefile format.

5.3 Use of the Abu Dhabi Blue Carbon Mapping Toolkit to enhance Blue Carbon ecosystem layers

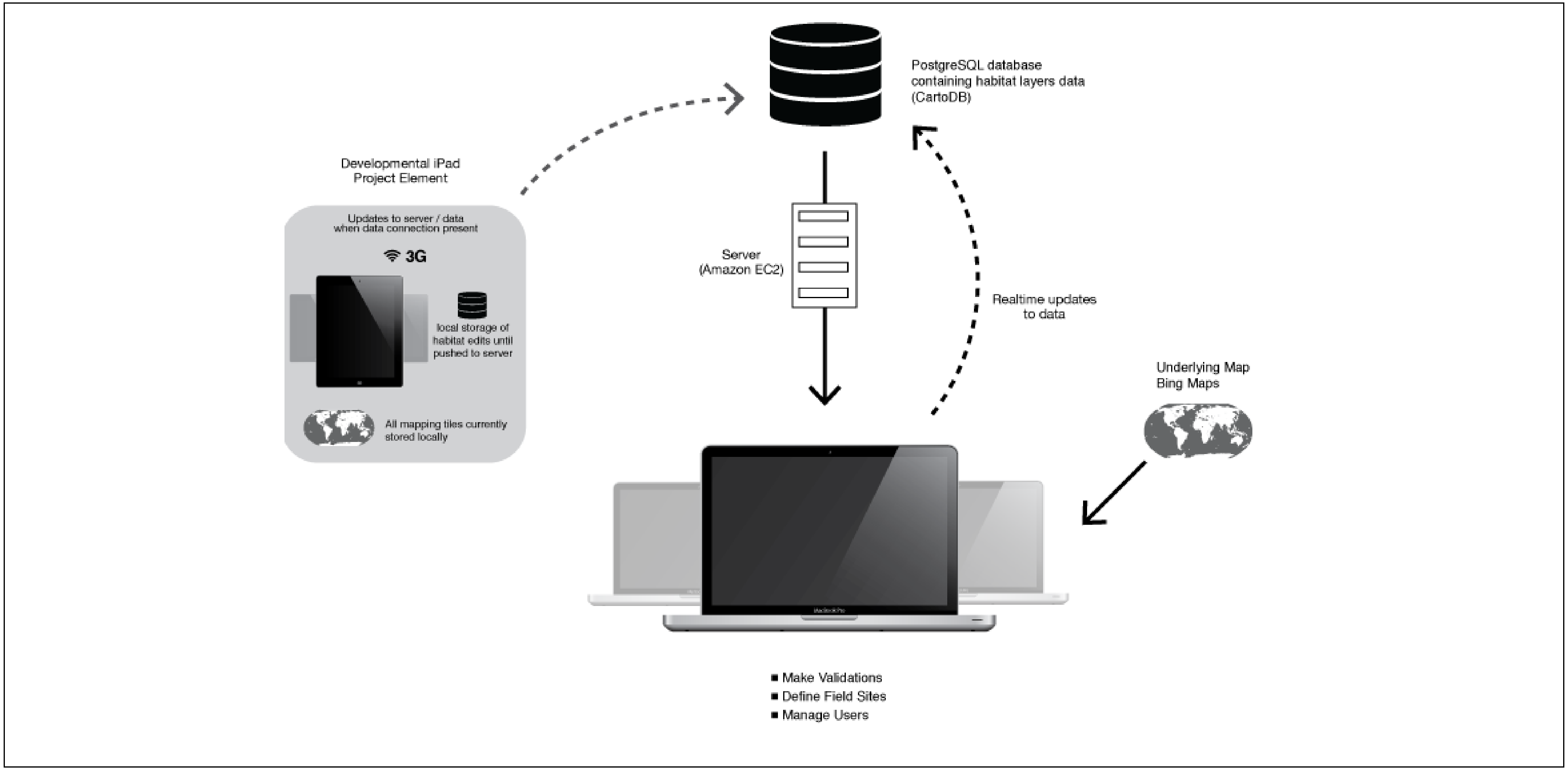
5.3.1 Key Features of the Mapping Toolkit

The Mapping Toolkit provides a platform through which the current ecosystem layers can be continually updated, validated and refined, both through its *in situ* offline, and its desktop-based, online capability. This can be achieved either through the tablet-based functionality as well as through an online, desk-based application. The ecosystem updates are immediately incorporated into the *front-end* Abu Dhabi Blue Carbon Mapping Toolkit website, ensuring that the most up to date information is available to the user. Here we provide a brief overview of the Toolkit components. More information can be found on the website (currently http://bluecarbon.unep-wcmc.org/) and within the Toolkit Technical document (*Online Geographic Data Tool – Specifications).*

The online **Validation Tool** is the administrative, *back end* of The Mapping Toolkit. It allows users to validate and update the spatial extent based on the underlying satellite imagery, local knowledge or data received from field observations. Scientists can also conduct validations in the field using an offline, **Tablet-based Validation Tool** which has been developed to support field-based work. When there is an internet connection, ecosystem data is updated and presented on the online tools, ensuring that the latest information is displayed at all times.

A central, cloud-based database stores all data and corresponding carbon values in vector format. Further data can be added to incorporate more information as it becomes available. **Figure 8** provides an overview of how the Blue Carbon tools work together.

Figure 8 The Abu Dhabi Blue Carbon Mapping Toolkit



5.4 Recommended next steps

The EAD, Environment Information Science and Outreach Management (EISOM) Habitat Classification Project will provide a new classification of Abu Dhabi's coastal, marine and terrestrial ecosystems, based on recently acquired satellite imagery and visual and supervised image interpretation. It is understood that marine data from this project is likely to be made available in November 2013, the ground-truthing undertaken in 2014; and the whole project is scheduled to be completed by December 2014. It is understood that the ecosystem parameters from this project will be incorporated into this, where feasible and appropriate, to allow the updated layers to be incorporated into The Mapping Toolkit. It is recommended that ecosystem classes that showed a high misinterpretation should be priority sites for review under the classification project. These include salt marshes and algal mats, as well as seagrasses which are likely to be underestimated with the current ecosystem layers.

Seagrasses in particular can be difficult to map, both in the field due to the inherent limitations of underwater survey, but also remotely, due to the difficulty with interpreting seagrasses in deeper and low-visibility water. A large-scale, randomized sampling effort would help assess the likely extent of seagrass beds.

It is also recommended that additional sampling of sabkha ecosystems be undertaken to enhance the current understanding of the carbon content of sabkha at various elevations.

5.4.1 Recommendations for improving ecosystem accuracy

Under the new Habitat Classification Project, it is recommended that an accuracy assessment be incorporated into the remote sensing exercise. This should ideally take place concurrently with the remote sensing work to minimize any discrepancy caused by seasonal or coastal development changes to ecosystem extent. It is not necessary to use the updated map in order to conduct the validation exercise, in fact it is recommended not to have it in order to minimize biases in the results.
Further ways to rapidly enhance the accuracy of the outputs could include:

1) Inclusion of additional ecosystem parameters within classifications such as density, age, status and species composition (Table 6);
2) A final stakeholder engagement workshop to remind potential users of the Validation Tool of its various application and therefore encourage accurate usage in the future;
3) Engaging additional users including students and organizations to use the off-line Validation. Final approval of validated layers would need to be controlled by an administrator to ensure the validations are an accurate representation of the situation on the ground.

5.3.2 *Use of the Abu Dhabi Blue Carbon Mapping Toolkit to enhance the quality of the ecosystem maps*

The quantitative accuracy assessment highlighted the current ecosystem maps are prone to mis-classification in particularly for salt marsh and algal mats. Seagrasses are also likely to be underestimated on the existing ecosystem layer.

The Mapping Toolkit has the potential to enhance the accuracy of the supporting ecosystem layers through its online and offline validation and editing functionality. Through The Mapping Tool, registered users can view ecosystem layers over a Bing Maps base layer. Areas of Interest can be defined by clicking on the map to define a polygon shape. Within this area, a selected ecosystem can then be validated (i.e. confirm that the current ecosystem extent is correctly mapped), deleted or added to the existing layer. Furthermore, additional parameters about the ecosystem state, species composition and condition can be incorporated into an ongoing effort to increase the quality of the ecosystem data and thus, the accuracy of the associated carbon stock assessments (Table 6). The parameter status provides a corresponding carbon 'multiplier' that calculates the approximate carbon stock of the ecosystem. As part of this Demonstration project, the 'Condition' and 'Age of the ecosystem' parameters for mangroves were found to have a significant effect on carbon stock. Natural mangroves were found to store approximately 1.4 times as much carbon as planted mangroves, making a case for the importance of preserving natural mangroves over replacing them. Further multipliers can be included as more carbon and ecosystem state data becomes available.

Finally, images can be attached to the validation, providing a time-referenced visual snapshot of the ecosystem. This can be a powerful function and will facilitate changes over time to be monitored.

Table 6: Ecosystem parameters associated with the Abu Dhabi Blue Carbon Validation Tool

Ecosystem Parameters	No. of categories	Mangrove	Saltmarsh	Coastal sabkha	Seagrass	Algal Mats
Density of Ecosystem	**No. of categories: 5[5]:** Unknown Sparse (<20% cover) Moderate (<20-50% cover) Dense (50-80% cover) Very Dense (>80% cover)	X	X	N/A	X	N/A
Evidence Type	**No. of categories: 3:** Underlying imagery in browser Local Knowledge Field Visit	X	X	X	X	X
Condition	**No. of categories: 5[6]:** Undisturbed/intact Degraded Restored/rehabilitating Afforested/created Cleared	X	N/A	N/A	N/A	N/A
Species	**No. of categories: 5[7]:** Unknown *H. uninervis* *H. ovalis* *H. stipulacea* *Mixed species*	N/A	N/A	N/A	X	N/A
Age of ecosystem	**No. of categories: 4[8]:** Unknown Natural mangrove 2-10 yrs old 10-20 yrs old 25-50 yrs old	X	N/A	N/A	N/A	N/A
Recorded date	**N/A**	X	X	X	X	X
Notes	**N/A**	X	X	X	X	X

[5] Where there is an associated vegetation biomass
[6] Only applicable to mangrove forest state
[7] Only applicable to mixed species habitat
[8] Only applicable to non-natural habitat - mangrove

6 Conclusions

The mapping and validation work undertaken as part of the geographic assessment component of the *Abu Dhabi Blue Carbon Demonstration Project* has confirmed the extensive area of coastal ecosystems that support the storage and sequestration of significant carbon stocks, estimated to be around 38 million tonnes of carbon dioxide equivalent. Based on the most recent outputs from the Tool, the total extent of Abu Dhabi's Blue Carbon ecosystems is currently estimated to be around 188,000 ha (1,880 km^2). Seagrass meadows in particular were found to be of significant size and the current estimate of 158,000 ha (1,580 km^2)is likely to be an underestimate, given that seagrasses were found at depths beyond the 3.5 m threshold to which they are currently mapped from satellite imagery. Fieldwork sampling regularly encountered seagrass meadows at 10 m and even at 12 m depth.

The field-based accuracy assessment has highlighted the importance of ensuring that high quality and up to date information are available to support future decision making. Timely updating of the underlying ecosystem maps in order to reflect an accurate representation of the situation on the ground is essential for ensuring the carbon outputs are within an acceptable margin of error where they can be used to support management decisions.

The overall accuracy of the existing ecosystem maps was generally found to be below the recommended accuracy of >80%. The fact that much of the maps were based on imagery from around 2000 means that what may have been an accurate reflection a decade ago, is now likely to be outdated for areas where coastal development has taken place. Mangrove ecosystem data proved to be of a good accuracy, as was seagrass and coastal sabkha data. Algal mats and salt marshes were often confused with other ecosystems and should be the focus of a reclassification. Although the ongoing validation effort has greatly improved the overall accuracy of the ecosystem data, further validation is recommended. Seagrass areas in particular would greatly benefit from a reclassification. An expansion of this work may well provide a higher overall accuracy.

The ecosystem mapping work currently being undertaken by EAD will greatly enhance the accuracy of the carbon stock estimates. The latest updated layers can be incorporated into the Abu Dhabi Blue Carbon Mapping Toolkit, and will in turn enable them to validated and edited to reflect current changes in a dynamic environment such as Abu Dhabi.

The development of field- and desktop-based tools will help ensure that the best available data is used to assess Blue Carbon stocks for Abu Dhabi. In combination with carbon stock data, The Mapping Tool is able to provide very rapid estimates of carbon stocks for the four different ecosystems, making it an intuitive and simple-to-use but effective management tool for Abu Dhabi's coastal resources.

References

AGEDI. (2012a). *Local , National Regional Biodiversity Assessment Project. Decision Table of Terrestrial Habitat Workshop.* (p. 12).

AGEDI. (2012b). *Local , National Regional Biodiversity Assessment Project. Decision Table from Marine Habitat Workshop.* (p. 8).

AGEDI. (2012c). *Local, National Regional Biodiversity Assessment Project. Decision Table from Terrestrial Habitat Workshop* (p. 6).

Brown, G., & Böer, B. (2004). *Interpretation Manual of the Major Terrestrial Natural and Semi-Natural Habitat Types of Abu Dhabi Emirate* (p. 62). Doha, Qatar.

Congalton, R. G., & Green, K. (2008). *Assessing the Accuracy of Remotely Sensed Data* (2nd ed., p. 183). Boca Raton, FL.: CRC Press.

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. doi:10.1016/S0034-4257(01)00295-4

Herold. (2011). Resolution vs Minimum Mapping Unit - Size does matter. *NOAA*. Retrieved February 29, 2013, from http://www.csc.noaa.gov/digitalcoast/geozone/resolution-vs-minimum-mapping-unit-size-does-matter

Holness, S. (2012). *Final UAE - Initial Ecosystem Threat Status and Protection Level Assessment Layers Package* (p. 52).

Knight, J. F., & Lunetta, R. S. (2003). An Experimental Assessment of Minimum Mapping Unit Size, *41*(9), 2132–2134.

Parr, S. (2012a). *UAE Habitat Expert Workshops 27 / 28 June 2012* (p. 6).

Parr, S. (2012b). *Final Abu Dhabi Data Scoping Report - LNR Biodiversity Assessment Project* (p. 40).

Appendix A

Sample fieldsheet

Site ID (day_site_source)	20_site45_wcmc	21_site46_wcmc	21_site48_wcmc
Site	Site20	Site21	Site22
Date	16.01.13	17.01.13	17.01.13
Source	WCMC	WCMC	WCMC
Point type	Random	Random	Transect
Waypoint (in GPS)	23SB28	23SB29	23SB30
Habitat classification (mapped)	seagrass	algal mat	salt flat
Oberved habitat	seagrass	salt marsh	mangrove
Ground truthing action	Confirm	Edit	Edit
Depth (m)	6m	n/a	n/a
Density	Very dense	n/a	Sparse
Species(seagrass)	*Holodule uninervis , Halophila stipulacea*	n/a	n/a
Age of mangroves	n/a	n/a	Natural
Canopy density	n/a	n/a	20%
Size	n/a	n/a	3-4m/5-6m
coverage	90%SG,10%MUD	10%ALG 50%SM 40% white clay	20%MG 10%SM 70%CLAY
Photos	n/a	wcmc;11:00	wcmc;11:08
Photo orientation	n/a	W-S-E-N	W-S-E-N
Notes			