K&C Science Report – Phase 1
Characterisation of inland wetlands in Africa

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Abstract - **Inland wetlands occur extensively across Sub-Saharan Africa. These ecosystems typically play a vital role in supporting rural populations and their sustainable management is thus critical. In order to prevent depletion of resources and ecosystem services provided by these wetlands, a balance is required between ecological and socio-economic factors. The sustainable management of wetlands requires information describing these ecosystems at multiple spatial and temporal scales. However, many southern and eastern African countries lack regional baseline information on the temporal extent, distribution and characteristics of wetlands. PALSAR data provides invaluable information related to the flooding patterns and vegetation characteristics of these wetlands, and is being used to document and characterise specific sites within the region which have been identified due to their vulnerability to both climatic variability and agricultural activities. The information derived from the PALSAR data is needed to assist managers in making decisions about future land uses in wetlands that are intensively used for agriculture and fisheries, and which are an important natural resource for local communities.**

***Index Terms*—ALOS PALSAR, K&C Initiative, Wetland Theme, Africa, flooding patterns, vegetation.**

I. INTRODUCTION

Throughout Sub-Saharan Africa, floodplains and wetlands are extensive [1]. These ecosystems depend on frequent flooding. They also make critical contributions to the livelihoods of many people. Many hydrological interventions (i.e. dams and irrigation schemes) either already exist within these basins, or are being planned to increase economic benefits and food security. However, these interventions will not be without consequences and both the costs and benefits need to be carefully evaluated. One likely consequence of increased flow regulation is reduced downstream flooding. Annual time series of PALSAR data are an invaluable dataset for identifying seasonal patterns of inundation, and are used here to determine flooding patterns and to map the temporal dynamics of inundation within selected sites in southern and eastern Africa. The data are also used to provide detailed maps of the vegetation for specific wetland sites.

II. DESCRIPTION OF THE PROJECT

A. *Relevance to the K&C drivers*

The project aims to generate knowledge to assist in the sustainable management of wetlands which are utilised for agriculture and fisheries activities, and to assist the countries concerned to put in place or enhance mechanisms that minimize degradation of the wetlands, in order to optimize the ecosystem and livelihood benefits. Project objectives also include the provision of baseline wetland information from remote sensing and GIS data, and the generation of generic guidelines, tools and methodologies for wetland mapping and characterisation.

The Wetlands Theme of the K&C Initiative focuses on the provision of remote sensing datasets that can be used to assist the global mapping and monitoring of wetlands and identifying and quantifying the threats to which these are exposed. Specifically, it aims to develop a suite of products which may be used to improve the understanding of carbon cycle science, assist the implementation of conservation and management strategies and support national and international obligations to multi-national conventions [2]. The work reported here is of relevance to all three of the thematic drivers: **C**arbon, **C**onservation, and **C**onventions i.e. the three C's. The draining and transformation of wetlands for agricultural (as well as for other) uses is likely contributing to the carbon imbalance in the atmosphere [3]. Wetlands contain and cycle a significant amount of carbon and play a key role in the global carbon cycle, not least because of the large turnover of methane within these systems; it is estimated that natural wetland sources emit about 20% of the methane entering the atmosphere each year [4] and they are responsible for a significant proportion of biogeochemical fluxes between the land surface, the atmosphere, and hydrologic systems [5]. A basic requirement for modelling regional to global methane or carbon dioxide emissions from wetlands is information on their type and distribution.

In Africa where wetlands are utilised extensively for agriculture and fisheries activities, the loss of these ecosystems will also have a more direct effect on local populations. Long-term preservation and sustainable use of these resources is therefore critical for the economic and social well being of current and future generations. Key requirements include the establishment of regional and temporal datasets of wetland extent and condition which incorporate an understanding of the inundation dynamics of an area and spatially quantifiable measures of both anthropogenic and natural pressures and threats to wetland communities [2].

The Ramsar Convention on wetlands of International Importance promotes the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world (Ramsar COP8, 2002). The Convention aims to halt and reverse the global trends of wetland degradation and destruction through the dissemination of information, involvement of local communities and establishment of sustainable management plans. While Contracting Parties to the Convention have been encouraged to undertake better and more efficient wetland inventory, and to establish and maintain national inventories, many African countries lack the resources to achieve this. Remote sensing technologies are essential in providing up-to-date spatial and temporal information about wetlands and their catchment basins, and should be seen as a fundamental component in the development of wetland management plans for conservation and sustainable utilisation. While mapping of wetlands has proved difficult in many areas because of the lack of temporally and spatially consistent datasets, the systematic data acquisition strategy of ALOS PALSAR seeks to redress this [3].

B. Site description

The analyses have been conducted at two inland wetland sites located in Malawi and Mozambique (Figure 1). Both sites have been nominated by the countries as priority sites for analysis, as they are vulnerable to both climatic variability and agricultural activities. Population pressure and increased exploitation of resources within these wetlands and the surrounding catchments are leading to serious degradation and loss of biodiversity and inter-connected ecosystem services. Lake Chilwa is a transboundary wetland located in a tectonic depression in south-eastern Malawi and western Mozambique. The catchment covers a total area of 8349km^2, 97% of which is located in Malawi and 3% in Mozambique. The wetland (an area of approximately 2250km^2) is a Ramsar site, and a UNESCO Biosphere Reserve. While the Lake is fed by 7 streams, it is an endorheic system with no outflow. As the lake is shallow with an average depth of 1-2m (Figure 2), its size varies considerably depending on precipitation levels in the catchment with small increases in water level resulting in

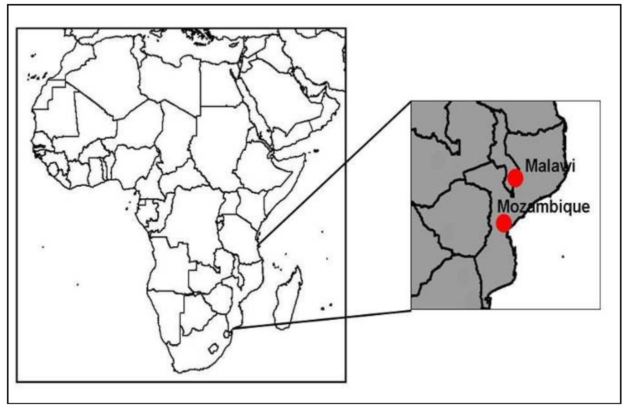


Figure 1. Site locations © JAXA/METI and acquisition date (here: Jan 15, 2009)

large increases in spatial extent. The wetland has a history of cyclic drying and filling; in the last century alone it has dried and filled eight times, with the last recession occurring in 1996/97. The hydrology of the lake is an important control on the ecology of the wetland, determining not only the water chemistry and physical properties, but also the composition of the vegetation and soil characteristics [7]. The only available information relating to the vegetation within the wetland complex was produced from a ground survey conducted in the 1970’s [8], and no digital data on spatial patterns of inundation is available.

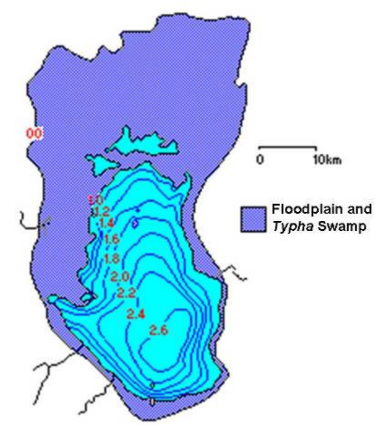


Figure 2. Bathymetric map of Lake Chilwa (source: UNESCO, 2004).

Lake Urema and the surrounding wetlands are located in Gorongosa National Park in central Mozambique. An understanding of the ecology and hydrology of the lake and wetlands is essential for the conservation of the floodplain habitats which are critical for maintaining the biodiversity of the Park. There are concerns that the hydrology and ecology of the lake have changed in recent years, possibly dues to climatic variability and land use changes, as well as tectonic activity [9]. The analyses conducted here aim to provide baseline data on the vegetation composition, spatial extent, and seasonal variations in the wetlands around Lake Urema, in order to improve understanding of their vulnerability to changes in the hydrological regime.

C. Materials and methods

The analyses were performed on multitemporal datasets of ALOS PALSAR fine beam data. Where available, optical images and topographic data were also incorporated. For both sites extensive field campaigns were conducted according to the following methods. Latitude and longitude grids were overlaid on maps of the sites, and depending on access, field sites were selected at one second intervals.

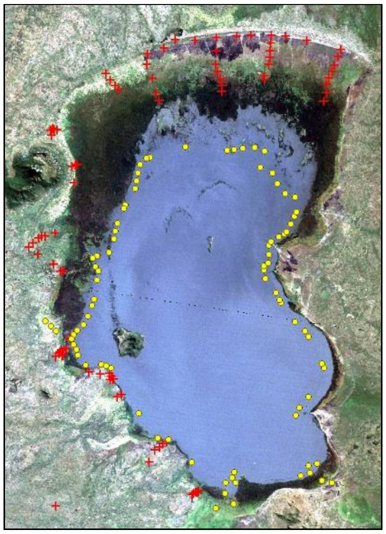


Figure 3. Air photo (yellow circles) and field site (red crosses) locations, Lake Chilwa, Malawi. Base image: Landsat TM real colour composite

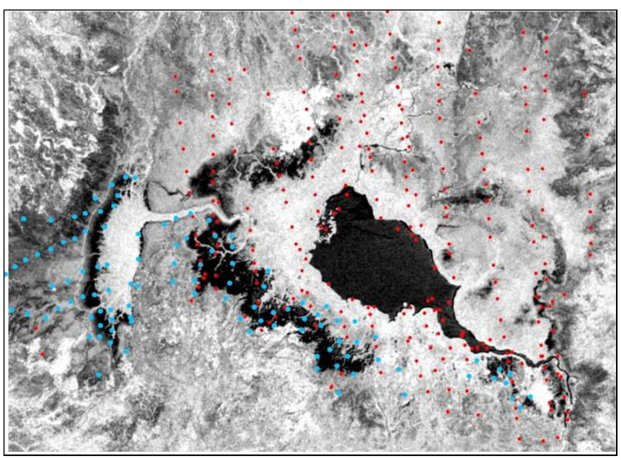


Figure 4. Air photo (red circles) and field site (blue circles) locations, Lake Urema, Mozambique. Base image: ALOS PALSAR HH, Feb 2007 © *JAXA/METI*

An area of 20x20m was demarcated at each site, and various data recorded including vegetation species, ranked biomass, species dominance, land use and hydrology. Where cloud (and smoke) free optical datasets were available, these were incorporated into the analysis. The remote sensing datasets for each site are described in Table 1. In addition georeferenced low altitude aerial photos were acquired at both sites (for Lake Chilwa courtesy of the Danish Hunters Association, DANIDA). The locations of field sites and aerial photos are illustrated in Figures 3 and 4. Data were collected at 90 field sites (92 aerial photos) around Lake Chilwa, in October 2006 (a PALSAR FBS image was also acquired this month) and at 120 sites (250 aerial photos)

Site	Sensor	Wavebands/ mode	Acquisition date
Lake Chilwa	Landsat TM	VNIR, TIR	18th Nov 2005
	ASTER	VNIR, SWIR, TIR	21st May 2006
	PALSAR	FBD	17th May 2006
		FBS	2nd Oct 2006
		FBS	Feb 2007
Lake Urema	PALSAR	FBS	Dec 2006
			Feb 2007
		FBD	Jun 2007
		POL	Jun 2007
		FBD	Aug 2007
			Sep 2007
		FBS	Feb 2008

Table 1. Remote sensing datasets used in the analysis

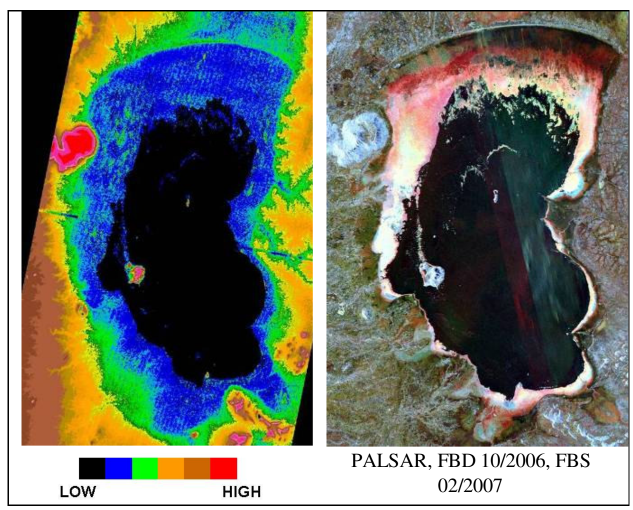


Figure 5. 15m DEM derived from ASTER, PALSAR composite image (R: HH, G: HV, B: HH) © *JAXA/METI*

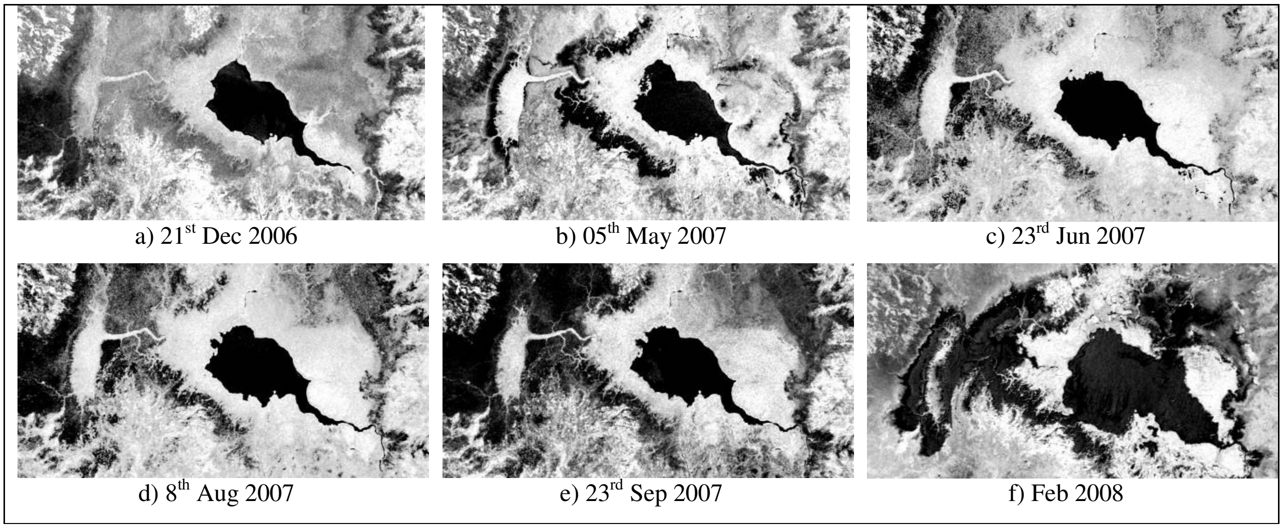


Figure 6. ALOS PALSAR scenes, Level 1.5, 12.5 pixel spacing © *JAXA/MET*

around Lake Urema in July 2007 (PALSAR POL and FBD images were acquired in June and August 2007 respectively). A 15m DEM was derived using the two visible bands of the ASTER image. This and the PALSAR data are shown in Figure 5.

For Lake Chilwa, the classification of the remote sensing data into dominant wetland types was performed using a Decision Tree (DT) classifier, based on a series of binary decision rules. DT classifiers allow multistage classifications to be performed, recursively partitioning the input dataset into increasingly homogenous subsets. A particular advantage of this approach is that datasets with different spatial resolutions, as well as ancillary datasets can be used together during the classification process. Image segmentation was performed at each node based on histogram analysis in order to separate the data into two mutually exclusive classes. The vegetation within the "wetland vegetation" class was subsequently classified into species dominance based on a subset of the field sample sites (50% of the sites were randomly selected) and the aerial photograph locations.

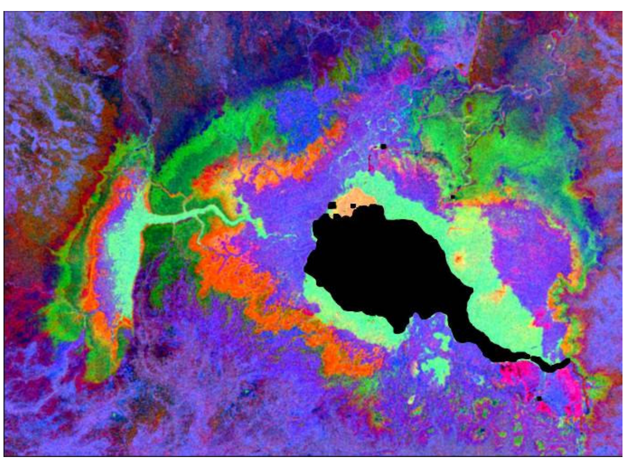


Figure 7. Principal Components Analysis of 7 ALOS PALSAR FBS, FBD and POL scenes (RGB: PCA 1, PCA 2, PCA 3), ALOS K&C © *JAXA/METI*

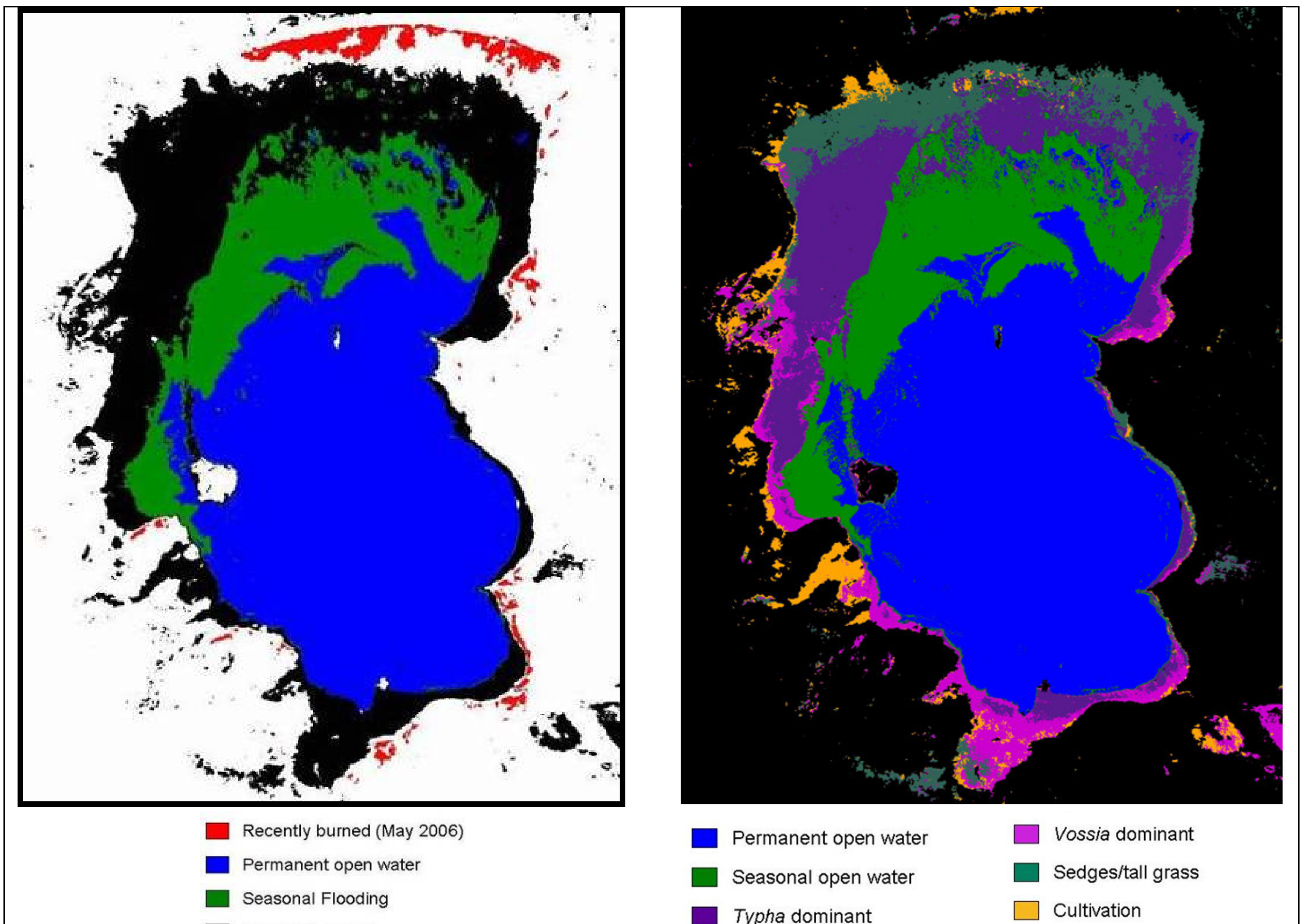
Over central Mozambique cloud cover in the wet season, and smoke from burning during the dry season presents a problem in the acquisition of suitable optical datasets. All PALSAR images available (Figure 6) over a 14 month period (Dec 2006 – Feb 2008) were therefore used in the analysis, in an attempt to characterize the seasonal variations in the Lake and surrounding wetlands. The PALSAR images (with a pixel size of 12.5m) were smoothed using a 5x5 pixel median filter, to reduce the influence of speckle. This filter was chosen as it preserves edges, while smoothing the data. For wetland areas the boundaries of the wetlands are thus preserved while a more homogenous within-wetland pixel value is achieved [10]. The variations observed in the PALSAR images between the various dates (Figure 6) are predominantly due to changes in the flood condition and soil moisture.

In order to quantify the temporal variance in the data, a Principal Components Analysis (PCA) of the filtered temporal sequence of PALSAR images (Figure 6, Table 1) was performed on the filtered images, thereby providing information on the duration of the flood conditions. Figure 7 shows the results for the multitemporal PCA analysis. Areas with minimal changes across all dates exhibit very low variance (low values in each PCA band), and are represented by the black areas in Figure 7. This corresponds to the permanently flooded areas (between Dec 2006 and Feb 2008) of Lake Urema. Variations in the hydrologic regime over the time period of the study for the wetland areas surrounding the Lake are clearly evident from a visual analysis of Figure 7. A supervised classification was performed using the first three PCAs as input in addition to the individual PALSAR images, in order to identify classes within the wetland based on frequency of flooding and their hydrologic condition over the 14 month period. Visual analysis of the PCA results, the aerial photos and the field data collected suggested a high correlation between the dominant vegetation species and the time/duration of flooding. Training sites for the classification were selected based on dominant vegetation species, as identified during the field campaign. 50% of the 120 sites were selected at random for this purpose, along with 125 of the aerial photo locations. Thus based on the field data the flooding patterns have been linked to the different vegetation communities.

III. RESULTS AND SUMMARY

Two products have been created for the Lake Chilwa wetland; i)a map depicting the spatial zoning of broad wetland classes derived from the annual flood dynamics, and ii)a map illustrating the spatial distribution of the wetland vegetation. These are shown in Figure 8. In addition to the open water, the wetland consists of a band of dense reed swamps and marshes, and a seasonally inundated grassland floodplain. The distribution and dynamics of the wetland flora and fauna are dependent on the seasonal and annual fluctuations in water levels. An accuracy assessment of the classification results (Figure 8b) based on an independent sample (the 45 field sites not used in the training phase) indicated a classification accuracy of 89%. The identification of wetland classes for Lake Urema and the surrounding wetlands has been determined based on flooding regime. These results are displayed in Figure 9. Accuracy assessment of the results is currently underway.

The ALOS PALSAR datasets have been used in this project to detect spatial and temporal changes in hydrologic conditions of inland wetland ecosystems in Africa. The images have been used to provide baseline data for two biodiversity hotspots; Lake Chilwa, a Ramsar wetland site of



a) Broad wetland classes derived from annual flood dynamics

b) Distribution of wetland vegetation

Figure 8. Principal Components Analysis of 7 ALOS PALSAR FBS, FBD and POL scenes (RGB: PCA 1, PCA 2, PCA 3), ALOS K&C © *JAXA/METI*

International Importance, and a UNESCO Biosphere Reserve in Malawi, and Lake Urema, a key component of the Gorongosa National Park in Mozambique. The analysis has provided information on the vegetation composition and seasonal variations in the wetland extent, thereby increasing understanding of the ecology and hydrology of these ecosystems and providing information crucial for their sustainable management and conservation. ALOS PALSAR proved to be an essential data source for these analyses due to i) frequent cloud cover over the areas of interest thereby preventing the use of optical data, ii) a systematic observation strategy [11] and frequent image acquisition allowing for characterisation of the flood dynamics at a high temporal resolution, iii) FBD in addition to FBS coverage of the wetlands during the summer months enabling discrimination of different vegetation structural types.

Building on the work reported here, future work will attempt to scale out to larger areas.

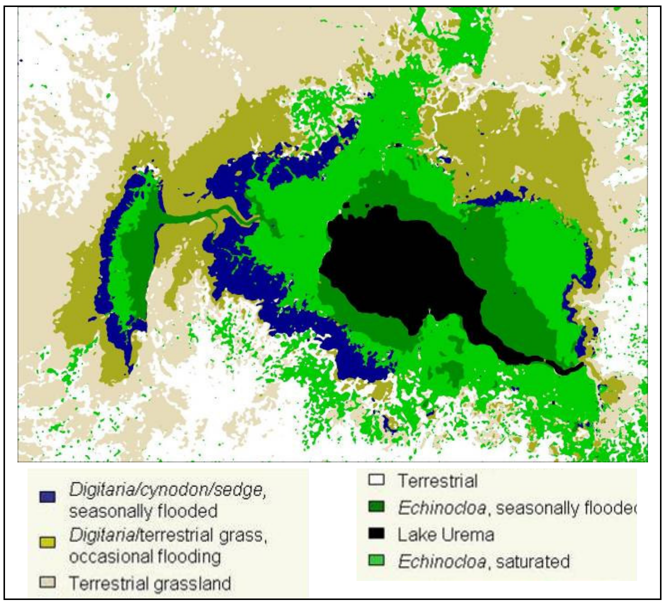


Figure 9. Lake Urema, Mozambique: Identification of wetland classes based on flooding regime. ALOS K&C © *JAXA/METI*

Annual time series of PALSAR (ScanSAR) data are an invaluable dataset for identifying seasonal patterns of inundation, and will be used to determine flooding patterns and to map the temporal dynamics of inundation across selected regions of the White Nile and the Zambezi.

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