Ongoing sedimentological and palaeoecological investigations at Lielerai Kimana and Ormakau Swamps, Kajiado District, Kenya

A report to the local authorities of Kimana and Namelok, Olive Branch Mission Africa Operations, and the National Museums of Kenya Palaeobotany and Palynology Section.

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Further information can be found at http://www.real-project.eu/amboseli-fieldwork

Cover photo: Lielerai Kimana Swamp and hippopotami pool (Geert van der Plas and Colin Courtney Mustaphi, 2 April, 2014).

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Abstract

This report summarizes fieldwork done by members of the REAL project who are studying wetlands in Kajiado District, southern Kenya, to understand how these systems have evolved through time. We employ sedimentological and palaeoecological approaches to physically characterise the swamp basins and to gain a deeper understanding of how these swamps have changed in response to past variability of climate and human land use practices. Multiple wetlands exist upon the semi-arid landscape of southern Kenya within the boundaries of the previous extent of Amboseli Lake that are ecologically and developmentally important to the region. Hydrologically, these swamps are recharged through groundwater flows from Mt Kilimanjaro, which are sensitive to climatic change and extraction pressure by nearby populations. Historically, these wetlands have been key landscape features serving wildlife, livestock, and human populations with water particularly during droughts. The multiple stakeholders within the area have vested and often competing interests regarding how these critical ecosystems should be managed in a sustainable framework for the future of these communities. Previous studies have shown that these wetlands are sensitive to late Holocene climatic variability, large wildlife herbivory, and changes in human land use patterns. Continued scientific study is needed due to the diversity of wetland ecosystems across this landscape and varying spatial controls influencing the environmental conditions. This is especially true considering the multiple, recent, rapid and intense landscape transformations that have occurred. Some of these transformations include the creation of societal and physical enclosures around wetlands, increasing human population, land subdivisions and tenure changes, fluctuations within the conservation and tourism industry, drainage for conversion to croplands and increases in irrigated agriculture wildlife and livestock population changes in the Amboseli basin, poaching, and declining wet montane forest cover on the slopes of Mt Kilimanjaro, Tanzania. This document reports ongoing scientific study of the physical wetland systems and how the sites have evolved over geological time scales in response to climatic and land-use behavioural changes.

Contents

List of Acronyms

BLF	Big Life Foundation
ESR	Early-Stage Researcher
ER	Experienced Researcher
GDP	Gross Domestic Product
GPS	Global Positioning System
KES	Kenyan shilling
KFS	Kenya Forest Service
KITE	York Institute for Tropical Ecosystems
KWS	Kenya Wildlife Service
ITN	Initial Training Network
NACOSTI	[Kenya] National Commission for Science, Technology and Innovation
NMK	National Museums of Kenya
REAL	Resilience in East African Landscapes, Marie Curie ITN project
USD	United States of America dollar

1.0 Introduction

1.1 Purpose and Scientific Approach

This report describes some preliminary fieldwork undertaken as part of a larger project entitled 'Resilience in East African Landscapes: Identifying critical thresholds and sustainable trajectories – past, present and future (REAL)', a Marie Curie Initial Training Network funded by the European Commission. This project aims to use a multi-disciplinary approach to examine the ontogeny of East African landscapes, focusing on important drivers of environmental change, interactions between natural ecosystem processes, and impacts of anthropogenic activities (Gelorini and Verschuren, 2012). To improve our understanding of human-environment interactions we make use of multiple investigatory approaches to reconstruct and critically examine past environmental changes using techniques from earth sciences, archaeology, history and anthropology, that will be beneficial for informing sustainable and equitable development initiatives and planning (Marchant *et al*., 2010; Marchant and Lane, *In press*).

1.2 Regional Setting

The Amboseli Wetland Basin is located in Kajiado South County (formerly Loitokitok District) along the northern base of Mt. Kilimanjaro and borders Tanzania to the southwest, Kajiado District to the north, Kibwezi District to the east and Taveta District to the south (Fig. 1.1). The area is generally arid to semi-arid with limited variations in its agro-ecological zones. The Amboseli is approximately 3000 km^2 (Western, 1975) and is a semi-arid savannah experiencing bimodal rainfall distribution. This distribution is caused by the movement of the Intertropical Convergence Zone (ITCZ; Hulme, 1996, Swift *et al*., 1996). The Amboseli ecosystem lies in the rain-shadow of Mt. Kilimanjaro and rainfall varies from 350 mm y^{-1} to 500 mm y^{-1}, with higher rainfall amounts falling closer to the foothills where altitudes are greater (Githaiga *et al.,* 2003). Altmann *et al.* (2002) also reports that temperatures range from highs of 35°c in Feb/March to lows of 12°c in July and that both the maximum and minimum diurnal temperatures in the Amboseli Basin have risen by 0.275 °C and 0.071 °C, respectively, between 1971 and 1996. Wetlands cover less than 4% of the Amboseli Park ecosystem (Western and Sindiyo, 1972). The Amboseli ecosystem includes the Amboseli basin to the South and the wetlands to the East with water feeding the wetlands coming from aquifers, except for Esoitpus that is fed by Lolterish River. Hydrological studies carried out on the basin suggest Lake Amboseli and Ol' Tukai wetlands overlay Pleistocene lacustrine and fluviatile deposits, whereas the Enkongo Narok, Longinye, Kimana, Namelok, Lenkir and Esoitpus wetlands overlie volcanic rock, primarily basalt (Irungu, 1992; Western, 1994). These wetlands have critical ecosystem function roles for local and regional communities. The Chyulu hills are located to the north of the Amboseli, the Chyulu ranges have no surface water courses as the extremely porous material (volcanic pyroclasts) allow complete water infiltration which then flows into the Amboseli forming springs which are an important source of water in the Amboseli.

Figure 1.1: Location of swamp sites in South Kajiado County, southern Kenya.

1.3 Regional History

Competition for land tenure and water resources in Kajiado District has a long history. In 1902 the abundance of wildlife in Amboseli in conjunction with colonial 'tribal' containment/land grabbing policies led to the creation of the Southern Maasai Reserve, which was expanded in 1911 to 38,000 km^2 to accommodate Maasai who were being resettled from the abolished Northern Reserve. Within the Southern Reserve, land was communally owned by Maasai and administered by Kajiado County Council. While disputes did arise over access to grazing areas, particularly during droughts, water was not a majorly contested resource as the Amboseli area provided large, year-round open sources in the forms of swamps (Western, 1994: 22). Pressures directing people toward more organised land ownership structures came from the 1945 National Parks Ordinance that established within the Southern Reserve the 3,260 km^2 Amboseli National Park, later becoming the Amboseli Game Reserve for wildlife conservation. In addition, post-Independence settlement of Kikuyu and Kamba cultivators on the lower slopes of Kilimanjaro and around the swamps of Amboseli fueled Maasai land annexation anxieties.

In response, the Amboseli landscape was divided into a number of group ranches, a process that was underway in Kajiado District as early as the 1950s, and was operating by the late 1960s (Rutten, 1992). Though the formation of group ranches was certainly influenced by the desire to ensure legal authority over land in Kajiado, water has consistently been recognized as a prioritised resource in the development and operation of group ranches in Kajiado. The first official group ranch development project in Kajiado saw, in 1969, the provision of $1.8 million USD by the World Bank Kenya Livestock Development Project, with 57 % allocated toward water resources (Rutten, 1992: 278). The physical boundaries and membership policies of group ranches were implemented in accordance with notions of self-contained ecological units ostensibly containing adequate water and pasture. Major droughts, however, repeatedly led to local disputes and disregard for official ranch demarcations (Grandin 1991). Sub-division of group ranches in Kajiado District was increasingly demanded by the late 1970s due to frustrations among members regarding management, facilities, individual title deeds, and unwillingness to repay Agricultural Finance Company and World Bank loans (Rutten, 1992).

The sub-division of group ranches in Kajiado District is a complex issue by rising populations, migration, and ultimately expansion of cultivation and settlement down the ecological gradient of Mt Kilimanjaro and onto wetter rangeland areas. Thus, an overall trend of landscape fragmentation centered on water abundant areas is evident. During drought periods in 1960-1961, 1973-1976, 1980, and 1984, pressure was put on Maasai, who saw huge reductions in herd numbers, to join or sell/lease plots of land to non-Maasai groups. These groups cultivated along the margins of wetland areas such as Kimana and Namelok (Campbell, 1979). The drought provided further economic incentives to privatise land and to re-stimulate existing, and establish new, irrigation schemes. Cultivated land expanded at a rapid pace as a result of irrigation and a marked shift away from livestock herding to cash crop production by the 1980s (Rutten, 1992: 313). Land sub-division further catalysed enthusiasm for cultivation as some people unwittingly sold their title deeds for quick cash and it was increasingly recognized that agriculture provided more economic incentives than livestock rearing. Furthermore, practicing pastoralism was made more difficult within restricted boundaries and a changing ownership landscape.

In 1977, in the midst of contentious changing land use practices and tenure systems in Kajiado, the government also established the 388 km^2 Amboseli National Park enclosing Enkong'u Narok and Longinye Swamps. Apart from being a wildlife refuge, Amboseli National Park is one of Kenya's most important assets for wildlife-based tourism, an industry that in 2009 accounted for 15% of the GDP totaling revenues of KES 73.68 billion (Republic of Kenya, 2011). Yet, migratory, grazing wildlife and livestock that had once predictably concentrated during the dry season around perennial waters then dispersed during the wet season to the larger northern bushland ranges with more nutritious grasses grow were separated after the enforcement of national park legislation (Western and Lindsay, 1984; Western, 2007). In accordance with trends embracing community-focused conservation and pro-poor tourism, various development programs have since been implemented in order to provide Maasai with continuous appreciable benefits in return for compromises in land use initiated by the creation of the National Park and tolerance of wildlife encroachment. The efficacy of these policies, however, remains debatable (Lindsay, 1987; Norton-Griffiths and Southey, 1995; Okello *et al.*, 2011). Furthermore, conservationists are conveying dissent in response to the insularization of Amboseli National Park due to infrastructure developments, the disruption and segregation of the once fluid herder, livestock, and wildlife populations, and ongoing issues of competition over water for agriculture, which some predict will result in the park becoming an unviable ecological island (Newmark and Hough, 2000; Okello and Kioko, 2010; Reid, 2012).

Continually, the history of Kajiado reveals the vital role of water for shaping its future. Water is one of the most important resources controlling ecological and economic functions on the landscape. In addition to attracting and supplying migratory wildlife, and consequently tourists, the wetlands are integral to the livelihoods of people in the region dependent on livestock production and irrigation farming. The interconnected streams and swamplands have been experiencing increasing pressure from human populations over the past few decades and there is a need to evaluate management of these resources to ensure ecosystem services and sustained socioeconomic benefits locally and regionally. Multiple wetlands have been effectively drained to establish irrigation schemes for crops such as tomatoes, onions, *Capsicum*, maize, and beans for markets in Tanzania, Mombasa and Nairobi, reducing the area available for grazing and complicating access to water for domestic animals and wildlife. Intense small scale irrigated farming has led to the drainage and almost complete transformation to cultivation of some swamps, for example Isinet. Such drastic landscape-scale modifications highlight the importance of the need for sustainable land management planning and land-use enforcement strategies that adequately balance conservation, socioeconomic development, and ecosystem function goals.

A survey carried out across the Amboseli wetlands to compare water quality along land-use classes identified the main land use types having the highest negative impact on the wetlands (Githaiga *et al*., 2003). Expanding agriculture (irrigation) was found to have the highest negative impact on water quality and quantity through competition with other water users and chemical contamination from fertilizer/pesticide use. Namelok was identified as representing the highest level of human impact from irrigated agriculture and wildlife impacts while Kimana was identified as experiencing intermediate levels of impact from irrigation, livestock and wildlife.

1.4 Study Sites

1.4.1 Lielerai Kimana Swamp Sanctuary

The Kimana wetlands, situated in the former Kimana-Tikondo group ranch (that is currently in the process of sub-division) in Kajiado South County (formerly Loitokitok District), are part of the larger Amboseli wetland system. Kimana Swamp is located at 2° 44.930' S, 37° 30.922' E at an elevation of 1221 m asl, covering 6400 ha and is channel fed by the Kimana River that is hydrologically sourced by natural springs that are recharged from the Chyulu Hills to the east and the northern slopes of Mt. Kilimanjaro 40 km to the south-southwest (Fig. 1.2). The majority of precipitation is derived from the Indian Ocean and topography south of the swamps orographically uplifts air masses causing precipitation. During positive phases of the Indian Ocean Dipole, the surface waters of the western Indian Ocean are warmer leading to increased convections and heavier rains in East Africa (Saji *et al*., 1999; Marchant *et al*., 2006). The surface runoff percolates into the basaltic bedrocks and the groundwater flow toward the low elevation Amboseli Basin are the sources for the springs. The Kimana basin is flat with depressions scattered across it, Kimana River flows south to north through the sanctuary and floods during the short rains and merges hydrologically with Marura Swamp. Local soils are Inceptisols, suborder Tropepts. *Lielerai*, derived from *Olerai*, is a Maa word meaning the *Acacia xanthophloea* tree and *Kimana* means ‘continuous circle’ or ‘something going around’. Immediately surrounding the wetlands is open woodland of trees, woody shrubs and grasses. Kimana wetlands are dominated by Cyperaceae and Poaceae (Table 1.1).

Table 1.1: Plant species identified at Kimana.

Functional grouping	**Family, subfamily**	**Species**
Trees	Fabaceae, Mimosoideae	*Acacia xanthophloea*
	Convolvulaceae	*Ipomoea arborescens*
	Arecaceae	*Phoenix roebelenii*
Shrub	Apocynaceae	*Tabernaemontana elegans*
	Malvaceae	*Abutilon mauritanium*
	Fabaceae	*Senna* spp.
Herb	Lamiaceae	*Ocimum gratissimum*
Grasses		*Cynodon dactylon*
		Digitaria ciliaris
		Pennisetum clandestinum
Aquatics (emergent)	Cyperaceae	*Cyperus laevigatus*
		Cyperus papyrus
		Cyperus rotundus
	Juncaceae	*Juncus* sp.

The Kimana sanctuary occupies an area of 6400 ha and the Lielerai Kimana swamp is located here. It functions as an important dry season refuge and wildlife dispersal region connecting animals to other migration corridors outside the boundaries of Amboseli National Park. Lielerai Kimana Swamp supports a number of large mammals such as elephants, giraffes, large cats, zebras, ungulates, jackals, and elands, and a resident breeding population of hippopotami. The swamp has been the focus of various conservation and tourist industry claims since 1996 when the United States Agency for International Development financed the Kimana Community Wildlife Sanctuary. The architects of this for profit community conservation pilot project were David Western (former director of KWS) and Paul L. Ole Nangoro, the chairman of Kimana-Tikondo Group Ranch. Kimana Sanctuary was designed to direct the monetary benefits of tourism to the approximate 840 Maasai families living on the Kimana-Tikondo group ranch at the time. The Kimana Community Wildlife Sanctuary unfortunately failed to meet community expectations of suitable benefits to wildlife protection, and in 2000 the sanctuary was leased for 10 years to a tourism company, African Safari Club.

According to a Meguro and Inoue (2011), employment generated by Kimana Lodge (as it was renamed) increased substantially with the change in management and annual average revenues skyrocketed by a factor of 567%. Africa Safari Club built two lodges and a tented camp in addition to an airstrip on the sanctuary that could accommodate and transport a total of 160 ecotourists at any given time. More than KES 20 million of the income generated by African Safari Club management of the protected swamp was used by the Kimana-Tikondo group ranch committee to subdivide, a decision no doubt spurred on my contested land claims over cultivatable areas. Community members that we spoke with in March-April 2014 informed us that each registered Kimana-Tikondo group ranch member received 25 ha of land in addition to a 0.8 ha farming parcel with access to water for cultivation.

In March 2011, Swiss-owned African Safari Club group became insolvent and ceased trading, though the company's operations had been suffering for some years prior. Stephen Sindole, an Olive Branch Mission employee, relayed to us that 2009 had been the pivotal year for the cessation of Kimana Lodge tourist operations. Unfortunately, 2009 was also a major drought year in Amboseli, thus the permanent water in the Kimana protected area was seriously attractive to wildlife, livestock, and agriculturalists. In 2010 management responsibilities and direction in the Kimana protected area was unclear until Richard Bonham, co-founder and director of operations in Africa of Big Life Foundation and owner of nearby ol Donya safari tourism lodge on the former Mbirikani group ranch became involved. Big Life Foundation was established in 2010 in response to a 2009-2011 rise in poaching activity in the Kilimanjaro area (Big Life Foundation, 2012; Wittemyer *et al*., 2013). Big Life Foundation has 21 anti-poaching outposts staffed by 250 rangers in addition to anti-poaching patrol vehicles, a Microlight plane for aerial monitoring in Tanzania, and two sets of fully-trained tracker dogs (BLF, 2012). Big Life Foundation brought this para-military might to the Kimana protected area to enforce anti-grazing, cultivation, and poaching regulations. In the interim Kimana-Tikondo group ranch officials had been engaged in negotiations with other conservation/tourist industry investors until in 2014, Olive Branch Mission, a Chicago based Christian humanitarian, environmental, and spiritual organization committed to a 25-year lease of the Kimana Swamp Sanctuary. Olive Branch Mission aims to protect and manage the sanctuary for wildlife, but also to promote community benefits through multiple integrated initiatives.

Figure 1.2: Lielerai Kimana swamp (center) and surrounding landscape.

1.4.2 Ormakau Swamp

Ormakau Swamp is a Cyperaceae-Poaceae dominated swamp located at 2° 43.166’ S, 37°27.329’ E, at an elevation of 1170 m asl, in Namelok, Kajiado South County (Figs. 1.3 and 1.4 and Table 1.2). The swamp is sustained by five springs opening from the basaltic bedrock. Local soils are Inceptisols, suborder Tropepts. There are numerous small gullies within the steeper hypsographic gradients near the swamp and there is one ephemeral river channel entering from the east side of the swamp. The springs are fed from sources on the northern slopes of Mt Kilimanjaro, located 40 km to the south-southwest. *Ormakau* is a Maa word meaning "hippopotamus" and *Namelok* means "sweet place".

Table 1.2: Plant species identified at Ormakau.

Functional grouping	Family, subfamily	Species
Trees	Fabaceae, Mimosoideae	*Acacia brevispica*
		Acacia mearnsii
		Acacia tortilis
		Acacia xanthophloea
		Albizia spp.
	Fabaceae	*Senegalia senegal*
	Sterculiaceae	*Dombeya burgessiae*
Shrub	Apocynaceae	*Tabernaemontana elegans*
	Solanaceae	*Solanum incanum*
	Myrtaceae	*Syzygium* spp.
	Malvaceae	*Abutilon mauritanium*
Herb	Amaranthaceae	*Achyranthes aspera*
		Amaranthus hybridus
	Asteraceae	*Aspilia pluriseta*
	Lamiaceae	*Leonotis mollissima*
		Ocimum gratissimum
		Plectranthus barbatus
	Malvaceae	*Pavonia patens*
	Salvadoraceae	*Azima tetracantha*
Grasses	Poaceae	*Pennisetum clandestinum*
	Juncaceae	*Juncus* sp.
Aquatics (emergent)	Cyperaceae	*Cyperus laevigatus*
		Cyperus papyrus
		Cyperus rotundus
	Polygonaceae	*Polygonum* spp.
		Rumex usambarensis
	Typhaceae	*Typha latifolia*

Namelok swamps fell under what used to be Mbirikani and Olgulului/Lolahashi group ranches, but these have since been subdivided. Currently, the two main swamps in Namelok are Ormakau and Engumi, named after two perennial rivers. Engumi and Ormakau Rivers flow from Mount Kilimanjaro and drain eastwards towards the Chyulu Hills. A sediment study at Engumi Swamp based on a core that provided a 3100 year record showed that the vegetation in the area had responded to changes in climate and land use activities by humans and herbivores (Rucina *et al*., 2010). As of 2003, over 50% of the original Namelok swamp had been converted to agriculture (Worden *et al*., 2003).

In the early 1970s irrigated agriculture was practiced in Namelok, though it intensified during a drought period in the mid-1980s. The water available in the swamp system became increasingly valued and utilized for agricultural activities as pastoralists suffered livestock losses and competition for dwindling resources. Conflict with wildlife also escalated so that in 1999, with assistance from the European Union, electric fences were built around the entire Namelok swamp system to restrict access by wildlife as part of a larger scheme to support irrigated agriculture in the area. Buffalo and hippopotami have been extirpated from Ormakau. Solomon Miseyieki, the chairman of the Namelok Swamp irrigation scheme informed us that at one time Ormakau swamp was 24 km^2 with surrounding forests covering 10 km^2. Ormakau Swamp currently occupies an area of 0.95 km^2, which is entirely enclosed by a stone wall erected in early 2014 with financial assistance from the African Development Bank and Ministry of Agriculture. The wall is designed to deter livestock and wildlife but also any unsanctioned human activity from occurring within the boundary in order to protect the water that is used to irrigate the surrounding plots. There are five clustered springs which feed into the swamp, all of which flow through underground channels through vesicular basalt bedrock. Omakau is certainly a resource that is essential for the livelihoods of agriculturalists in the Namelok area, though it is no longer a viable habitat for livestock and the majority of the wildlife species it used to sustain. Miseyieki also revealed to us that access to water from Omakau for cultivation purposes in the future will require the payment of taxes in order to meet loan requirements from the African Development Bank. Continued utilization of Omakau for cultivation requires sustainable management.

Figure 1.3: Ormakau swamp (center) and Namelok village (left).

Figure 1.4: Typical Cyperaceae vegetation at Ormakau. Photograph: Esther Githumbi, 30 March 2014.

2.0 Methods

2.1 Field Methods

Vegetation surveys, sediment depth profiling (Fig. 2.1), sediment coring (Fig 2.2 and 2.3), and placement of pollen traps (Fig. 2.4 and 2.5) were undertaken at Ormakau Swamp from 30-31 March and 2 April and at Lielerai Kimana Swamp on 29 March and 1 April, 2014. Two cores were retrieved from Ormakau swamp ORM 1 which was 121cm and ORM 2 which was 304cm, the Lielerai Kimana swamp core was 384cm long. A Russian Corer was used to collect the sediment stratigraphies in 50-cm drives that overlapped by ~10 cm to ensure the full stratigraphy was represented. Cores were wrapped in plastic and aluminum foil and stored at the National Museums of Kenya. Surface samples of the uppermost 2 cm of the sediments were collected in Whirl-pak bags® from the coring sites as well as most pollen trap locations. Pollen traps, following the Behling design (Behling *et al*., 2001; Jantz *et al*., 2013; Schüler *et al*., 2014; Fig. 2.4), were deployed within and surrounding the swamps to characterise the spatial variability of the modern pollen rain and to assess vegetation-pollen relationships. Deployment locations were chosen to cover the variability of vegetation surrounding the wetlands. At each swamp, 20 traps were placed and GPS coordinates recorded. Pollen traps were assembled at the National Museums of Kenya using 75 mL Fisherbrand™ centrifuge tubes, which contained 5 mL of glycerol ($C_3H_8O_3$) jelly and a wad of synthetic cotton wool stuffing, strapped to 50 cm long wood stakes (Fig. 2.5). Interested volunteer participants agreed to periodically monitor the pollen traps at each site to ensure continual collection of the pollen rain (see acknowledgements; Fig. 2.5D).

Figure 2.1: Assessing the sediment depth at Ormakau using metal rods to reach the bedrock under the swamp sediments. Photograph: Rebecca Muthoni, 30 March 2013.

Figure 2.2: Collecting deep sediments from Ormakau using a Russian Corer with extension rods. Photograph: Esther Githumbi, 31 March, 2014.

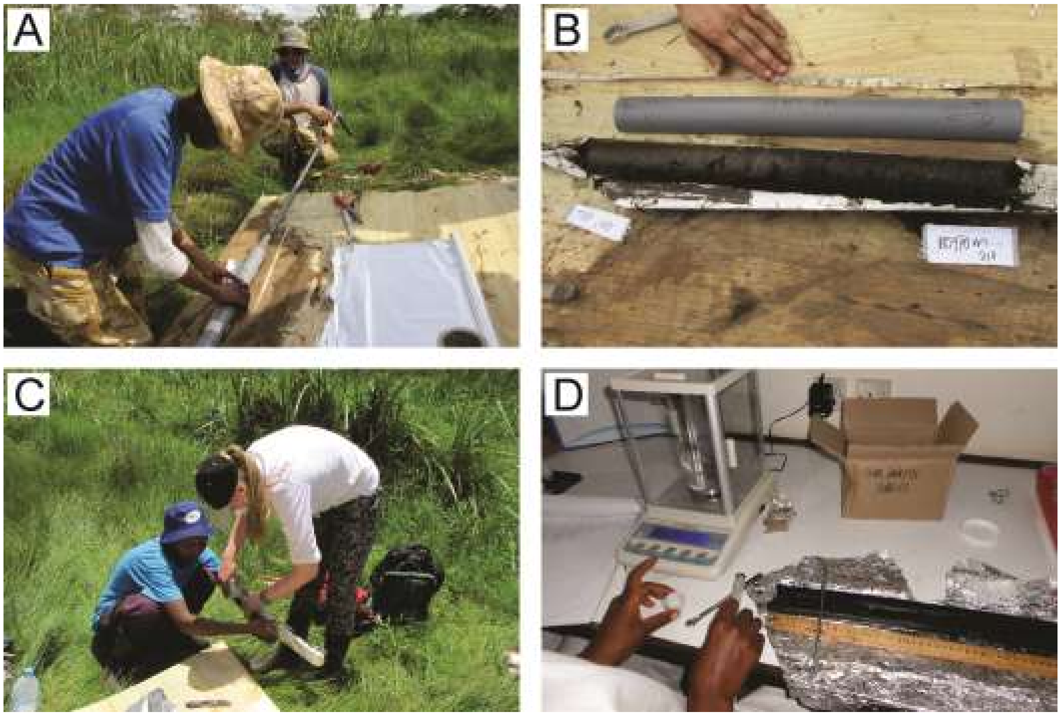

Figure 2.3: A) Sediment core extrusion in the field at Ormakau, B) Core section ORM 2E of the sediment stratigraphy from 160-210 cm depth. C) Wrapping of the cores in plastic and aluminum foil for storage and shipping. D) Laboratory work on sediments at the National Museums of Kenya, Palaeobotany and Palynology Section, Nairobi. Photographs: A-C Esther Githumbi, D Colin Courtney Mustaphi.

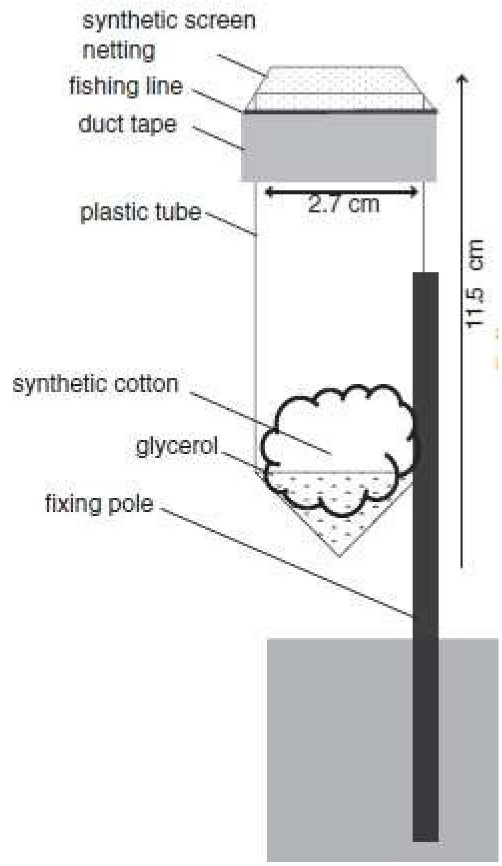

Figure 2.4: Behling pollen trap design (adapted from Jantz *et al*., 2013).

Figure 2.5: A) Main components of the Behling design pollen traps (Behling *et al*., 2001; Jantz *et al*., 2013), B) a completed trap, C) traps were shipped from the National Museums of Kenya covered in plastic, and D) a deployed trap at Kimana Swamp location 6. Photographs: A-C Colin Courtney Mustaphi and D Esther Githumbi.

2.2 Laboratory Methods and Future Analyses

The recovered sediments will be used for sedimentological investigations and vegetation reconstructions using pollen analysis (Fægri and Iversen, 1989; Moore *et al*., 1991), plant macroremains, and charcoal analysis (Whitlock and Larsen, 2001). Laboratory analyses to characterise the sediments and understand the depositional environment will include determination of detailed lithology, bulk density, organic and inorganic content, magnetic susceptibility and radiocarbon dating. An exotic marker, for example *Lycopodium* spores, will be added prior to pollen analysis to aid in calculation of absolute concentrations (Stockmarr, 1971). This analysis will provide samples needed for the identification and enumeration of the pollen, spores and charcoal. A 1 cm^3 subsample interval will be used and concentration quantified as abundance (number of particles per unit of volume). The analysis will be carried out at a magnification of ×400 to ×1000 and from each slide a minimum of 400 pollen grains, excluding Poaceae and Cyperaceae, will be counted. Pollen grains will be identified using published references and a reference collection at the National Museums of Kenya.

The study will provide a lithological description of soils from the different sites and a chronology providing dates at different levels which will be important in time periods for the occurrences of the different variations such as changes in climate, introduction of exotic species, human impacts like burning, grazing and agriculture. Charcoal analyses (Conedera *et al*., 2009) will provide insight into the history of biomass burning in the region and be used to assess the dominant controls of the fire regimes during the geologic past (Whitlock *et al*., 2010; Bowman *et al*., 2011). Long term vegetation records from the pollen will be used to assess changes in the ecosystem and the influence of climate change and human activities will be obtained. A fire history record from the charcoal data will also be acquired and analysed. The pollen and charcoal data will also be used to identify the occurrence of large disturbance events if any and the responses which is important in trying to predict future ecosystem responses to similar events. The data will give evidence of ecosystem changes experienced in the past and help us understand the major drivers of environmental change in the region.

3.0 Capacity-Building Outcomes

3.1 Field Methods Training and Experience

A substantial focus during fieldwork was multidisciplinary training of REAL ESRs and NMK staff in palaeoenvironmental sampling techniques and methods. This training complemented a palaeoenvironmental workshop assembled by a REAL ER held at the NMK, Nairobi, from 17-20 March, 2014. The workshop provided participants with a theoretical understanding of how scientists analyse sedimentary records and how these data are used to interpret past environmental conditions and to understand landscape processes at various scales. NMK staff and REAL students attended the workshop and the following students undertook field-based training in Amboseli, Kajiado District, southern Kenya:

- Aynalem Z. Degefa, REAL ESR, Ghent University
- Rebecca Muthoni, intern, National Museum of Kenya
- Nik Petek, REAL ESR, Uppsala University
- Anna Shoemaker, REAL ESR, Uppsala University
- Geert van der Plas, REAL ESR, Ghent University

Previous range of knowledge and practical experience in palaeoenvironmental work ranged from novice to expert levels. As a result, Geert van der Plas was actively assisting in teaching and explaining the work coring work undertaken and experience with tropical ecosystems. During the training participants were expected to:

- Fully participate in any activity that would have helped them better understand the objectives and outcomes of the fieldwork
- Assist Esther Githumbi and Colin Courtney Mustaphi in the collection of cores and other field-based data collection
- Engage with the local community and build up a relationship with them
- Assist in the preparatory logistics for fieldwork
- Apply knowledge gained from the palaeoenvironmental workshop at NMK

- Be inquisitive about the present and past environments, and learn about plant species, ecosystem dynamics, and landscape processes

The learning outcomes, upon completion of the training/fieldwork, were:

- An understanding of what a robust coring site is and how to recognise it
- An understanding of tropical wetland ecology and the local flora
- An understanding of palaeoenvironmental fieldwork from start to finish
- Having the ability to undertake coring and properly preserve cores in the field
- An understanding of what complementary datasets to sediment cores were needed
- The ability to be critical when interpreting palaeoenvironmental research papers pertinent to the participants area of study

The participants divided the workload and took part in as many activities as possible. There were extensive unstructured discussions with locals and students about the politics surrounding the swamps and in what ways the communities relate to them. At the same time they established contact with local students and 'digital morans' (the educated warrior age set of the Masaai) who were interested in the work the group was doing. Anna Shoemaker and Rebecca Muthoni also inspected the environment outside the immediate vicinity of Ormakau swamp with Solomon (Local guide). The group also set up transects across Ormakau swamp to probe the sediment depth in order to find the best coring spot. At Lielerai Kimana Sanctuary swamp probing of sediment depth was done at random, but in as many different micro-ecological spots as possible. The participants experienced various survey techniques and learnt to record the probes using a GPS and measuring. Through this process they also learnt to identify suitable spots for coring, what sediments are best suited for pollen preservation, and what plant types are necessary for peat formation and stratigraphic preservation.

The trainees learned how to use a Russian corer, and how to prepare and preserve the core in the field for transport and later analyses in the laboratory setting. Once target coring locations were scouted, Colin Courtney Mustaphi, Aynalem Degefa, Nik Petek, and Geert van der Plas, focused on sediment core acquisition and extraction, while Esther Githumbi, Rebecca Muthoni and Anna Shoemaker catalogued and prepared the cores for shipping and storage. Later, all participants deployed pollen traps to collect modern pollen rain in the area, setting them up alongside a varied set of plant species assemblages to assess the spatial variability of pollen deposition. Aynalem Degefa, Nik Petek, and Geert van der Plas, were taught how to operate a remotely controlled quadcopter (DJI Phantom II) with a GoPro Hero 3+ camera for air photography and documentation of the vegetation zones of the swamps (Page 31). Aynalem Degefa, Esther Githumbi, Nik Petek, and Geert van der Plas were also taught by Rob Marchant, Phil Platts (U. of York), and Marion Pfeiffer (ICL), on the acquisition and use in ecological researcher of hemispherical photography to estimate leaf-area coverage for the calibration of satellite imagery to examine plant productivity metrics. At Kimana Sanctuary, the group was joined by two sets of O-level students working with Olive Branch Mission (Loitokitok). Because of the wet conditions, the students could not enter deeper into the wetland. The students learned about palaeoecology and its application to environmental research the design and use of pollen traps, and took part in deploying them out with the group. This cooperation also offered the opportunity for REAL and NMK trainees to show what they have learned during the previous days and engaged one on one with the students to discuss questions about the wetlands, its history, and its governance.

3.2 Volunteerism

During fieldwork volunteers from the local communities and the Olive Branch Mission partook in some of the activities; notably, toward the deployment of the pollen traps and monitoring efforts of the traps for the duration of one year. Collection is scheduled for May 2015. These efforts will reduce the probability of disturbance to the traps and facilitate collection. This also gave the participants time to discuss the recent history of the swamp, its importance, and perspectives on management.

4.0 Planned Outcomes and Scientific Contributions

These datasets and interpretations will contribute to a PhD dissertation at the University of York, UK, and the results will be published in the peer-reviewed scientific literature and data made publicly available. This information will contribute to our knowledge of the evolution of these ecosystems, the dominant earth system processes in operation that have been occurring in concert with the human land-use relationship with the landscape, and give us a stronger understanding of how these critically important wetland systems may respond to climate change and human land-use patterns in the future. Specific contributions are anticipated to our understanding of vegetation responses to climate variability and human activities in the Amboseli Basin during the late Holocene, an understanding of the role of fire in influencing plant biogeography and diversity, in response to natural drivers of fire activity and human behavioural patterns, and insights into vegetation-pollen relationships to further understand plant land cover distributions in the pollen records.

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Table A: Pollen trap locations at Kimana Sanctuary

ID	Latitude	Longitude	Water depth (cm)	Sediment depth (cm)	Description
1	S 02° 45.179'	E 037° 31.024'	0	n/a	
2	S 02° 45.126'	E 037° 31.019'	0	n/a	
3	S 02° 45.034'	E 037° 31.004'	0	39	floodplain, bioturbated
4	S 02° 45.002'	E 037° 30.994'	0	n/a	next to *Tabernaemontana*
5	S 02° 45.075'	E 037° 30.978'	0	n/a	Under *Acacia xanthophloea*
6	S 02° 45.014'	E 037° 30.955'	2	140	Organic clay sediment.
7	S 02° 44.976'	E 037° 30.941'	8	172	Clay sediment, organic-sand at base
8	S 02° 44.953'	E 037° 30.924'	2	n/a	Organic rich
9	S 02° 44.939'	E 037° 30.927'	0	n/a	
10	S 02° 44.930'	E 037° 30.922'	2	388	**Coring point**: Ends at thick sandy layer
11	S 02° 44.938'	E 037° 30.908'	22	165	Under *Acacia xanthophloea*, H_2O pH=7
12	S 02° 44.896'	E 037° 30.874'	0	1	
13	S 02° 44.892'	E 037° 30.878'	0	n/a	In Cyperaceae
14	S 02° 44.868'	E 037° 30.865'	0	153	
15	S 02° 44.857'	E 037° 30.869'	0	176	
16	S 02° 44.849'	E 037° 30.875'	0	n/a	Too many roots
17	S 02° 44.850'	E 037° 30.883'	0	459	
18	S 02° 44.848'	E 037° 30.889'	0	500	
19	S 02° 44.824'	E 037° 30.868'	0	132	
20	S 02° 44.820'	E 037° 30.884'	0	176	

Table B: Pollen trap locations at Ormakau Swamp

ID	Latitude	Longitude	Water depth (cm)	Sediment depth (cm)	Description
1	S 02° 43.126'	E 037° 27.331'	0	58	Two sandy layers
2	S 02° 43.114'	E 037° 27.331'	0	10	Sandy layer at top
3	S 02° 43.106'	E 037° 27.343'	0	12	
4	S 02° 43.094'	E 037° 27.339'	0	142	
5	S 02° 43.083'	E 037° 27.357'	0	23	
6	S 02° 43.092'	E 037° 27.362'	30	160	
7	S 02° 43.071'	E 037° 27.330'	0	42	Rocky bottom
8	S 02° 43.068'	E 037° 27.370	14	294	
9	S 02° 43.044'	E 037° 27.361'	N/A	3	Root underneath
10	S 02° 43.037'	E 037° 27.355	0	N/A	Soil too dry
11	S 02° 43.039'	E 037° 27.377'	78	279	One sand layer
12	S 02° 43.044'	E 037° 27.379'	56	14	
13	S 02° 43.056'	E 037° 27.372	0	0	
14	S 02° 43.166'	E 037° 27.342	11	143	
15	S 02° 43.176'	E 037° 27.357'	0	79	
16	S 02° 43.131'	E 037° 27.366'	20	0	Thin clay layer
17	S 02° 43.051'	E 037° 27.399'	0	0	Dry soil sample
18	S 02° 43.027'	E 037° 27.405'	0	0	
19	S 02° 43.016'	E 037° 27.425'	1	73	
20	S 02° 43.004'	E 037° 27.428'	0	0	

Table C: Sediment depths at Kimana Sanctuary

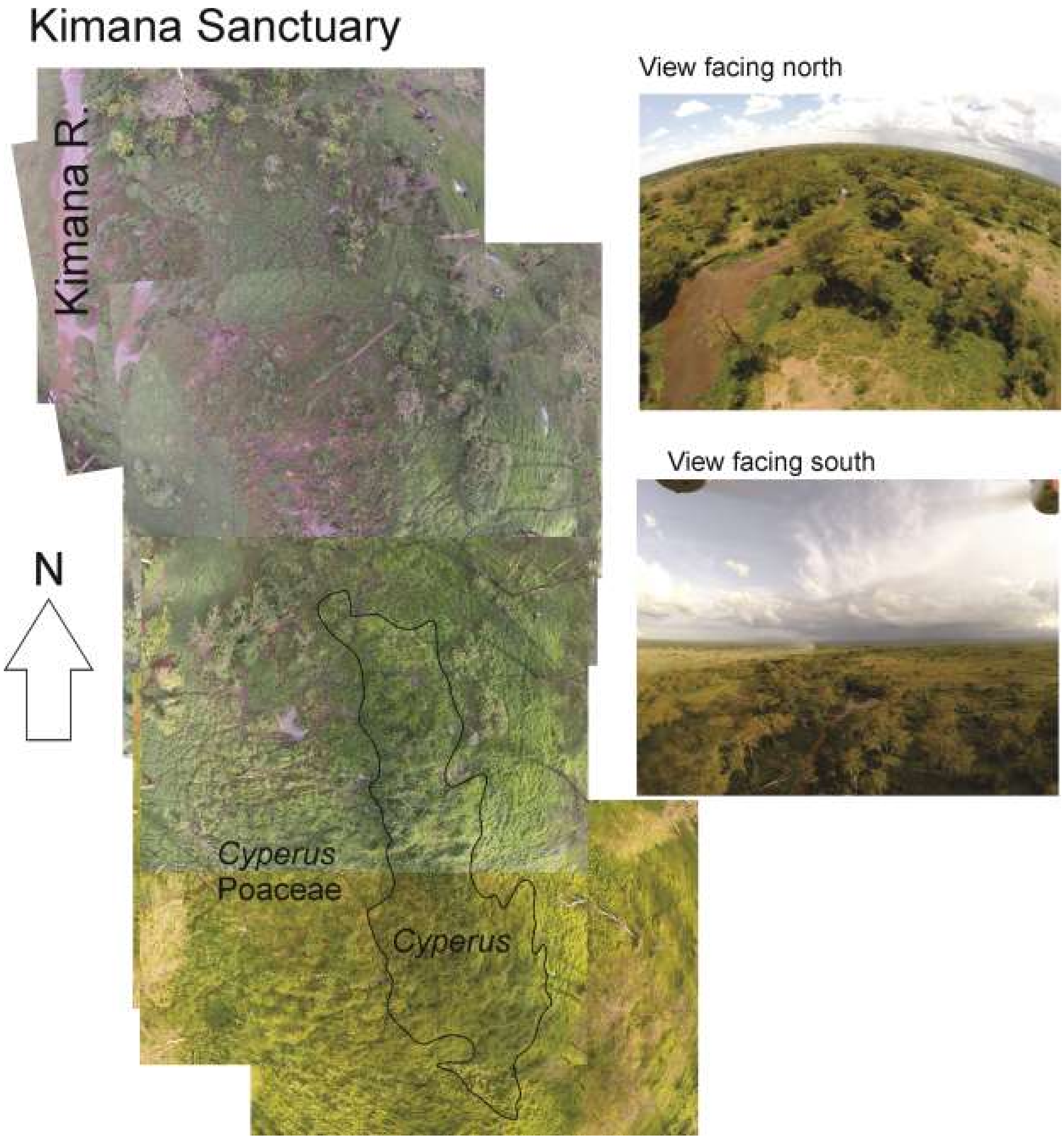
Latitude	Longitude	Water depth (cm)	Sediment depth (cm)	Description
S 02° 45.004'	E 037° 30.939'	2	103	Silty organic sediment. *Acacia xanthophloea*, *Pennisetum clandestinum*. base rock
S 02° 44.987'	E 037° 30.923'	1	102	*Acacia*, minor sedge, grass. base rock
S 02° 44.981'	E 037° 30.919'	0	128	clay silty organic
S 02° 44.978'	E 037° 30.933'	0	117	clay silty organic, rock bottom
S 02° 44.970'	E 037° 30.914'	0	88	Grassy area, Juncaceae
S 02° 44.972'	E 037° 30.916'	1	118	minor sedges, grasses
S 02° 44.963'	E 037° 30.932'	8	136	sedges, grasses
S 02° 44.957'	E 037° 30.926'	14	258	organic silt with sand, short sedge and grass
S 02° 44.936'	E 037° 30.904'	18	134	organic rich clay with small sand particles
S 02° 44.924'	E 037° 30.899'	10	158	organic rich sediment, mainly Cyperaceae and grasses
S 02° 44.894'	E 037° 30.868'	6	114	organic rich clay with sand. Cyperaceae and palmae (*Phoenix*) present
S 02° 44.879'	E 037° 30.859'	0	81	Light-coloured clay
S 02° 44.852'	E 037° 30.866'	3	159	Cyperaceaea dominated
S 02° 44.848'	E 037° 30.879'	0	281	organic rich clayey sediment. Cyperaceae and sedge dominated
S 02° 44.942'	E 037° 30.931'	2	396	Path to the inside, silty organic sediment.
S 02° 44.931'	E 037° 30.928'	0	400	Thick fine sand layer at the bottom.
S 02° 44.952'	E 037° 30.939'	2	392	Organic rich
S 02° 44.930'	E 037° 30.922'	2	381	**Coring area.** Ends at thick sandy layer
S 02° 45.014'	E 037° 30.998'	0	33	still in flood plain, highly bioturbated
S 02° 44.977'	E 037° 30.942'	1	45	Organic rich
S 02° 45.034'	E 037° 31.004'	0	39	floodplain, bioturbated by hippos
S 02° 45.014'	E 037° 30.955'	2	140	Organic clay sediment.
S 02° 44.976'	E 037° 30.941'	8	172	Clay sediment/ organic and sand at the bottom
S 02° 44.930'	E 037° 30.922'	2	388	Ends at thick sandy layer
S 02° 44.938'	E 037° 30.908'	22	165	Under *Acacia xanthophloea*, H_2O pH=7
S 02° 44.896'	E 037° 30.874'	0	1	
S 02° 44.868'	E 037° 30.865'	0	153	
S 02° 44.857'	E 037° 30.869'	0	176	
S 02° 44.850'	E 037° 30.883'	0	459	
S 02° 44.848'	E 037° 30.889'	0	500	
S 02° 44.824'	E 037° 30.868'	0	132	
S 02° 44.820'	E 037° 30.884'	0	176	

Table D: Sediment depths at Ormakau Swamp

Latitude	Longitude	Water depth (cm)	Sediment depth (cm)	Description
S 02° 43.165'	E 037° 27.343'	n/a	16	
S 02° 43.160'	E 037° 27.344'	n/a	175	fine sandy silt, coarser towards the bottom.
S 02° 43.161'	E 037° 27.342'	n/a	34	
S 02° 43.160'	E 037° 27.331'	n/a	23	
S 02° 43.162'	E 037° 27.332'	n/a	147	fine sandy silt, coarser towards the bottom.
S 02° 43.160'	E 037° 27.343'	n/a	139	
S 02° 43.163'	E 037° 27.348'	n/a	120	
S 02° 43.134'	E 037° 27.346'	n/a	275	coarse sandy layer, very compact at top
S 02° 43.135'	E 037° 27.351'	n/a	261	coarse sand layer at start
S 02° 43.122'	E 037° 27.340'	n/a	308	
S 02° 43.124'	E 037° 27.349'	n/a	313	
S 02° 43.125'	E 037° 27.355'	n/a	250	
S 02° 43.125'	E 037° 27.363'	n/a	156	
S 02° 43.149'	E 037° 27.370'	n/a	129	Sediment is organic rich
S 02° 43.149'	E 037° 27.366'	n/a	236	
S 02° 43.149'	E 037° 27.364'	n/a	209	
S 02° 43.135'	E 037° 27.331'	n/a	76	
S 02° 43.130'	E 037° 27.332'	n/a	294	coarse sand at the bottom
S 02° 43.112'	E 037° 27.340'	n/a	246	
S 02° 43.113'	E 037° 27.342'	48	307	silty organic, no sand layer. Hard sandy base
S 02° 43.111'	E 037° 27.346'	70	330	fine organic silt material, bottom is sand
S 02° 43.110'	E 037° 27.348'	110	270	fine organic clay material, thick clay base
S 02° 43.108'	E 037° 27.353'	77	287	fine organic clay silt sediment, shallow sand and pebble base.
S 02° 43.102'	E 037° 27.344'	0	215	2 sandy layers , clay, silt sand at the bottom
S 02° 43.091'	E 037° 27.358'	0	225	silty clay, two old trees near large grass clearing aroung papyrus.
S 02° 43.092'	E 037° 27.364'	0	425	sandy bottom
S 02° 43.096'	E 037° 27.367'	151	264	sediment is organic clay
S 02° 43.094'	E 037° 27.369'	212	156	clayish organic rich sediment
S 02° 43.068'	E 037° 27.359'	0	217	fine sand and clay sediment
S 02° 43.070'	E 037° 27.362'	on grass	181	organic rich and went through one sand layer
S 02° 43.070'	E 037° 27.365'	0	245	organic rich clayey with hard layer at bottom
S 02° 43.070'	E 037° 27.366'	0	344	deeper grass, organic rich
S 02° 43.068'	E 037° 27.370'	62	347	silty clay, 2 trees near grass clearing around *C. papyrus*.
S 02° 43.067'	E 037° 27.373'	62	223	

S 02° 43.066'	E 037° 27.376'	112	289	
S 02° 43.065'	E 037° 27.382'	170	223	
S 02° 43.040'	E 037° 27.369'	34	130	
S 02° 43.040'	E 037° 27.374'	68	192	
S 02° 43.041'	E 037° 27.380'	121	308	
S 02° 43.042'	E 037° 27.385'	151	278	
S 02° 43.039'	E 037° 27.385'	120	295	
S 02° 43.038'	E 037° 27.387'	n/a	273	
S 02° 43.044'	E 037° 27.378'	95	219	
S 02° 43.051'	E 037° 27.377'	50	258	
S 02° 43.053'	E 037° 27.375'	n/a	330	
S 02° 43.058'	E 037° 27.372'	n/a	350	no sand layer
S 02° 43.055'	E 037° 27.369'	19	122	sandy bottom
S 02°43.057'	E 037° 27.366'	12	43	rock base
S 02° 43.056'	E 037° 27.367'	12	262	rock base
S 02° 43.057'	E 037° 27.365'	0	130	
S 02° 43.126'	E 037° 27.331'	0	58	2 sandy layers
S 02° 43.114'	E 037° 27.331'	0	10	Sandy layer at the top
S 02° 43.106'	E 037° 27.343'	0	12	
S 02° 43.094'	E 037° 27.339'	0	142	
S 02° 43.083'	E 037° 27.357'	0	23	
S 02° 43.092'	E 037° 27.362'	30	160	
S 02° 43.071'	E 037° 27.330'	0	42	Rocky bottom
S 02° 43.068'	E 037° 27.370	14	294	
S 02° 43.044'	E 037° 27.361'	n/a	3	Root underneath
S 02° 43.037'	E 037° 27.355	0	n/a	Soil too dry
S 02° 43.039'	E 037° 27.377'	78	279	One sand layer
S 02° 43.044'	E 037° 27.379'	56	14	
S 02° 43.056'	E 037° 27.372	0	0	
S 02° 43.166'	E 037° 27.342	11	143	
S 02° 43.176'	E 037° 27.357'	0	79	
S 02° 43.131'	E 037° 27.366'	20	0	Thin clay layer
S 02° 43.051'	E 037° 27.399'	0	0	Dry soil sample
S 02° 43.027'	E 037° 27.405'	0	0	
S 02° 43.016'	E 037° 27.425'	1	73	
S 02° 43.004'	E 037° 27.428'	0	0	

Ormakau Swamp



Lielerai Kimana Swamp