SITE SUITABILITY ASSESSMENT OF THE PROPOSED SITE FOR LAND BASED AQUACULTURE PARK IN APAC

Report prepared for the Department of Fisheries Resources (DFR), Ministry of Agriculture, Animal Husbandry and Fisheries (MAAIF)

By

National Fisheries Resources Research Institute (NaFIRRI), National Agricultural Research Organization (NARO)

JANUARY 2019

Table of Contents

List of Acronyms

AP	Aquaculture Park
CGS	Course Grained Soils
Cond	Conductivity
DFR	Department of Fisheries Resources
DSIP	Development Strategy and Investment Plan
DO	Dissolved Oxygen
FGS	Fine Grained Soils
FR	Flow rate
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MWE	Ministry of Water and Environment
MoTIC	Ministry of Trade, Industry and Cooperatives
MoFPED	Ministry of Finance Planning and Economic Development
NaFIRRI	National Fisheries Resources Research Institute
NDP	National Development Plan
NEMA	National Environment Management Authority
SD	Secchi Depth
SRP	Soluble Reactive Phosphorous
Temp	Temperature
TD	Total depth
TSS	Total Suspended Solids
TWG	Technical Working group
UIA	Uganda Investment Authority

1.0 General background

The concept of aquaculture parks has been referred to in the few last years, both in the "Strategy for the Development of Aquaculture in Uganda" (completed in 2011), and the "Development Strategy and Investment Plan" (DSIP) of the Ministry of Agriculture, Animal Husbandry and Fisheries (MAAIF) 2010/11 to 2014/15. However, no specific policy, strategy or technical studies had been undertaken. For this reason, the technical working group (TWG) of the 3rd cycle Presidential Investors Round Table (PIRT) on the fish value chain singled out the setting up of aquaculture parks as central to a model that could be adapted to the Uganda context to reverse the current slow pace of aquaculture production and development. Uganda can easily meet the expected production target of the DSIP (MAAIF 2011/15) of at least 300,000 tonnes of fish from aquaculture if policy gaps and constraints along the value chain can be appropriately addressed.

Despite a favorable investment climate and abundant water resources, aquaculture production in Uganda remains insignificant (less than 120,000 tonnes annually). FAO 2011 reports over 50,000 tonnes production from 2006) in which limited capital and inputs constrain commercial investments. Even if these were to be assured, undefined land use and land tenure systems in areas of high potential for commercial scale aquaculture remain major constraints.

The EU, through EDF 11, has availed the Government of Uganda funds for the "Promoting Environmentally Sustainable Commercial Aquaculture Project in Uganda". The Financial Agreement between the EU and the GoU, was signed by the Ministry of Finance, Planning & Economic Development (MoFPED), who are the National Authorising Officer (NAO) for the Project. The Supervisory Authority is MAAIF, through the Department of Aquaculture Management & Development (DAMD) where the Project Management Unit (OMU) for the project is located in Entebbe.

Under Result 2 of the Project, specifically Activities 2.8 to 2.10, the specific outputs are to be the establishment of two Aquaculture Parks (AquaParks) in Apac and Kalangala Districts.

This study is focused on the Apac land based Aquapark site, where a land based aquaculture Park will be established. As a first step, the specific site suitability needs to be determined with regards to what production systems will be used, location, the various water and soil parameters that are integral to that process. A team was dispatched to undertaken this study using expertise from NaFIRRI and NARO and supported by DAMD.

1.1 The Assignment:

Following the approval of the Onekgwok and Tarogali in Apac district for establishment of the land based Aquaculture Parks (APs) in Uganda by MAAIF under the Promotion of Environmental Sustainable Commercial Aquaculture (PESCA) project, a technical composed of MAAIF and NaFIRRI scientists was constituted to assess suitability of the proposed area for establishment of land based aquaculture park.

2.0 Objectives of the Study

The general objective of this assignment was to undertake in-depth assessments of the suitability of the Onekgwok-Tarogali proposed site for establishment of a land based Aquaculture Park (AP) as proposed in the PESCA project.

2.1 Specific objectives

i. To assess the general topography and environmental characteristics of the proposed site for the land based Aquaculture Park at Onekgwok and Tarogali.

ii. To assess the physico-chemical characteristics of the waters accessible in the proposed land based aquaculture park

iii. To collect soil samples from the different points within the proposed site for the land based Aquaculture Park at Onekgwok and Tarogali to be analyzed for their suitability for aquaculture production.

iv. To characterize and map the topographical, socio-economic, and environmental features associated with the proposed aquaculture sites at Onekgwok and Tarogali in Apac District.

v. To management recommendations on suitability of the proposed sites for the land based Aquaculture Park.

3.0 MATERIALS AND METHODS

3.1.1 Study Area

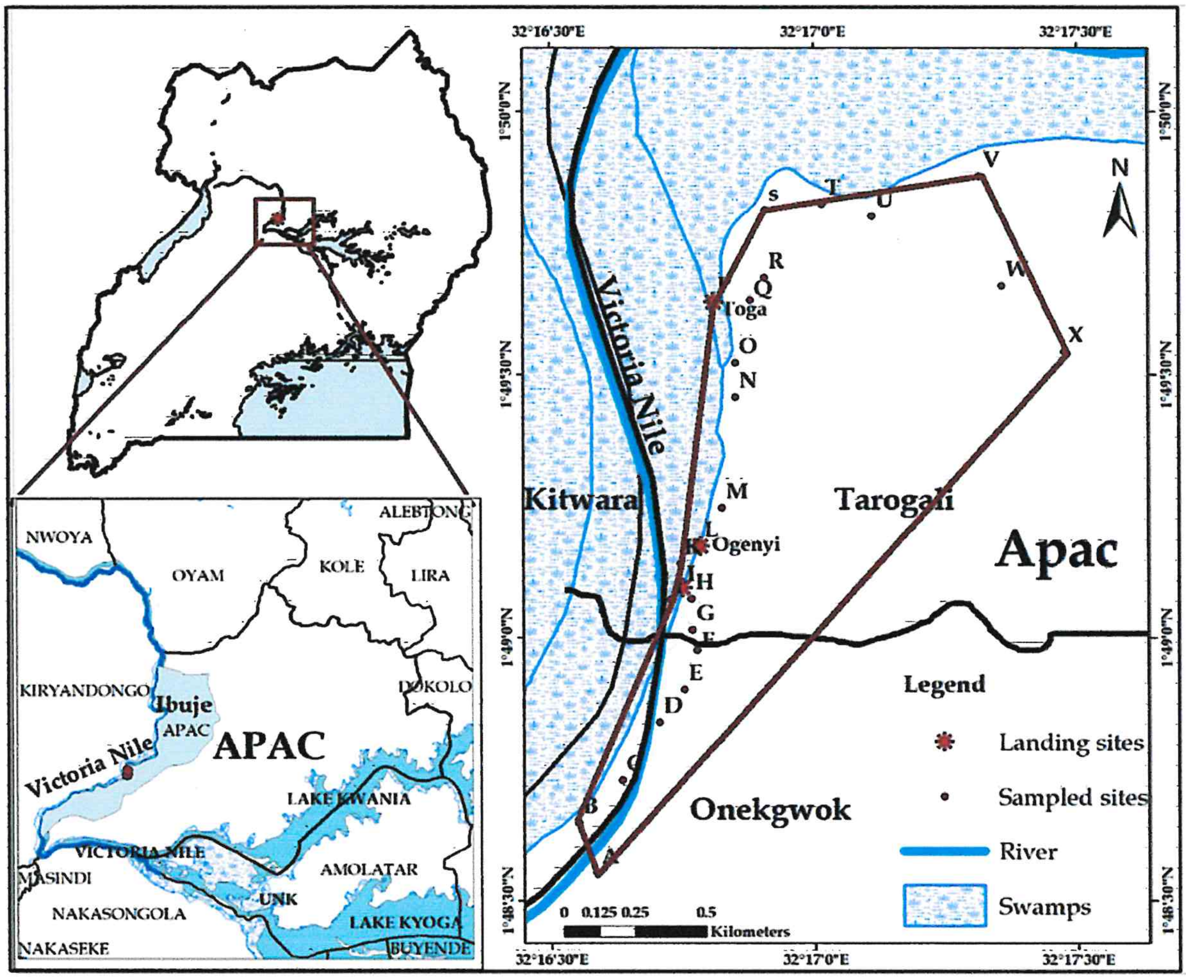

Figure 1; Map of the different sites that were visited during the survey to assess site suitability for land based and lake based Aquaculture Parks at Onekgwok and Tarogali in Apac District.

The sites were proposed largely from generalized examination of geographical features (e.g. bays, shelter, landing sites, access, infrastructure, etc). Since no site specific studies were conducted in the proposed site, in this present study, general topographical and environment parameters, soil characteristics, water physic-chemical characteristics, land use and vegetation cover partners of the Onekgwok-Tarogali were examined. The GPS locations of the identified sites were taken and subsequently mapped using an Arch View 3.

3.1.2 Study Area and Description

Twenty-three sites were surveyed to assess their suitability for establishment of either earthen ponds or tanks to be used in the land based / river fed aquaculture parks. The proposed area for establishment of the aquaculture park was found to be in Onekgwok and Tarogali cells all of which were found to be adjacent to the Nile River in Apac district. The Tarogali area was found to be largely covered with small shrubs and grasslands with small scale cattle grazing being the dominant economic activity (figure 2). The Onekgwok area was found to be mainly grasslands with small tress and papyrus along the river banks. The Dominant economic activity in this area was small scale crop agriculture.

Figure 2; Cattle grazing in the grasslands and small shrubs in Tarogali areas

Figure 3; Study team walking through the grasslands and papyrus swamp while collecting soil and water samples along the shores of the Nile River in Onekgwok areas

3.2 METHODS

Extensive desk and online reviews were done to obtain literature of Aquaculture suitability site selection. Topographical, physical, chemical criteria (nutrient analysis) and soil characteristics were adopted as a means of assessing site suitability.

3.2.1 Topographical and General Environmental Assessment

A Global Positioning System (GPS) unit (GARMIN 12XL) was used to take the GPS coordinates of the surveyed sites. Bordering land features and morphometry were assessed through visual observations.

The slope, soil type, flood risk, land use, existing infrastructure, socio-economic importance, community perception, and water availability were used to assess suitability under the topographical and general environment assessment criteria. In addition to the topographical and general environmental assessment, soils and water samples were taken for detailed laboratory analysis. In the field at each of the sampling point, detailed physical characteristics of the soil like color, odour, stickness, and texture were examined. Where water was accessible, physical characteristics of the water (temperature, pH, Conductivity and Dissolved oxygen) were measured in-situ. Water samples for detailed nutrient analysis in laboratory were collected at each of the sampling points where water was accessible.

3.2.2Physical Assessment

At each of the selected sample sight where water was accessible, physical parameters; depth, temperature, dissolved oxygen, and conductivity were measured in-situ using a CTD probe, SeaBird Electronics Inc USA. SBE model 19-03 197m. The total depth in the sampled sites was determined using an echo-sounder. A secchi disc was used to determine the secchi depth (transparence) of the water at the different sampled sites. The flow rate (m/s) was determined using a flow rate meter (valeport, model: 0012/B). The pH was determined using an OAKTON pH Tester 30. The bottom sediment was collected using a mud grub. The collected water samples were stored in cooler boxes in the field and later transported in the laboratory for nutrient analysis. At each of the sampling points, where applicable all the selected physical parameters were sampled from surface to bottom

Four sampling points (a, b, c, and d) were set across the river at each of the surveyed / sampled site, with 'a' being the on the river bank, 'b' and 'c' being in the middle and 'd' being on the opposite bank. All the above mention parameters were measured at each of the sampling point from surface to bottom where applicable.

3.2.3Chemical / Nutrient Analysis

Nitrite-Nitrogen (NO_2-N), Nitrate-Nitrogen (NO_3-N), Total Ammonia – Nitrogen (NH_4-N), soluble Reactive Phosphorous (SRP) and Total Suspended Solids (TSS) were the chemical parameters which were determined in this study because of the high relevance and importance in aquaculture. Water samples were picked from various stations and depths by use of a Van Dorn water sampler. Water samples for dissolved nutrients; soluble reactive phosphorus (SRP), ammonia-nitrogen (NH_{3}-N) and nitrite-nitrogen (NO_{2}-N) were, filtered through 47mm pore Whatman GF/C filter papers and analysed by spectrophotometric methods following procedures by Stantoin *et. al* 1977. Water samples were also analysed for total suspended solids (TSS). These were measured in mg/l for all the different parameter and compared with both the recommended and acceptable ranges (table 3) in the land based / river fed and lake based sites.

3.2.4Soil Suitability Assessment

At each of the soil sample collection site, three (3) samples were extracted using a hand held hoe with a distance of separation between the different soil sample collection sites being approximately 100m. These were collected at a depth of 15cm from the surface. Physical observations for colour, texture, stickness, and odour carried out in the field. The collected soil samples were wrapped in black polyethane bags after physical observation and stored in cool boxes to be taken in the laboratory for further detailed analysis. In the laboratory, the collected soil sampled were analysed for dry consistency, plasticity (wet soils), plastic limit (toughness on thread), percent organic matter content, cation exchange (CEC), pH (-), conductivity, Nitrates, Phosphorous and Bi-carbonate concentrations.

Figure 4; NaFIRRI Scientist testing soil texture and stickness in the field at Onekgwok

Soil permeability at each of the different sites was determined in the field by digging a hole of about 50cm depth, filled with water and observed the rate at which the water disappeared in the soils.

Figure 5; A hole used to test for water retention and the observed soil profile at Onekgwok

3.4 Data analyses and interpretation

3.4.1 Topographical and General Environmental Assessment

The different topographical and general environmental assessment parameters considered in the different sites as given in appendix 1 and 2 were rated / ranked according to their importance towards a given site being suitable for aquaculture. In this rating / ranking, a higher value implies that the parameter being rated is of a higher significance. The different ratings of the selected parameters in the different sites were summed. A site with the highest total rating was considered the most suitable. The topographical and general environment suitability assessment findings were summarized in appendices 1 and 2 .

3.4.2Physical Assessment

The means and standard deviation of the collected data for the different physical parameters measured as given in 3.2.2 above were calculated using MS.excel 2007. The calculated means and their standard deviations were for each of the surveyed sites both for the land based / river fed and lake based sites were compared with both the recommended and acceptable ranges for aquaculture (table 4.2.1). Sites whose measured physical parameters were within the recommended range were considered to be most suitable followed by sites whose physical parameters were found within the acceptable range. The acceptable and recommended ranges for the selected physical parameters are summarized in Table 3.4.2 below;

Table 3.4. 1; Recommended and acceptable ranges for water physical parameters in aquaculture

Site	Station	TD	SD	FR	pH	Cond	DO	Temp
Units		(m)	(m)	(m/s)	(-)	(µS/cm)	(mg/L)	(°C)
Recommended range		> 5	0.45	(9 -15)	6.8 – 9.5	100 – 2,000	>4	24 - 30
Acceptable range		> 5	<0.6		5.5 – 10.0	30 – 5,000	>2	21 -32

Adopted from; *Queensland water Quality guideline, 2009, and Water Quality and Water Quality Management in Aquaculture (http://www.neospark.com/images/Waterqua.pdf).*

3.4.3 Chemical Assessment Criteria (Nutrient analysis)

Nitrite-Nitrogen (NO_2-N), and Nitrate-Nitrogen (NO_3-N) and were analysed following Wood *et al.*,(1967) Method, American Public Health Association (APHA). Total Ammonia – Nitrogen (NH_4-N), and soluble Reactive Phosphorous (SRP) were analysed following Soloranzo (1969) APHA, and Murphy and Riley, 1962 (APHA) respectively. Total Suspended Solids (TSS) were analysed using following Wood *et al.*, (1967) Method, American Public Health Association (APHA). The mean (X) and the standard deviation of the selected chemical parameters (nutrients) were calculated using MS excel, 2007 and these were compared with both the acceptable and recommended ranges for aquaculture (table 4.3.1). Sites whose chemical parameters were within the recommended range were considered the most suitable followed by those whose means and standard deviations were with the acceptable ranges.

Table 3.4.2 below gives a summary of the recommended and acceptable ranges for the selected chemical parameters (Nutrients) for aquaculture.

Table 3.4. 2; Recommended and acceptable ranges for selected nutrients in aquaculture

	Nutrients(mg/l)				
Site	NO2-N(mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	SRP (mg/l)	TSS (mg/l)
Recommended range	< 0 .1mg/l	<100mg/l	<1mg/l	0.005 - 0.5mg/l	<10mg/l
Acceptable range	<4mg/l	90-400mg/l	<4mg/l		

Adopted from: *Queensland water Quality guideline, 2009, and Water Quality and Water Quality Management in Aquaculture (http://www.neospark.com/images/Waterqua.pdf).*

3.4.4 Soil Suitability Assessment

From the physical field observations and laboratory analysis of the selected above mention parameters (section 3.2.4), the different soil properties and site characteristics were rated according to their importance to aquaculture site suitability. The ratings were summed for each of the survey site to get the total score for each site. The rating were given in order of importance whereby the more the importance the higher the rating. The site that had the highest score was considered the most suitable. The ratings for soil suitability were summarized in appendix 1 & 2.

4.0 RESULTS AND DISCUSSION

4.1 Topographical and General Environmental Assessment

The findings from the topographical and general environmental assessment criteria were summarized in appendices 1, and appendices 3 -7.

These proposed areas of Onekgwok and Tarogali were found on the upper bank of the Nile in Apac district and therefore less susceptible to flooding (appendix1). These sites being found on the upper side of the river brings in a pumping cost in the process of supplying water to both Onekgwok and Tarogali.

4.2. Physical Assessment

Table 4.2. 1; ***Physical criteria; mean(X) ± SD of the selected physical parameters that were considered in the assessment of site suitability.***

Site Land based/River fed	Site	TD (m)	SD (m)	FR (m/s)	pH (-)	Cond (µS/cm)	DO (mg/L)	Temp (°C)
R.Nile (Onekgwak)	a	1.2	0.4	96	7.2±0.2	92.9±0.1	7.0±0.0	24.8±0.0
	b	8.6	1.2	114	6.9±1.1	127.0±0.1	7.9±0.1	26.3±0.0
	c	8.1	1.3	169	6.7±0.6	123.0±0.3	5.8±0.5	26.3±0.0
	d	3.2	0.4	86.5	7.0±1.1	120.3±0.1	7.7±0.8	26.3±0.0
R. Nile (Tarogali)	a	3.36	1.6	328	6.2±1.2	142.8±0.1	6.5±0.0	24.1±0.0
	b	7.55	1.45	123	7.2±0.4	222.7±6.7	7.6±0.6	25.9±0.5
	c	3.11	1.5	260.5	7.7±0.3	140.9±0.2	5.9±0.1	24.3±0.0
	d	2.11	0.81	89.5	7.67±0.5	134.9±0.5	6.1±0.5	25.1±0.3
Recommended range		**> 5**	**0.6**	**(9 - 15)**	**6.5 – 9.5**	**100 – 2,000**	**> 5**	**24 - 30**
Acceptable range		>5	0.4-1.2		**5.5-10**	**30-5000**	**>2**	**22 -35**

At both Onekgwok and Tatogali the total depth and transparence (secchi depth) of the river increased from the banks towards the middle with the depth again decreasing from the middle towards the banks on the Kyarandongo side of the river. The deepest points of the river were at b

(8.6m) for Onekgwok with b (7.55m) being the depst at the Tarogali area. The highest observed transparence was at 1.6m at Tarogali a. With the exception of Onekgwok a (96cm/sec) whose flowrate was within acceptable range for cage aquaculture production, the rest of the sampled points were found to be higher than the acceptable range. The dissolved oxygen (DO) at the different point was found to be within acceptable ranges for aquaculture production with the highest being 7.9±0.1mg/l measured at Onegwok b and the lowest being 5.8±0.5mg/l measured at Onekgwok b. The pH, Temperature and conductivity at the different measured points were found to be within acceptable ranges for aquaculture production. The highest and lowest measured temperatures were found to be 26.3±0.0°C and 24.1±0.0°C respectively (table 4.2.1).

4.3 Chemical /Nutrient Analysis

Table 4.3. 1; Chemical criteria; X±SD *of concentrations of the selected nutrients found in water samples collected from the Nile river adjacent to the proposed at Onekgwok and Tarogali areas*

		Mean±SD Nutrients(µg/l) at the different sites				
Site	**Station**	**NO_2-N (mg/l)**	**NO_3-N(mg/l)**	**NH_4-N(mg/l)**	**SRP (mg/l)**	**TSS (mg/l)**
R.Nile (Onekgwok area)	a	0.026±0.0034	0.039±0.0150	0.003±0.0001	0.014±0.0020	0.004±0.0001
	b	0.017±0.0026	0.038±0.0229	0.002±0.0013	0.015±0.0019	0.002±0.0016
	c	0.026±0.0033	0.036±0.0229	0.002±0.0019	0.018±0.0012	0.002±0.0007
	d	0.018±0.0067	0.022±0.0050	0.002±0.0007	0.015±0.0007	0.001±0.0008
Tarogali	a	0.017±0.0028	0.024±0.0070	0.006±0.0069	0.023±0.0007	0.002±0.0008
	b	0.016±0.0021	0.039±0.0100	0.004±0.0042	0.019±0.0035	0.037±0.0016
	c	0.021±0.0033	0.039±0.0150	0.001±0.0001	0.013±0.0020	0.002±0.0008
	d	0.015±0.0062	0.021±0.0051	0.003±0.0007	0.016±0.0006	0.002±0.0007
Recommended range		**0 – 1mg/l**	**<90mg/l**	**0-2mg/l**	**0.005 -0.5mg/l**	**<10mg/l**
Acceptable range		**<4mg/l**	**90-400mg/l**	**<4mg/l**		

Water samples from the Nile river around Onekgwok a (0.026±0.0034mg/l) and c (0.026±0.0033mg/l) had the highest NO2-N among the different sampled points. Among the different sampled points, it was Tarogali a (0.006±0.0069mg/l) had the highest ammonia-nitrogen concentration, followed by Tarogali b (0.004±0.0042mg/l). The highest nitrate-nitrogen levels among the different sampled sites were found in Onekgwok a and Tarogali c which was

0.039±0.0150mg/l. Tarogali a had the highest soluble reactive Phosphorous (SRP) levels at 0.023±0.0007mg/l while Tarogali b at 0.037±0.0016mg/l had the highest total suspended solids (TSS) (table 4.3.1). All the considered chemical parameters Nitrite-Nitrogen (NO_2-N), Nitrate-Nitrogen (NO_3-N), Total Ammonia-Nitrogen (NH_3-N), Soluble Reactive Phosphorous (SRP) and Total Suspended Solids (TSS) in all the sampled sites were found to be within the recommended range for aquaculture.

4.3 Soil Assessment

4.3.1 Soil properties and area characteristics

The vegetation cover of Tarogali and Onekgwok was found to be predominantly swampy with small shrubs and trees more especially along the river banks (appendix 7/figure 12, figure 2 & 3). Of all the different soil samples collected from Onekgwok and Tarogali proposed sites, it was only soils from Onekgwok that were found to be slightly permeable with good water retention. The soils in the other proposed area in Tarogali were permeable. While the surface soils in the proposed site at Onekgwok were shallow and black in color (figure 5), the surface soils in the proposed sites at Tarogali were shallow and brown in colour (Appendix 5/figure 10). For all the sampled sites it was only Onekgwok site 2 and 3 which were found to have fine-grained soils. Soils at Tarogali were found to be rocky with some parts having gravel and small stones. Of all the collected soil samples it was only soil samples from Onekgwok that was found to be sticky with high plasticity. The soil samples from Onekgwok were found to be slightly hard to hard in terms of dry consistence (Appendix 2).

4.3.2 Land physical properties

Both Onekgwok and Tarogali were found to be gently sloping with no flooding risks (Appendix 1 & 4). Onekgwok areas were found to have some sites with clay while others had loam soils. The collected soil samples from Tarogali were found to be mainly hydrosols with some silt and clay (appendix 1 and Appendix 3). When subjected to the shaking test reaction, soils from the proposed site at Tarogali showed a slow to none response reaction. Although soils with high plasticity, dry consistency and toughnes on thread are preferred for earthen pond aquaculture due to their advantages like the good water retention, pond wall compaction, being too sticky makes the pond excavation process hard. Such soils tend to stick on the hoe and other tools used in the excavation process hence making the process more teadious. When subjected to shaking test

reaction, soils samples from Onekgwak showed rapid to slow and rapid to medium response. All soil samples from Onekgwak had a slight plastic and toughness on thread (Appendix 2). This was because soils from Onekgwok areas were found to have some composition of clay and such soils would be preferred for earthen pond aquaculture in comparison to the Tarogali soils.
The high levels of stickness, wet plasticity, plastic limit and toughness on thread with a high dry consistence of soil samples from the Onekgwok sites was because the high composition of clay that was found in this area. The very fine particles in clay make it to be very sticky, with high wet plasticity and dry consistence (Appendix 1 & 2). Soils of this type do have a very good water retention which is an essential requirement for sites where earth pond aquaculture is to be done. The slow to none response when subjected to shaking test reaction can be explained by the fact that usually areas with clay soil composition get easily compacted and do not easily disintegrate when subject to the shaking test reaction.

5.0 CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

From the rating of soil properties and area characteristics (Appendix 1 & 2), Onekgwok soils were the most preferred option for establishment of earthen pond aquaculture establishment with total scores of 21, 25 and 26 for Onekgwok 1, 2 and 3 respectively.

Because of the rocky, stony and silty nature of the soils at Tarogali, ponds would be expensive to construct and would require linners to hold water. Tanks can be used in areas where earthen pond construction is not possible.

Although in both Onekgwok and Tarogali areas pumping is required if these sites are to access water, Tarogali areas being on a relatively lower contour with a small gradient (Appendix 4/ figure 9) would require a less pumping cost.

Both sites at Tarogali and Onekgwak had enough space / acreage and good vegetation type (appendix 6 / figure 11) with no huge trees which would complicate the process of pond excavation.

The biggest constraint with both Tarogali and Onekgwok areas is the road infrastructure and electricity power which is approximately 24km away from the proposed sites. In both case it would require road access opening as well as extending power to these sites. Because the main activity in the proposed is areas is small scale subsistence farming with no permanent built structures(appendix 7 & figure 12), no major compensations would be required while opening road access and electric power extension to the site.

6.0 REFERENCES

1. **Blow, P. and Leonard, S. (2007)** A review of cage aquaculture: sub-Saharan Africa. In M. Halwart, D. Soto and J.R. Arthur (eds). *Cage aquaculture – Regional reviews and global overview*, pp. 188–207. FAO Fisheries Technical Paper. No. 498. Rome, FAO. 2007. 241 pp.
2. **Hecky. R.E, Bugenyi F.W, Ochumba.P, Talling J.F, Mugidde. R, Gophen. M and Kaufman. L.(1994).** Deoxygenation of the deep water of Lake Victoria, East Africa. Limnology and Oceanography, Vol. 39, No. 6 (Sept, 1994), 1496 – 1481
3. **Queensland Water Quality Guidelines, 2009.** Queensland guidelines for values and Uses of waters other than ecosystem protection.
4. Water Quality and Water Quality Management in Aquaculture (http://www.neospark.com/images/Waterqua.pdf).
5. FAO (1989). Site Selection Criteria for Marine Finfish Netcage Culture in Asia. Rome: FAO. p. 16.
6. **Nathan M. Stone and Hugh K. Thomforde,** Understanding Your Fish Pond Water Analysis Report. Cooperative Extension Program, University of Arkansas.
7. **Howerton, Robert (2001)** Best Management Practices for Hawaiian Aquaculture, Center for Tropical Aquaculture. Publication No. 148
8. **Agricultural Sector Development Strategy and Investment Plan 2010/11 -2014/15.** http://www.agriculture.go.ug/userfiles/Agricultural%20Sector%20Development%20Strategy%20and%20Investment%20Plan%281%29.pdf
9. FAO. 2006-2013. National Aquaculture Sector Overview. Uganda. National Aquaculture Sector Overview Fact Sheets. **Text by Mwanja, W.W.** In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 19 July 2005. [Cited 25 January 2013]. http://www.fao.org/fishery/countrysector/naso_uganda/en
10. National Investiment Policy for Aquaculture Parks in Uganda, 2012.
11. FAO (1989) Site selection criteria for marine finfish netcage culture in Asia, Island studies Journal, Vol 5, No 2 .
12. Jensen, J. W. 1989. Watershed Fish Production Ponds: Site Selection and Construction. Southern Regional Aquaculture Center Publication No. 102

APPENDICES

Appendix 1; Topographical criteria and general environmental site suitability analysis for Onekgwok and Tarogali areas proposed for the land based Aquaculture park

Parameter		Score	Site suitability rating					
			T1	**T2**	**T3**	**O1**	**O2**	**O3**
slope	Level to near level	**5**						
	Gently sloping	4	4		4	4	4	4
	Undulating to rolling	3		3				
	Rolling	2						
	Steep	1						
	very steep	0						
	rivers	0						
soil type	clay/loam	5						
	clay	4					4	
	loam	3				3		2
	sandy/silty clay	2		2				
	silty	1	1					
	sandy	1						
	hydrosols	1			1			
Fload risk	No floading	4			4	4	4	4
	non to slightly	3	3	3				
	moderately susceptible	2						
	severely susceptible	1						
Land use	Wetland	5						5
	Grain crops	4				4	4	
	Industrial crops	3						
	Grasslands	3	3					
	shrubs	2		2	2			
	Forests	1						
	special land use	0						
Existing Infrastructure	to roads	4	4	4	4	4	4	4

Parameter		Score	Site suitability rating					
			T1	T2	T3	O1	O2	O3
	markets	4						
	suppliers	4						
	hatcheries	4						
	Electricity	4						
Socio-economics	No cultural importance	5	5		5	5	5	
	socio-cultural importance	4						
	Tourism	3						
	Agriculture	2		2				2
	Human settlement	1						
Water	Enough Good quality free flowing accessing site	4						
	Enough good quality, requiring pumping to site	3	3	3	3	3	3	3
	Poor quality water requiring treatment	3						
	low water volumes	1						
	No water	0						
Total score			**23**	**12**	**13**	**19**	**16**	**16**

Key

T1 = Tarogali 1

T2 = Tarogali 2

T3= Tarogali3

O1=Onekgwok 1

O2=Onekgwo k 2

O3=Onekgwo k 3

Appendix 2: ***Soil properties and area characteristics in the surveyed sites at Onekgwok and Tarogali land based aquaculture park areas***

Parameter		**SR**	**Site suitability rating**					
			T1	**T2**	**T3**	**O1**	**O2**	**O3**
Permeability	Impermeable	5						
	slight permeable	4					4	4
	semi-permeable	3				3		
	Permeable	2	2	2	2			
	Highly permeable	1						
surface soil characteristics	Deep and dark black in colour	5						
	deep and brown in colour	4						
	shallow and black in colour	3				3	3	3
	shallow and brown in colour	2		2				
	shallow and yellowish	1	1		1			
soil texture and structure	Fine-Grained soils (FGS)	5					5	5
	Coarse Grained Soils (CGS)	4				4		
	Gravel	3			2			
	small stones	2		2				
	Rocky	1	1					
Stickness	very sticky	4						4
	sticky	3				3	3	
	slightly sticky	2		2	2			
	none sticky	1	1					
Plasticity (wet soil)	very plastic	4						
	plastic	3				3	3	3
	slightly plastic	2		2	2			
	not plastic	1	1					

Parameter		SR	Site suitability rating					
			T1	T2	T3	O1	O2	O3
Dry consistency	extremely hard	7						
	hard - extremely hard	6						
	hard	5						
	slightly hard -hard	4					4	4
	slightly hard	3				3		
	soft	2		2	2			
	loose - soft	1	1					
	loose	0						
Plastic limit, toughness on thread	High	5						
	medium -high	4						
	medium	3					3	3
	slight - medium	2				2		
	slight	1		1	1			
	none	0	0					
Total score			**7**	**13**	**12**	**21**	**25**	**26**

Key

T1 = Tarogali 1

T2 = Tarogali 2

T3 = Tarogali 3

O1 = Onekgwok 1

O2 = Onekgwok 2

O3 = Onekgwok 3

Appendix 3

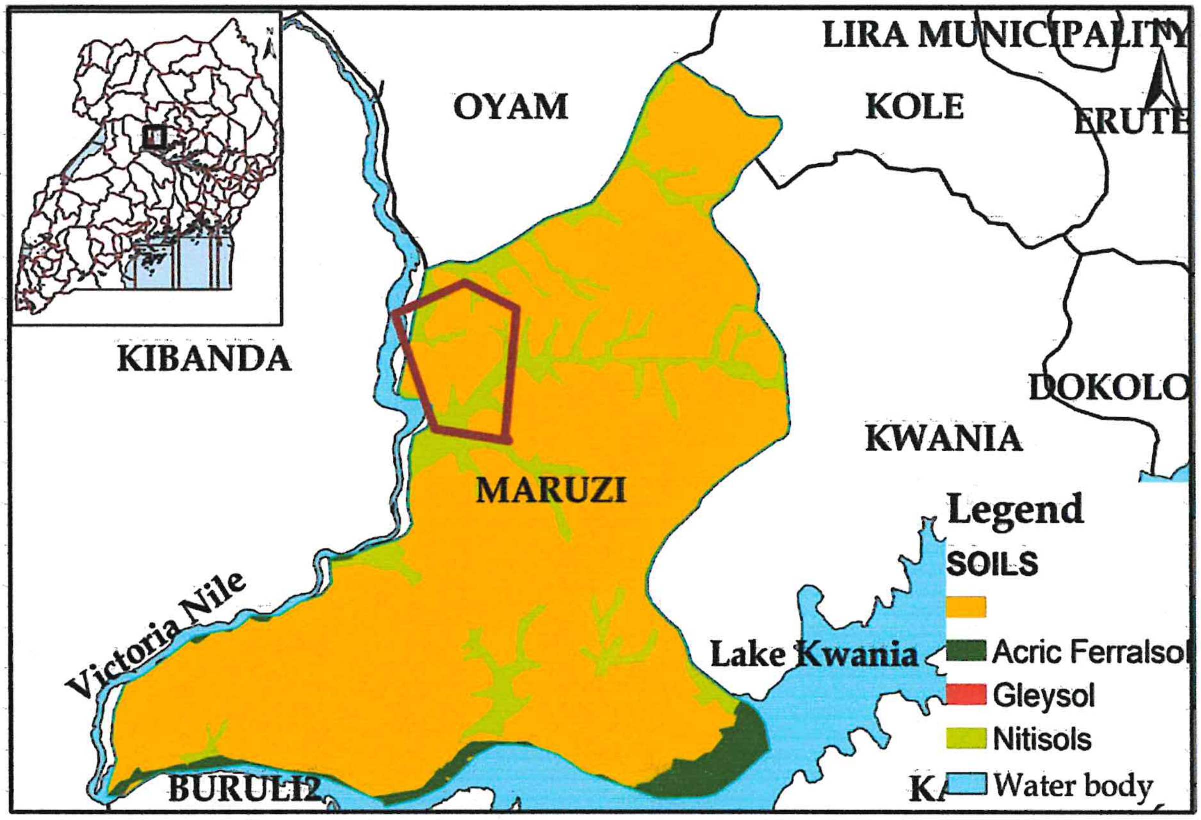

Figure 6; Map of soil types of the proposed land based aquaculture park areas around Onekgwok and Tarogali in Apac District.

Appendix 4

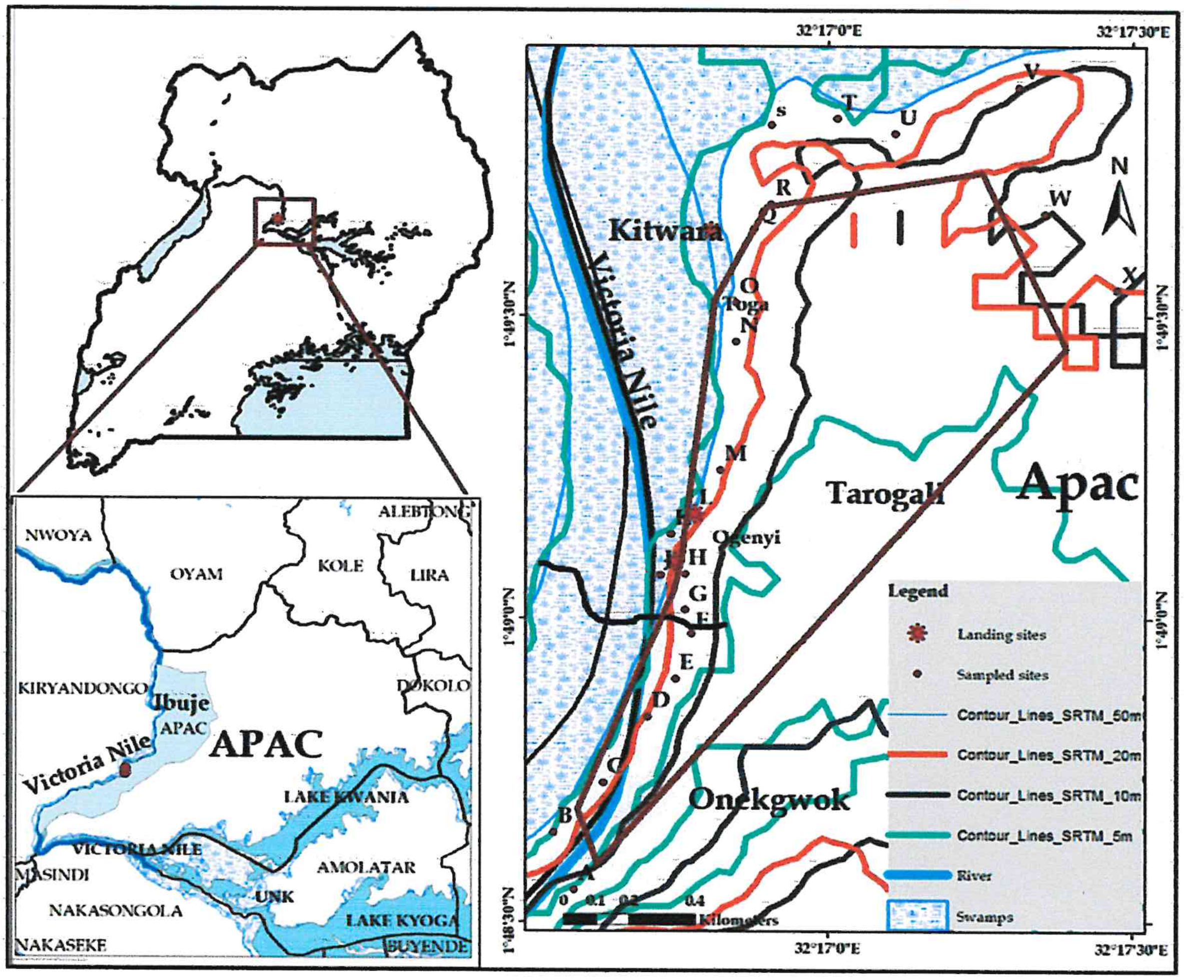

Figure 7; Contour map of the proposed area for establishment of the land based aquaculture park in Apac district.

Appendix 5

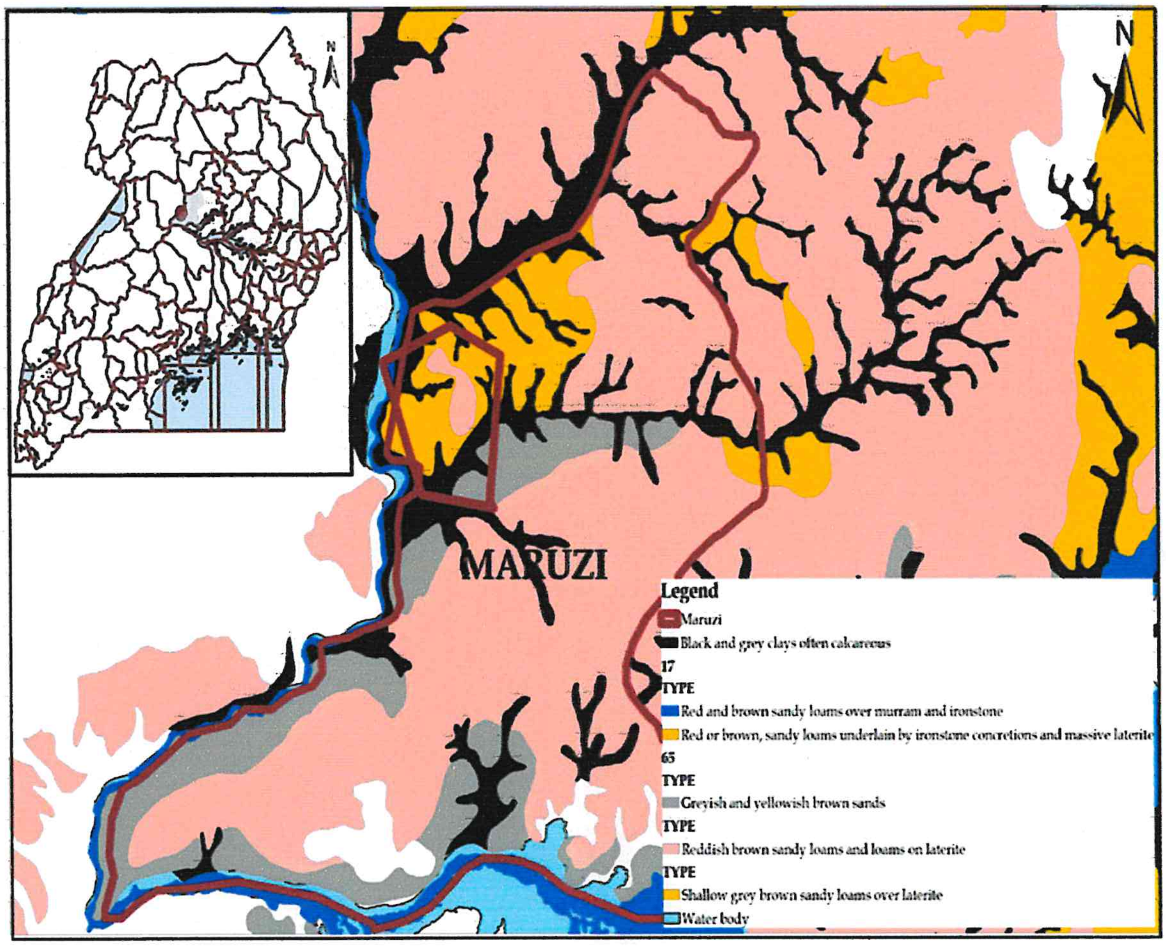

Figure 8; Map showing Soil colour and partners of the proposed aquaculture park area

Appendix 6

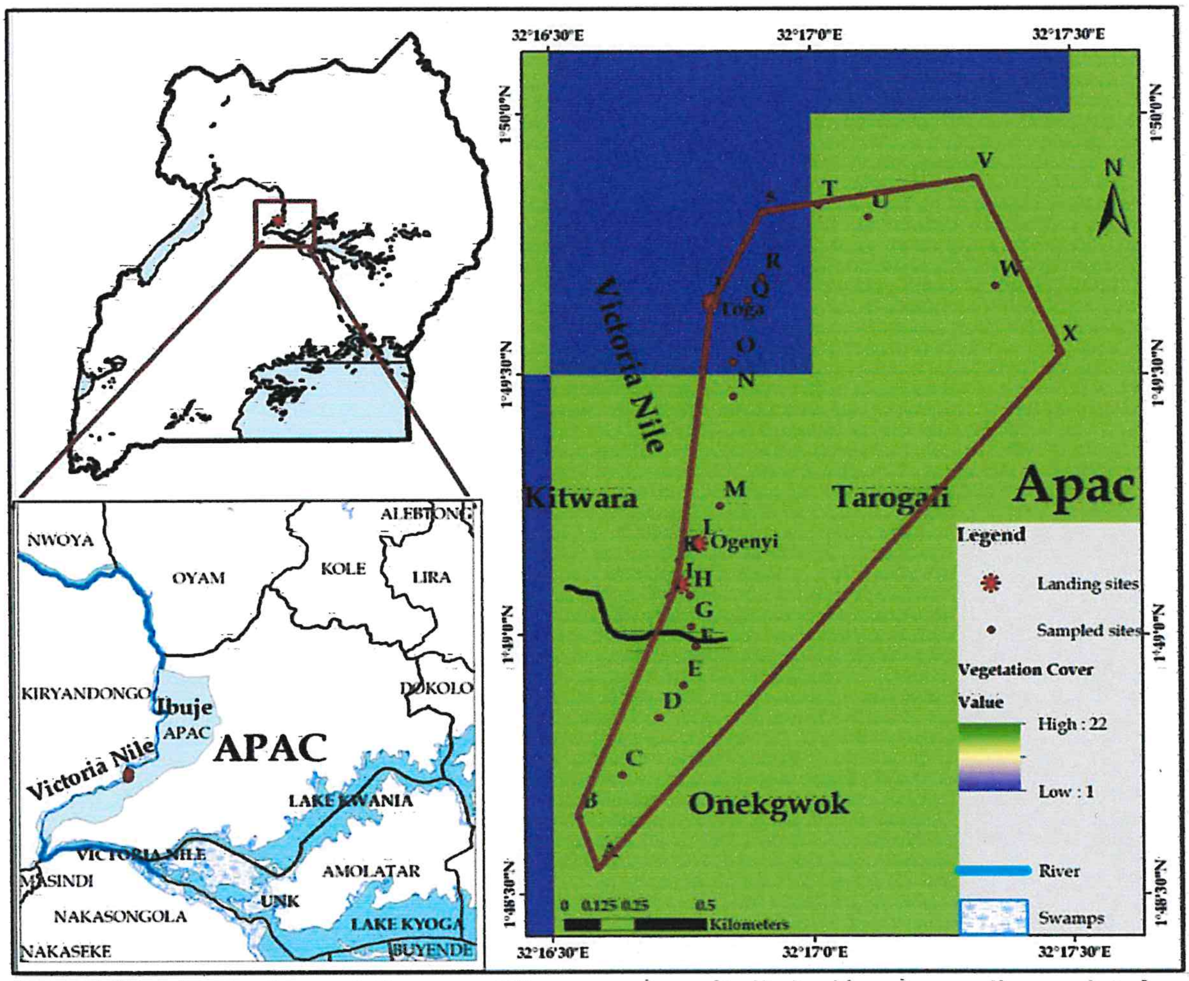

Figure 9; Map showing the vegetation cover of the proposed area for the land based aquaculture pack in Apac

Appendix 7

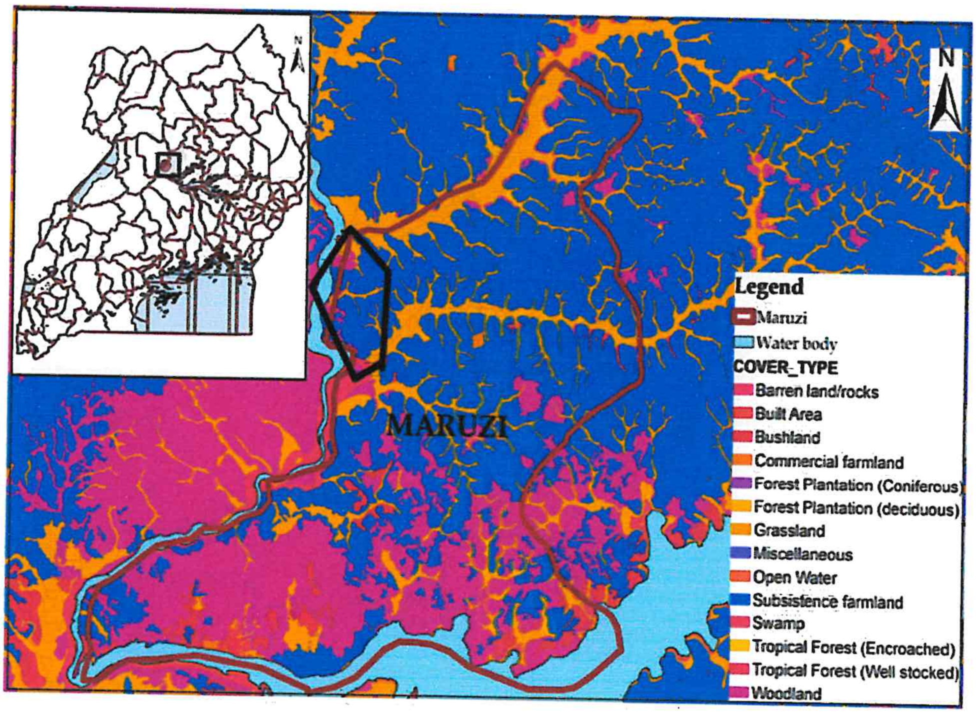

Figure 10; Vegetation and Land use partners map

Figure 11; Aquaculture expert testing soil compactability at one of the soil sample collection site at Onekgwok


Figure 12; A site in Onekgwok whose soils were being used brick making