

FEED THE FUTURE INNOVATION LAB FOR COLLABORATIVE  
RESEARCH ON AQUACULTURE & FISHERIES  
(AQUAFISH INNOVATION LAB)

# SITE DESCRIPTIONS

FOR THE 2016 – 2018 IMPLEMENTATION PERIOD



Published March 2017

AquaFish Management Office  
Oregon State University  
Corvallis, Oregon 97331 USA





## AQUAFISH INNOVATION LAB: SITE DESCRIPTIONS 2016-2018

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Program activities are funded in part by the United States Agency for International Development (USAID) under CA/LWA No. EPP-A-00-06-00012-00 and by participating US and Host Country institutions.

The mission of AquaFish Innovation Lab is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. Bringing together resources from Host Country institutions and US universities, the AquaFish Innovation Lab emphasizes sustainable solutions in aquaculture and fisheries for improving health, building wealth, conserving natural environments for future generations, and strengthening poorer countries' ability to self-govern.

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The primary Host Country sites for AquaFish research provided in the [2016 – 2018 Implementation Plan](#) are the same locations presented in the [2013 – 2015 Site Descriptions](#) document; therefore, the contents of this document were not changed and is reflective of what was submitted by AquaFish Principle Investigators in 2013.

### **Acknowledgments**

The Management Entity of AquaFish Innovation Lab gratefully acknowledges the contributions of AquaFish researchers and the support provided by participating US and Host Country institutions.

### **Cover Photo**

Participants harvest a pond at an aquaculture best management practices workshop in Kenya. Photo courtesy of Charles Ngugi.

### **This publication may be cited as:**

AquaFish Innovation Lab. Carroll, L., Bodman, S., Goetting, K., and Evans, F., (eds). March 2017. AquaFish Innovation Lab Site Descriptions 2016 – 2018. AquaFish Innovation Lab, Oregon State University. Corvallis, Oregon. 50 pp.

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## INTRODUCTION

The Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries (AquaFish Innovation Lab, or AquaFish) is one of several agricultural Innovation Labs supported by the US Agency for International Development (USAID) under the authority of Title XII of the International Development and Food Assistance Act of 1975. Its mission is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquaculture and fisheries. AquaFish is tasked by USAID to “develop more comprehensive, sustainable, ecological and socially compatible, and economically viable aquaculture systems and innovative fisheries management systems in developing countries that contribute to poverty alleviation and food security.”

The site descriptions included in this document provide detailed information on research locations for the five current AquaFish projects for [2016 – 2018 Implementation Plan](#), including infrastructure, facilities, and other relevant capabilities. The sites presented in this document are the same sites included in the 2013 – 2015 Site Descriptions document; therefore, the contents of this document reflect what was submitted by AquaFish Principle Investigators in 2013. The descriptions span eight countries and include 10 Host Country (HC) institutions in formal funded partnerships. More than 60 other institutions collaborate in informal partnerships. Five research projects feature 24 investigations that are outlined in the [2016 – 2018 Implementation Plan](#).

Data for AquaFish sites that are no longer active can be accessed in earlier editions of Site Descriptions on the AquaFish website at: <http://aquafish.oregonstate.edu/>.

# UNIVERSITY OF MICHIGAN



## ADVANCING AQUACULTURE SYSTEMS IN NEPAL FOR MORE SOCIAL AND ENVIRONMENTAL SUSTAINABILITY

### NEPAL

*(Information provided by Dr. James Diana, US Project PI, in 2013)*

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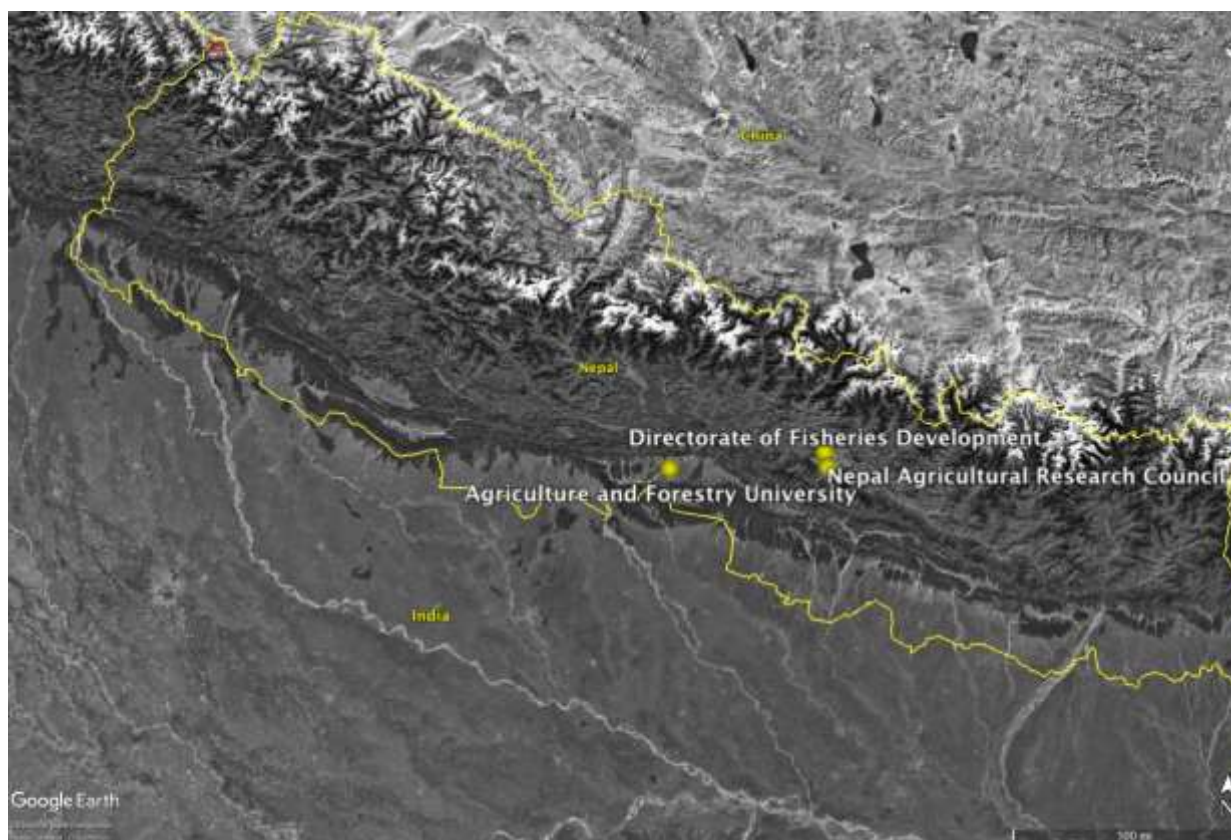
Geographically, Nepal is divided into three ecological regions: the mountain zone in the northern portion of the country, the central hill zone, and the southern Terai, or plains. In contrast to high altitudes found in the first two regions, average elevation in the Terai ranges from 100 – 300m above sea level. Climate in the Terai is tropical and subtropical, and soils in this region are the most fertile in Nepal. The Terai holds 70% of the country's agricultural lands despite making up only 17% of Nepal's total area.

Residents of Nepal depend on fish and meat consumption for nutrition, especially for protein and certain vitamins and minerals. The country has major problems with food availability and, as a result, 41% of the children are stunted in growth. Total fish production in Nepal is 54,357 mt, with about 60% originating from aquaculture, mainly in the Terai region. Pond culture is the most popular method of aquaculture, but annual pond yield averages only 3.83 t/yr. Carps are popular warm water fish for culture in Nepal, contributing more than 99% of aquaculture production in the country. Dramatic improvements in pond production are possible without addition of much inputs to make pond culture more efficient. While experiments have been done to incorporate sahar, tilapia, and small indigenous species into the carp polyculture system, so far aquaculture remains dominated by carp polyculture. Current research in aquaculture is concentrated at the Agriculture and Forestry University in Rampur, and a number of government labs also support research and extension of aquaculture practices. The government is interested in increasing aquaculture production, especially targeted at increasing food for poor, small scale farmers. While some political instability exists in the country, we have collaborated with researchers in Nepal for over ten years and have now developed a mature and stable relationship.

The primary Host Country site for the AquaFish research in Nepal is the Aquaculture Farm at Agriculture and Forestry University (AFU), which will be described in more detail below. On-farm research will be conducted at private farms located in Chitwan and Nawalparasi. In addition, one private farm located at the Center of Aquaculture Research and Production in Kathar, Chitwan will serve as the site for testing improved culture protocols.

In addition to partners at University of Michigan located in the US and AFU, other collaborating partners of the Nepal projects are located at Oregon State University in the US and the Nepal Agricultural Research Council and the Directorate of Fisheries Development in Nepal.

## Country Map



*Map of Nepal indicating the location of Agriculture and Forestry University, the Nepal Agricultural Research Council, and the Directorate of Fisheries Development in Nepal.*

### AGRICULTURE AND FORESTRY UNIVERSITY (AFU)

#### **General Location**

Rampur, Chitwan, Nepal. AFU is located in the Terai southwest of Kathmandu (*see map of country*), near the town of Narayangarh, in the southern portion of Nepal's central plain, about 160 km southwest of Kathmandu.

Nepal is a small country with a diverse climate, from the highest peaks in the world with alpine tundra to low-level plains with a tropical climate. AFU is situated in the plains of Nepal, where 94% of fish ponds in the country are found, making this an ideal location for conducting aquaculture research.

#### **DESCRIPTION OF AREA/REGION**

##### **Climate**

Humid subtropical, wet-and-dry type, with distinct dry and rainy seasons

##### **Temperature**

Annual average: 24.7 °C

Range of monthly average: 18.0 – 30.6 °C

Absolute minimum: 7.8 °C

Absolute maximum: 37.9 °C

**Precipitation**

0.6 – 626.5 mm per month and an average of 2,323 mm annually; low month is January, with an average of 1.5 days of precipitation; high month is July, with an average of 29 days of precipitation.

**Humidity**

A warm and humid atmosphere prevails throughout the year, with an annual mean relative humidity of 85%.

**Seasonality**

Nepal has clearly defined wet and dry, hot and cool seasons, with wide temperature variation throughout the year. The rainy season is from June to October, the cool dry season is from November to February, and the hot dry season is from March to May. The hottest month is generally April, and the coolest is January.

**Topography**

Geographically, Nepal is divided into three ecological regions: the mountain zone in the northern portion of the country; the central hill zone; and the southern Terai, or plains. In contrast to high altitudes found in the first two regions, average elevation in the Terai ranges from 100 to 300 m above sea level.

**Geology/Soils**

Chitwan is a valley surrounded by Silwalik Range in the north and Churiya Range in the east, west, and south.

**Soil and Water Data**

Soils in the Terai are the most fertile in Nepal, and the region accounts for 70% of the country's agricultural lands despite making up only 17% of Nepal's total area.

**Layout of the Site**

*Map of Rampur Campus, including AFU's research pond complex.*



## DESCRIPTION OF SITE

### Map Coordinates

27°38'14.1" N and 84°21'25.2" E

### Elevation

257 m

### General Background

The AFU, Rampur, campus occupies an area of about 210 ha near the town of Narayangarh, southwest of Kathmandu. AFU's research pond complex is one of several aquaculture facilities operated by its Aquaculture and Fisheries Department. Facilities at AFU include laboratories for analysis of water chemistry and fish body composition; ponds and tanks for experiments; infrastructure for safety and protection of experimental materials; and an aquaculture laboratory with ovens, a muffle furnace, water distillation equipment, an autoclave, a centrifuge, an electronic balance and deionizer column, and consumable chemicals. AFU has 38 earthen ponds ranging from 100 to 450 m<sup>2</sup> in size and 18 concrete tanks (24 m<sup>2</sup> each), along with drainage canals. There is also an area for growing terrestrial crops that may be of interest for fish feed components as well as an area used for rearing livestock and poultry (ducks) that can be used in integrated aquaculture research. The Research Farm is fenced with barbed wire and cement poles and is supplied with electricity. The covered hatchery facility includes indoor tanks and a well-water supply system.

### Water Supply

Supply of water for the AFU pond complex comes from underground water that has a pH of 8.3 and total alkalinity of about 130 mg/L as CaCO<sub>3</sub>.

### Soils

Sandy loam

### Support Facilities

The Nepal Agricultural Research Council (NARC) collaborates with the main site at AFU. NARC operates several Fisheries Research Centers throughout the country. The Aquaculture Farm of AFU at Rampur and a private farm at the Center for Aquaculture Research and Production (CARP), Kathar, Chitwan, will be sites for testing of improved culture protocols. All of these stations have access to ponds for experiments; labs for physical and chemical analyses; and other facilities, such as local lakes, cages, and additional experimental apparatus.

The Directorate of Fisheries Development (DoFD) is the development/extension wing for aquaculture and fisheries of the Department of Agriculture, Government of Nepal. The DoFD operates several Fisheries Development Centers throughout the country. The DoFD collaborates in demonstration projects at the Bhairahwa fisheries station and Dayanagar farmers' field developed by AquaFish researchers.

### Primary Affiliations

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# UNIVERSITY OF CONNECTICUT AT AVERY POINT



## IMPROVING FOOD SECURITY, HOUSEHOLD NUTRITION, AND TRADE THROUGH SUSTAINABLE AQUACULTURE AND AQUATIC RESOURCE MANAGEMENT IN CAMBODIA AND VIETNAM

### **CAMBODIA**

*(Information provided by Dr. Robert Pomeroy, US Project PI, in 2013)*

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The vision of the Cambodia fisheries sector as described in the National Fisheries Sector Policy and the Strategic Planning Framework for Fisheries: 2010 – 2019 (SPF-2010-2019) is that “Management, conservation, and development of sustainable fisheries resources to contribute to ensuring people’s food security and to socioeconomic development in order to enhance people’s livelihoods and the nation’s prosperity”. The development approach of the Royal Government for the fisheries sector is based around three fundamental pillars: (1) Fishery – inland and marine; (2) Aquaculture – inland and marine; and (3) Post harvest and trade.

To support these pillars, a strong foundation of appropriate and enabling regulation is required, coupled with effective regulatory framework and service provision. The pillars themselves support the people in the fisheries sector and the overarching outcomes of food security, poverty alleviation, and economic growth. Direct actions will be taken under the SPF across each of the three pillars, as well as in relation to development of the regulatory framework and service provision.

Inland capture fisheries form the overwhelming bulk of current production and must be maintained and, wherever possible, improved. But there is a limit to the capacity of the natural resource to sustain a growing population, so growth of aquaculture is essential. At the same time, work is necessary to improve the quality and standards of the fish and fish products that are consumed and traded if real improvements are to be achieved in both livelihoods and exports.

Fisheries and other aquatic resources to be investigated are major sources of food and income for the population living along the Lower Mekong River Basin of Cambodia. The lower Mekong River basin is an ecological significant site, representing one of the most fish productive basins in the world, ranked second after Amazon River basins in terms of aquatic biodiversity. The primary Cambodia Lower Mekong River Basin site is representative of the ecological zone of fisheries and other aquatic resources; the primary site could serve as the activating nucleus of a scientific network for information and technology transfer and exchange, depending on the fishery resources to be investigated. Furthermore, Cambodia is one of the largest fish eating countries (approx. 63 kg/person/year on average), so fisheries and aquaculture production are crucial for all Cambodians in terms of food and household income.

The primary host country sites for the AquaFish research are the Inland Fisheries Research and Development Institute (IFReDI) and Freshwater Aquaculture Research and Development Center (FARDeC). Both facilities will be described in greater detail below. In addition to partners located at the University of Connecticut-Avery Point in the US, IFReDI, and FARDeC, other collaborating partners are located at the University of Rhode Island and Oregon State University in the US.

## Country Map



*Map of Cambodia indicating location of the Inland Research and Development Institute.*

## INLAND FISHERIES RESEARCH AND DEVELOPMENT INSTITUTE (IFREDI), PHNOM PENH



*Inland Fisheries Research and Development Institute (IFREDI) building, located in Phnom Penh (left), and IFREDI laboratories (right).*

## **General Location**

Fisheries Administration, 186, Norodom Blvd., Phnom Penh, Cambodia

## **DESCRIPTION OF AREA/REGION**

### **Climate**

Köppen classification Aw: Humid tropical group (A), tropical wet-and-dry type (w). Distinct dry and rainy seasons are observed.

### **Temperature**

The temperatures are remarkably and uniformly warm throughout the year and subject to small variation due to elevation, season, and maritime influences. Temperatures are high except during the early part of the northeastern monsoon when occasional outbreaks of cool air from central Asia sweep over the land. Cool spells occur during December and January, and the weather is hot and dry from the end of February to the break of the monsoon. These conditions last until the southwest monsoons commence in May. Mean minimum temperature is 22 °C in the area. Monthly average highs in Phnom Penh range 30 – 35 °C, and average lows range 22 – 24 °C.

### **Precipitation**

The rainfall is generally plentiful, but it is unevenly and seasonally distributed and largely depends on geographic orientation. Annual average precipitation is 2,000 – 3,000 mm in the low mountains of the northeastern region and 1,400 – 1,600 mm in southwestern coasts. About 90% of the annual precipitation falls between May and October (i.e., the wet or rainy season). The average number of wet days varies from less than one day a month in December and January to more than 12 days a month in August and September. The monthly average precipitations range from 7.6 mm in January to 251.5 mm in October.

### **Humidity**

The relative humidity is highest in the monsoon season at slightly more than 80% and lowest in March at just over 60%.

### **Seasonality**

All of Cambodia has clearly defined wet and dry seasons, with little temperature variation throughout the year. The rainy season is from May to October, the cool dry season from November to February, and the hot dry season from March to May. The hottest month is generally April, and the coolest is January.

### **Topography**

The area is part of Cambodia's vast, nearly level central alluvial plain (the Mekong or Mekong Delta Plain, which extends through Vietnam to the South China Sea through several tributaries and through canals that have been constructed in Vietnam to regulate flooding). The area is located at the confluence of the Mekong, Tonle Sap, and Bassac rivers. These rivers provide potential freshwater and other resources.

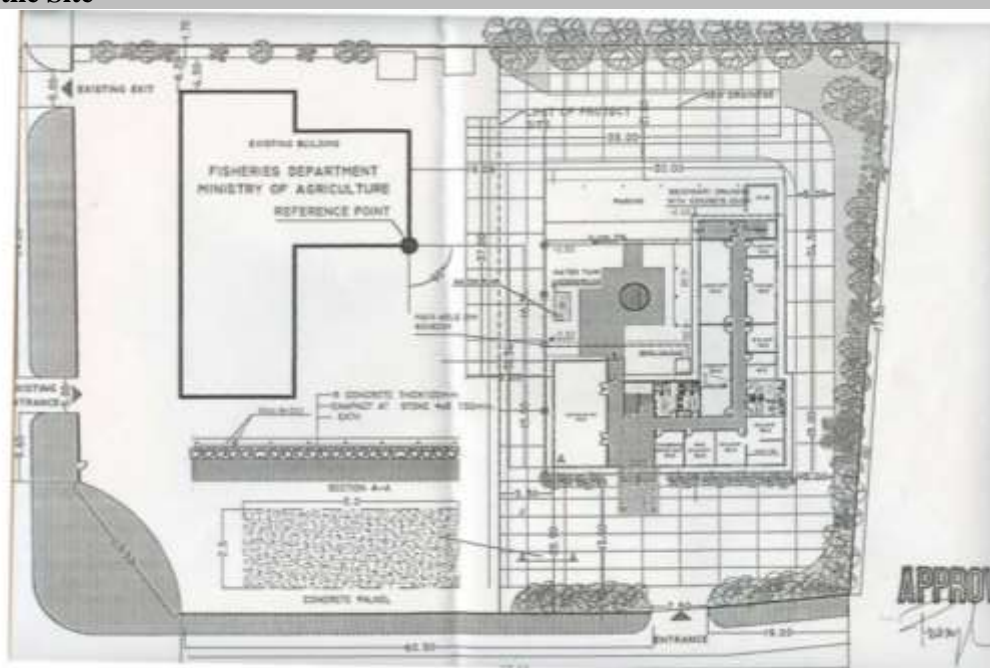
### **Geology/Soils**

Influence of the Mesozoic sandstone and its weathering products is attenuated by Tertiary and Pleistocene igneous geology and by Pleistocene and Holocene sediments that mantle a considerable proportion of the major rice growing parts of Cambodia. Recent and Pleistocene alluvial/colluvial sediments that now form the parent material for most of the agricultural soils of Cambodia are substantially derived from the weathering and erosional products of the Mesozoic sandstone. However, low hills from felsic igneous intrusions particularly in southern and southeastern Cambodia also have supplied siliceous sediments for the recent and older alluvial/colluvial terraces. In the northeast and west of Cambodia, basaltic lava flows of the Pleistocene cover significant areas of older alluvial terraces. Finally, the sediments deposited by the Mekong River along its floodplain and in the basin of Tonle Sap mean that much of central Cambodia is dominated by recent alluvial/lacustrine sediments derived in part from the Mekong River basin and in part from the immediate basin of Tonle Sap.

### **Soil and Water Data**

At IFReDI, the soils are quite acidic, with an average pH value of 4.9. Sand content averages 40%, silt 35%, clay 25%, organic C 7.2 mg/kg, and total N 0.7 g/kg.

## Layout of the Site



*Layout of the Inland Fisheries Research and Development Institute (IFReDI) laboratory complex*

### DESCRIPTION OF SITE

#### Map Coordinates

11° 33' 15" N and 104° 55' 21" E

#### Elevation

28 m

#### General Background

IFReDI occupies an area of about 0.5 ha located in the capital city of Phnom Penh. IFReDI is under the supervision of the Fisheries Administration and is comprised of six divisions, listed as follows:

- Biological Division
- Laboratory Division
- Socioeconomic Division
- Technology and Information Transfer Division
- Kandal Stung Fisheries Research Station
- Administration Division

Presently, IFReDI has four senior researchers with doctorates in biology, development communication, and rural/community development from abroad (i.e., Belgium, Japan, Philippines, and Vietnam). There are 12 staff members holding MS degrees in fisheries biology, aquaculture and aquatic resources management, natural resources management, watershed management, agricultural economics, development communication, and rural planning and development from both foreign (Australia, Malaysia, Philippines, Thailand, and Vietnam) and national universities. There are also 24 staff members holding BS degrees in fisheries science, aquaculture, and fisheries economics.

The IFReDI staff have extensive experience in fisheries biology and ecology, aquaculture development, fisheries policy development and planning, fisheries resources, development, management, and conservation, socio-economics and livelihoods, and participatory fisheries resources management.

The IFReDI laboratory complex houses instruments for measurement of the biological, physical, and chemical parameters of importance in fisheries and aquaculture.

#### Water Supply

Supply water for IFReDI laboratory comes from public/city water taps and ground water wells.

## Soils

The soils at IFRaDI are quite acidic, with average pH value of 4.9. They have sand contents averaging 40%, silt 35%, clay 25%, organic C 7.2 mg/kg, and total N 0.7 g/kg.

## Support Facilities

Laboratories and personnel at IFRaDI are available to the AquaFish project.

IFRaDI has a rich fisheries library, networking with the Food and Agriculture Organization of the United Nations (FAO), Mekong River Commission (MRC), WorldFish, and other libraries in the world.

IFRaDI research and development activities are funded by the Royal Government of Cambodia, AquaFish, MacArthur Foundation, MRC, Asian Development Bank (ADB), Oxfam, WorldFish Center, Danish International Development Agency (DANIDA), Swedish International Development Agency (SIDA), FAO, Southeast Asian Fisheries Development Center (SEAFDEC), Network of Aquaculture Centres in Asia-Pacific (NACA), International Union for Conservation of Nature, Agriculture Centre for International Agricultural Research (ACIAR), United Nations Environment Programme, Japan International Cooperation Agency (JICA), World Wildlife Fund, Conservation International (CI), Nagao Natural Environment Foundation (NEF)-Japan, and the European Union.

IFRaDI has close cooperation with the following universities and research institutes to strengthen research and exchange knowledge and information:

- US (7): University of Connecticut, University of Rhode Island, Oregon State University, University of Washington, Texas A&M University, Florida Museum of Natural History, and Princeton University
- Australia (2): Queensland University of Technology and Murdoch University (Perth)
- Europe (9): Swedish University, Beijer Institute and Stockholm Resilience Centre, and Royal Swedish Academics of Sciences (Sweden); Katholieke Universiteit Leuven and Ghent University (Belgium); University of Toulouse and University of Paul Sabatier (France); Royal Veterinary and Agriculture University Institute for Fisheries Management and Coastal Community Development (Denmark); and The Natural History Museum (United Kingdom)
- Asia (18): Living Aquatic Resources Research Center and the National University of Laos (Laos); Research Institute for Aquaculture 2, and Can Tho University (Vietnam); Kasetsart University, IFRaDI/Department of Fisheries, Ubon Ratchathani University, Srinakharinwirot University, Maejor University, and Aquaculture and Aquatic Resources Management, Asian Institute of Technology (Thailand); LGFS/University of Tokyo, Japan Water Research Center, and Kyushu University (Japan); University of Saint Malaysia (Malaysia); and Royal University of Agriculture, Prek Leap National College of Agriculture, Kampong Cham National School of Agriculture, and Royal University of Phnom Penh (Cambodia)

## Primary Affiliations

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## FRESHWATER AQUACULTURE RESEARCH AND DEVELOPMENT CENTER (FARDeC)



*Freshwater Aquaculture Research and Development Center's building located in Prey Veng province, Cambodia (left), and a domesticated-broodstock pond for AquaFish's snakehead project (right).*

### Layout of the Site



*Layout of the Freshwater Aquaculture Research and Development Center (FARDeC)*

### DESCRIPTION OF SITE

#### Map Coordinates

11° 16' N and 104° 17' E

#### Elevation

7 m

#### General Background

The Freshwater Aquaculture Research and Development Center (FARDeC), previously known as Bati Fish Seed Production and Research Station, is located along the bank of Tonle Toch (small) River of the Mekong basin in Bati village, Peam Ro district, Prey Veng province, about 68 km from the capital city of Phnom Penh by National Road 11. It has a total land area of about 13 ha.

FARDeC is the second largest of a series of aquaculture centers supervised by the Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries. It has major responsibilities in fingerling production of freshwater indigenous species such as river catfish, walking catfish, climbing perch, silver barb, giant freshwater prawn, and snakehead, plus exotic species such as

tilapia, Chinese carps, and Indian carps for distribution to fish farmers. In addition, the center has experience in operating a series of experiments on hatchery, nursery, and grow-out performances of both indigenous and exotic species, especially river catfish and giant freshwater prawn. It also provides training and technical assistance to fish farmers. The center consists of offices, a biological laboratory, a training and workshop building, a library, a dormitory, a storage building, one pump station, a commercial pellet feed mill, a hatchery, and a complex of experimental tanks and ponds for broodstock, nursery and grow-out. There are a total of 73 ponds, including eight ponds of 200 m<sup>2</sup>, 30 – 300 m<sup>2</sup> ponds, and 15 – 600 m<sup>2</sup> ponds with concrete, five 600 m<sup>2</sup> ponds, and 15 – 2,000 m<sup>2</sup> ponds. The 12 – 300 m<sup>2</sup> ponds have been assigned to the AquaFish project.

#### **Water Supply**

The water is pumped by a diesel-powered hydraulic pump from Tonle Toch (small) River and directly supplied by gravity to the ponds, whereas tanks are supplied by groundwater from an on-site well. The power is supplied by a generator and solar panel and expected to connect with electricity in the near future.

#### **Soils**

According to M. C. Nandeesha (1991), the major problem with the center soil is its high percentage of sand and low percentage of clay. The water holding capacity of the soils with high sand content is poor. The infiltration rate of the center soil is expected to be more than 5 – 7 cm/day.

Coarse sand (%): 28.8

Fine sand (%): 38.0

Silt (%): 13.4

Clay (%): 15.4

pH: 5.5

Avg. N (kg/ha): 454.7

Avg. P<sub>2</sub>O<sub>5</sub> (kg/ha): 45.2

Avg. K<sub>2</sub>O (kg/ha): 100.8

Zinc (ppm): 0.48

Copper (ppm): 0.77

Manganese (ppm): 28.0

Iron (ppm): 8.6

Boron (ppm): 0.16

#### **Support Facilities**

Students from The Royal University of Agriculture (RUA), Prek Leap National College of Agriculture (PNCA), and Kampong Cham National School of Agriculture (KCNSA) in Cambodia conduct thesis research at FARDeC and the AquaFish site (e.g., snakehead domestication and breeding and tilapia pond characterization) and assist in various activities in the center. A pellet feed mill and a laboratory are available in the center. A variety of agricultural by-products (e.g., corn, rice bran, wheat bran, soybean meal, etc.) are available from the various mills. Inorganic fertilizer is available at agricultural supply stores and organic fertilizers are available from local farms at low cost. The water quality laboratory of the Ministry of Agriculture in Phnom Penh has been used for water analysis. FARDeC has worked and is working with various local, regional, and international organizations and agencies such as PADEK (1993 – 1997), World Bank's Agriculture Productivity Improvement Project (2000 – 2004), Freshwater Agriculture Improvement and Extension Project/Japan International Cooperation Agency (2005 – 2010), AIMS/MRC (2005 – 2010), Aquaculture and Fisheries Collaborative Research Support Program (AquaFish CRSP; 2010 – 2011), and Department for International Development (2011).

<b>Affiliations</b>	
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## VIETNAM

*(Information provided by Dr. Robert Pomeroy, US Project PI, in 2013)*

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Located in the south of Vietnam, the Mekong Delta is considered an area of interest for aquaculture and fisheries. The Mekong Delta has over 1 million ha of water surface, over 700km of coastline, hundreds of islands, and has a large area of exclusive economic zone. Annually, this area produces over 70% of total aquaculture production and 20% of fisheries productions of the whole country. By the year 2010, the Mekong Delta had over 769,000 ha of aquaculture area and over 1,945,000 tons of aquaculture products, corresponding to 1,095,618 ha and 2,742,888 tons for the whole country. Main aquaculture species in the Mekong Delta are marine shrimp, mollusc, cat fish, giant freshwater prawn, tilapia. There are 26,894 farms in the region, which is the largest number compared to other regions in the country. For fishing, there are 16,699 fishing boats in the region and over 128,449 fishing boat in the whole country. Capture production reached 487,841 tons over 2,226,600 tons of the whole country. There are 70 boat maintenance stations in the region. For aquatic processing, there are 206 factories in the region, over 564 factories in the whole country.

The Fisheries Directorate (2011) reported that the total fisheries production of Vietnam reached 5.2 million tons, of which 3.0 tons were from aquaculture; and the export turnover was 6 billion USD that contributes 4% of GDP in 2011. The export turnover of the fisheries sector is ranked as the fourth of the export commodities of Vietnam.

According to the master plan to the 2020, fisheries products aim to contribute 30 – 35% GDP in Agriculture-Forestry-Fisheries area. Export value will reach to 8-9 billions USD, total fisheries products achieve 6.5 – 7.0 tons, of which aquaculture products cover 65 – 70%.

In order to achieve those objects, the Mekong Delta will play a very important role. According to the Master plan to 2020, aquaculture and fisheries will be the main economic industry in the region, which has large commercial production scale, highly competing capacity, and highly exported value. In the time coming, there will be the trends of intensive culture with large scale; aquaculture extension to marine, brackish and freshwater area; application of new, modern and advanced technology to improve yields, quality, efficiency, and to protect the environment. By the year 2020, total aquaculture area in the Mekong Delta will be 550,000 – 600,000 ha; capture fisheries stay with sustainable development, natural environment is protected and offshore fisheries and service are invested.

The Vietnamese government has issued a number of decrees and circulars regarding the strategic development plans of the fisheries sectors. Especially, fisheries and aquaculture sectors will continue playing one of the top priority economic sectors for the Mekong Delta in the years to come.

While aquaculture in Vietnam and the Mekong Delta particularly is very well known with rapid development of shrimp farming and catfish farming, it is now facing several serious problems of over-development, climate change, diseases, water pollution, product processing, and food safety. The marine aquaculture is still in very early stages. Meanwhile, fishing is characterized with small scale and near shore catch, and an over exploitation of these vessels caused a serious decline in production.

The primary site for AquaFish research is Can Tho University (CTU), which is located in the center of the Mekong Delta and has become a key university of the Mekong Delta. Being the leading multidisciplinary institution of the region and the country, the university is providing more than 87 undergraduate courses, 36 graduate courses, and nine specializations for fellow students. In addition to its training responsibilities, scientific research and technology transfer are considered very positive and dynamic activities of the university. CTU has actively taken part in scientific research projects, applying the advances in scientific

and technological knowledge to solving problems related to science, technology, economics, culture, and society in the region. A full site characterization for CTU is included below.

In addition to University of Connecticut-Avery Point located in the US and CTU, collaborating partners are also located at the University of Rhode Island and Oregon State University. One additional support facility in Vietnam is the Vietnam Fisheries and Aquaculture Institution Network (ViFINET).

#### **Country Map**



*Map of Vietnam indicating the location of Can Tho University..*

#### **CAN THO UNIVERSITY (CTU)**



*Can Tho University – College of Aquaculture and Fisheries*

### **General Location**

Can Tho University (CTU) is located in Can Tho City, Vietnam, in the center of the Mekong Delta.

### **DESCRIPTION OF AREA/REGION**

#### **Climate**

The Mekong Delta belongs to humid tropical group (A), tropical wet-and-dry type (w). Distinct dry and rainy seasons are observed.

#### **Temperature**

The temperatures are warm year-round and subject to small variations due to elevation, seasonal, and maritime influences. The average temperature ranges from 26 – 28 °C in the Mekong River Delta. During the months of December and January the temperatures are generally lower, while the climate becomes hot and dry from the end of February until the southwest monsoon begins in May

#### **Precipitation**

The rainfall is generally high but varies by season and is unequally distributed depending on geographic orientation. Annual average precipitation ranges between 1,600 – 1,800 mm in northeast part of the Delta and can exceed 2,000 mm on the southwestern coast. About 90% of annual rainfall occurs between May and November (i.e., the wet or rainy season). Heavy rains are common in July and August. The monthly average precipitation ranges from about 8 mm in January (dry season) to 250 mm in September (rainy season).

#### **Humidity**

The relative humidity is highest at about 80 – 85% in September and lowest in March at about 60 – 65%.

#### **Seasonality**

The weather in the Mekong River Basin (MRB) of Vietnam is divided into two seasons. The rainy/wet season is from May to November, while the dry season lasts from December to April. It is hottest in May and April, but coolest in December and January.

#### **Topography**

The MRB of Vietnam is a vast lowland area. The total natural area of about 4 million ha spreads from the Cambodian border to East Sea and the Gulf of Thailand. It is famous for two floodplains: Dong Thap Muoi and the Long Xuyen Quadrangle. There are two main branches of the Mekong River (Hau and Tien rivers) with a cross-network of natural and artificial canals that transport about 500 billion m<sup>3</sup> of freshwater from upstream to the sea every year.

#### **Geology/Soils**

There are two major types of soils in the MRB of Vietnam. Alluvial soils are found along the Tien and Hau rivers and cover an area about 1.1 million ha (about 28% of the Mekong Delta). Acid sulphate soils: occupy 1.59 million ha mainly in the Plain of Reeds and the Long-Xuyen-Ha Tien quadrangle. These are classified into potential acid sulphate soils, which cover about 1.1 million ha (28% of the Delta) and actual acid sulphate soils, which occupy 510,027 ha (13% of the Delta). Saline soils are found along the coastal regions and cover an area of 808,749 ha (21% of the Delta). The remaining soils are upland and mountainous peat soils. Alluvial soils are mainly located along the main river branches (Hau and Tien rivers). Actual acidic soils and potential acidic soils are common in the floodplains. Hilly and peat soils are mainly observed in the areas along the Cambodia border and the western coast. Saline soils are mostly located within mangroves in the eastern coast.

#### **Soil and Water Data**

The Mekong River's water flow in the wet season is about 40,000 m<sup>3</sup>/s — more than 20 times that of the dry season (1,800 m<sup>3</sup>/s). Water flow in dry season is about 1,700 m<sup>3</sup>/s. There are nine provinces and cities with between 1.4 – 1.9 million ha and 9 – 10 million of people affected by annual floods.

## Layout of the Site



*Aerial map of Can Tho University.*

### DESCRIPTION OF SITE

#### Map Coordinates

10° 2' 0" N, 105° 47' 0" E

#### Elevation

Sea level

#### General Background

The College of Aquaculture and Fisheries (CAF) at CTU was established in 1979. For more than 30 years, CAF has been developing itself to fulfil its missions of education, research, and technology transfer in the aquaculture and fisheries fields. These efforts help meet the demand for manpower and advanced technology for development of aquaculture and fisheries in Vietnam and the Mekong Delta.

At present, CAF has 107 staff, including 61 instructors and 43 researchers, holding different titles and degrees (12 Associate professors, 27 PhD, and 41 Masters). CAF has eight departments as follows:

- Department of Applied Hydrobiology
- Department of Aquatic Biology and Pathology
- Department of Aquatic Nutrition and Products Processing
- Department of Freshwater Aquaculture
- Department of Coastal Aquaculture
- Department of Fisheries Management and Economics
- Center for Aquaculture Promotion
- Administration Unit

CAF has a system of advanced laboratories, hatcheries, and field stations in both freshwater and brackish water areas, which meet the functions of education, research, and technology transfer locally and internationally.

#### *Laboratories*

- Laboratory for water and sediment analysis: analyzing more than 30 environmental parameters of sediments
- Laboratory for fish pathology: analyzing parasites, bacteria, virus, and cytology
- Laboratory for aquatic animal nutrition and feed: analysis of all feed quality parameters, feed ingredients such as protein, carbohydrate, lipid, fiber, mineral, moisture, vitamin C, and fatty acids
- Applied molecular biology laboratory: specializing on physiology, nutrition, and pathology
- Laboratory of food safety: analysis of residues of drugs and chemicals in water, sediment, and fishery products

#### *Wet labs*

- Live food production
- Mud crab broodstock and larval production
- Reproduction of ornamental fish
- Showroom for aquatic animal specimens

Two wet laboratories are used for nutrition research (100 tanks of 500 liters and 100 tanks of 100 liters). CAF also has one small mill (200 kg/hours) for aquatic feed processing.

#### *Experimental stations*

- Freshwater fish hatchery located at the CTU campus has been operating to reproduce fish species such as common carp, mud carp, tilapia, several catfish species, and some wild fishes (snakehead, broadhead catfish, snakeskin gourami, etc.).
- Marine shrimp and giant freshwater prawn hatcheries (based on-campus)
- Brackish-water field experimental stations in Vinh Chau, Soc Trang province (with a total area of 15 ha), and Bac Lieu province (6.5 ha)

The university has been establishing collaborations with more than 120 institutions around the world, which aids the development of bilateral and multilateral cooperation programs for CTU. From 2007 to 2011, CTU signed more than 110 memoranda of understanding and agreements with universities, institutes, and international organizations representing countries including Australia, Belgium, Canada, Denmark, England, Finland, France, Germany, Japan, Malaysia, The Netherlands, South Korea, Spain, Sweden, Taiwan, Thailand, and the United States.

#### **Water Supply**

Water for the operation of laboratories and experiments at CAF is sourced from public water taps with a pH of 7.5 – 8.0, and an alkalinity of 30 – 50 mg/L.

Water for ponds is sourced from a small Bun Sang canal behind CAF. The main water source of this canal is directly from the Hau River. Typical water parameters include: pH (6.5 – 7.0), alkalinity (30 – 50 mg/L), ammonia-N (0.02 – 0.05 mg/L), and nitrate-nitrite-N (0.02 mg/L).

#### **Soils**

See above *Geology/Soil* section of the *Description of Area/Region* on page 17.

#### **Support Facilities**

In collaboration, CAF also has strong relationship with the Vietnam Fisheries and Aquaculture Institution Network (ViFINET) and more than 30 international universities and organizations.

<b>Affiliations</b>	
<i>In-Country</i>	<i>US</i>
Can Tho University College of Aquaculture and Fisheries Can Tho, Vietnam	University of Connecticut–Avery Point Agricultural and Resource Econ/CT Sea Grant Groton, Connecticut, US
<b>Current Contacts</b>	
<i>In-Country</i>	<i>US</i>
Dr. Tran Thi Thanh Hien Can Tho University College of Aquaculture and Fisheries Campus II, 3/2 Street, Nink Kieu District Can Tho City, Vietnam Tel: +849 18 39 1916 E-mail: <a href="mailto:tthien@ctu.edu.vn">tthien@ctu.edu.vn</a> Website: <a href="http://caf.ctu.edu.vn/en">http://caf.ctu.edu.vn/en</a>	Dr. Robert S. Pomeroy University of Connecticut-Avery Point Agricultural and Resource Econ/CT Sea Grant Room 380 (Marine Science Building) 1080 Shennecossett Road Groton, Connecticut 06340-6048, US Tel: 1-860-405-9215 Fax: 1-860-405-9109 E-mail: <a href="mailto:robert.pomeroy@uconn.edu">robert.pomeroy@uconn.edu</a>

# PURDUE UNIVERSITY



## AQUACULTURE DEVELOPMENT AND THE IMPACT ON FOOD SUPPLY, NUTRITION, AND HEALTH IN GHANA AND TANZANIA

### GHANA

*(Information provided by Dr. Kwamena Quagrainie, US Project PI, in 2013)*

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Ghana is located in West Africa and is bordered on the north by Burkina Faso, on the east by the Cote D'Ivoire, and on the west by the Republic of Togo. The southern boundary is covered by the Gulf of Guinea, which provides a rich marine fishery for West Africa in general.

Aquaculture represents a significant alternative livelihood activity in Ghana and remains a formidable alternative employment for the rural poor. The contribution of aquaculture to the fish requirements of Ghana is fairly restricted; meanwhile harvest from capture fisheries is on the decline. Ghana's fish imports amount to about US\$200 million per annum, an amount that can be reallocated to other sectors of the economy such as the aquaculture industry to supplement fish requirements in the country. Ghana has recognized the importance of aquaculture to help offset the nation's deficit of about 400,000 metric tons of the country's fish requirements. Consequently, the government is aggressively pursuing an aquaculture development policy to make fish farming a profitable business venture and not just a hobby. The government is adopting strategies to address constraints such as quality fish seed and feed, inadequate extension services and support, and marketing. The government has increased staff levels and provided training to improve expertise and skills to assist fish farmers with extension services.

Small-scale farming dominates the industry producing various species of tilapia such as *Oreochromis niloticus*, *Tilapia zillii*, *Sarotherodon galilaeus*, *Hemichromis fasciatus*, *Heterotis niloticus* and the catfishes (*Clarias gariepinus* and *Heterobranchus bidorsalis*). Studies in Ghana by AquaFish have generated information and data on the economic profitability of fish farming, particularly, tilapia (*Oreochromis niloticus*), and catfish (*Clarias gariepinus*); and preliminary studies demonstrate that it is a profitable farm enterprise. Cage farming is becoming attractive and a considerable number of cage farming is proliferating in the Volta Lake, the largest man-made lake in the world by surface area. About 1% of the Volta Lake in Ghana has been earmarked by Government for the production of fish under cage culture systems, indicating the government's commitment to enhance aquaculture production in Ghana.

The Ministry of Fisheries (MOF) is the lead agency with administrative control of aquaculture responsible for planning and development in the aquaculture sub-sector. The MOF does not offer credit facilities to fish farmers but promotes the formation of fish farmers associations (FFAs). MOF support the growth of the FFAs by providing each FFA a D6 bulldozer on 7-year credit for the construction of ponds. Because Ghana is governed by a democratically elected government and the political climate is very stable, socioeconomic and political conditions are conducive for investment in aquaculture in the country. The political climate has attracted a number of financial institutions mainly banks from across the globe to invest in Ghana. This has made it possible for borrowing and leveraging of funds for various agricultural activities. It is expected that aquaculture will continue to develop and provide the required data and information to financial institutions so that the sector could benefit from support from banks and lending institutions. An Aquaculture Strategic Framework for the country has recently been fully documented and disseminated to relevant stakeholders.

The FFAs are responsible for lobbying on behalf of fish farmers, organizing purchase of inputs such as seeds and credit, and arranging markets for farmers' harvests. The Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR) is responsible for aquaculture research in Ghana.

The WRI is the major aquaculture research institution in the country, although the universities - Renewable Natural Resources Institute at Kwame Nkrumah University of Science and Technology (KNUST), Department of Fisheries and Oceanography at University of Ghana (UG), and the Department of Fisheries and Aquatic Sciences at University of Cape Coast (UCC) - also conduct some aquaculture research. These three universities and one agricultural college offer training in aquaculture as well. Some limited but informal collaboration exist between the KNUST and the Ministry of Fisheries and it is hoped that these links will be further strengthened as research and extension capacities are developed further.

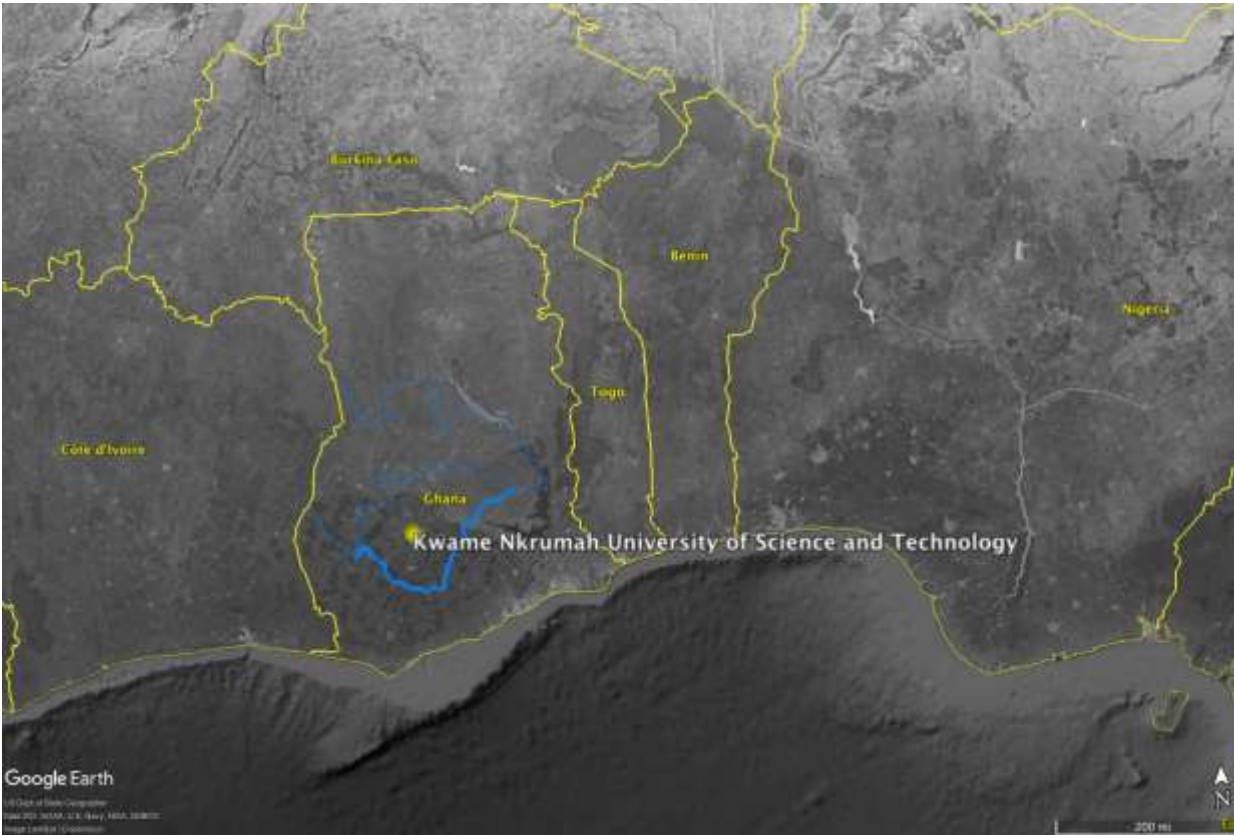
Ghana is endowed with abundant renewable natural resources. The country is well drained by many large rivers, streams and lakes, which makes it a potential location for aquaculture production in artificial waters in natural lakes and rivers. Although fish constitute 60% of the total animal protein intake in Ghana, the majority of these resources are of marine origin.

Unfortunately, the increasing human population now means that the marine fishery is no longer able to sustain the growing demand for fish and fish products. Aquaculture production is carried out in rural Ghana and in some semi-urban communities in Ashanti and Brong-Ahafo regions of the country. There is a considerable number of rural fish farmers who are actively involved in fish farming in the rural areas and whose livelihood depends on it. Some of the major farms in Ghana are Kumah Farms, Tropo Farms, Crystal Lake Farms, Aqua Farms, and several others that are actively involved in promoting aquaculture in Ghana.

The primary Host Country site for the AquaFish research is Kwame Nkrumah University of Science and Technology (KNUST) located in Kumasi, Ghana, which is described in more detail below. One additional support facility that will be used as needed is located at the Pilot Aquaculture Center of the Fisheries Commission.

In addition to partners at Purdue University located in the US and KNUST, other collaborating partners are located at the Virginia Polytechnic Institute and State University, University of Arkansas at Pine Bluff, and Oregon State University in the US, and Sokoine University of Agriculture and University of Dar es Salaam located in Tanzania.

## Country Map



*Map of Ghana indicating the location of Kwame Nkrumah University of Science and Technology in Ghana.*

### KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST)



*Department of Fisheries & Watershed Management, Institute of Renewable Natural Resources, KNUST, Kumasi.*

### **General Location**

The KNUST Department of Fisheries and Watershed Management Aquaculture Facility is located roughly 13 km east of Kumasi, in the Ashanti Region. This area is in the transitional forest zone and has an elevation that ranges between 250 – 300 m above sea level.

### **DESCRIPTION OF AREA/REGION**

KNUST has laboratory space and limited facilities for analysis of water quality of effluents from fish farms. Laboratories that complement those of the Faculty of Renewable Natural Resources include the water quality labs at the Departments of Civil Engineering, Chemistry, Biochemistry, and Applied Biosciences. Where necessary, the Ghana Water Company, Kumasi, at some cost, has allowed KNUST to access its water quality laboratories for mutual benefit. KNUST has its own fish ponds that are primarily used for teaching and research for both undergraduate and graduate students.

KNUST in Kumasi is strategically located in Ghana as far as fish farming is concerned. Kumasi is a strategic market center with the largest open market in West Africa, and is a central hub for Ghana.

### **Climate**

KNUST is within the Kumasi metropolis, which falls within the wet sub-equatorial type.

### **Temperature**

The average minimum temperature is about 21.5°C. The maximum average temperature is 30.7 °C

### **Precipitation**

Precipitation varies from around 5 mm in the dry season to nearly 200 mm in the wet season. It also varies by location, as the drier, northern parts of the country consistently receive less precipitation.

### **Humidity**

The average humidity is between about 60% and 85%, depending on the time of day.

### **Seasonality**

Precipitation and temperature vary significantly by season. The hottest and driest periods occur between October and March.

### **Topography**

Ghana is mostly plains, with a plateau area in the south-central part of the country below the massive Volta Basin.

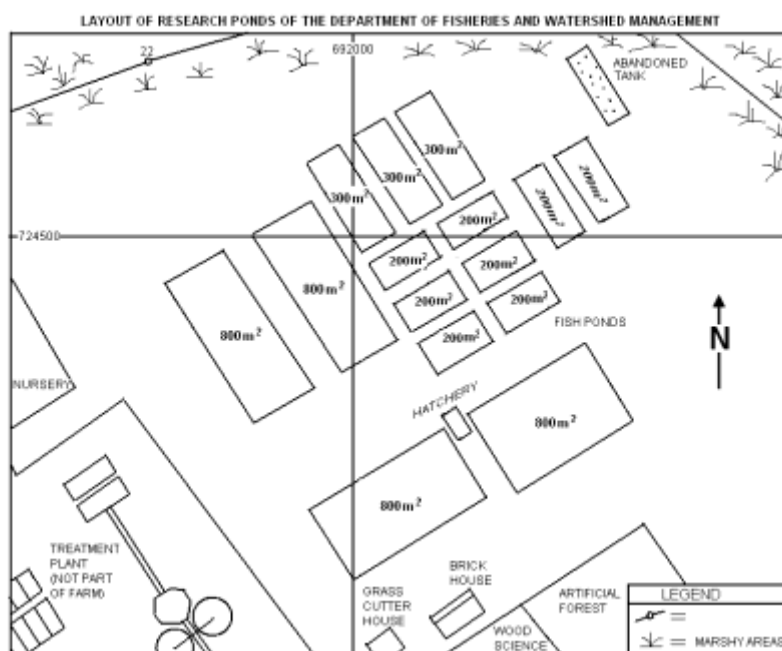
### **Geology/Soils**

Kumasi falls within the moist semi-deciduous Southeast Ecological Zone, with rich soils that are ideal for agriculture. The Kumasi Metropolitan area is dominated by the Middle Precambrian Rock, which is used in the construction industry. There are a few small-scale mining activities, including stone quarrying and sand industries.

### **Soil and Water Data**

The major soil type is the forest ochrosol, which is a very rich type used for the production of agricultural commodities such as vegetables, plantain, corn, and cassava.

## Layout of the Site



*Layout of the aquaculture teaching and research ponds located at KNUST.*

## DESCRIPTION OF SITE

### Map Coordinates

6° 40' 0" N, 1° 37' 0" W

### Elevation

250m

### General Background

Farmer trainings and workshops have been conducted in collaboration with the Ministry of Fisheries in Kumasi using facilities of both institutions, including the Pilot Aquaculture Training Centre in Kumasi and the Department of Fisheries and Watershed Management at KNUST.

The aquaculture teaching and research ponds are a major component of the farm complex of the Faculty of Renewable Natural Resources at KNUST. There are 15 earthen ponds of varying sizes, all of which are spring-fed. The ponds lie near the River Wiwi, which traverses the university campus from the south end. Three of the ponds have a total surface area of 300 m<sup>2</sup>, eight have a surface area of 200 m<sup>2</sup>, and four have a surface area of 800 m<sup>2</sup>. The average pH values of the pond waters range from 6.5 – 7.5, while water temperatures range from 25.3 – 26.5°C. There is also a wet laboratory, a storeroom, a small hatchery, and a site for a duck pen.

Current work and research at the fish farm include tilapia and catfish fingerling production, as well as fish feed and nutrition experiments to find locally-sourced, cost-effective feed for fish production for reducing dependence on imported feed. Most feeds available are made on-farm, and this represents a setback to viable aquaculture production. Research is needed to identify local feeds and formulate them. Most commercial feeds are imported from Brazil or Israel, but many have questioned the sustainability of these imports. Efforts are being made to produce extruded feed for the aquaculture industry and the government is backing this fully.

### Water Supply

Water supply is from two surface water treatment plants, the Owabi and Barekese headworks located 10 km and 16 km from Kumasi, respectively. The supplies of water from these headworks serve the Kumasi metropolis as well as surrounding communities. The area has a 13,800 m<sup>3</sup> storage reservoir located at Suame and a 1,900 m<sup>3</sup> capacity reservoir located at KNUST.

### Soils

The major soil type is the forest ochrosol, which is a rich type used for the production of agricultural commodities such as vegetables, plantain, corn, and cassava.

### Support Facilities

KNUST collaborates with many international agencies and universities in the UK, US, Canada, Netherlands, Israel, Germany, South Africa, and several other African universities. It has affiliations with some new university colleges in Ghana to provide oversight as they develop curriculum standards that meet international requirements. There are several formal and informal linkages with various institutions, such as the Council for Scientific and Industrial Research (CSIR), and these frequently offer limited training facilities for both undergraduate and graduate students. Facilities of the Pilot Aquaculture Center of the Fisheries Commission will also be used as needed.

### Primary Affiliations

<i>In-Country</i>	<i>US</i>
Kwame Nkrumah University of Science and Technology Kumasi, Ghana, West Africa	Purdue University West Lafayette, Indiana, US

### Current Contacts

<i>In-Country</i>	<i>US</i>
Dr. Stephen Amisah Faculty of Renewable Natural Resources Kwame Nkrumah University of Science and Technology Kumasi, Ghana, West Africa Tel: 231-51-60381	Dr. Kwamena Quagraine Dept. of Agricultural Economics Purdue University 403 W. State St., Krannert Building West Lafayette, Indiana 47907 US Tel: (765) 494-4200

## TANZANIA

(Information provided by Dr. Kwamena Quagrainie, US Project PI, in 2013)

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Aquaculture in Tanzania is dominated by small-scale freshwater fish farming. Farming practices include both extensive and semi-intensive fish farming but the majority are extensive small fish ponds integrated with other agricultural activities such as crop and animal production. Fish production activities are found mainly in Ruvuma, Iringa, Mbeya, and Kilimanjaro. Several species are cultured, but mainly dominated by tilapia (*Oreochromis niloticus*). Other species with potential for use in aquaculture include the milkfish (*Chanos chanos*), the flathead grey mullet (*Mugil cephalus*), the North African catfish (*Clarias gariepinus*), and shellfish such as shrimp, mollusks, crabs, oysters, and mussels. Various species of seaweed is farmed in Tanzania, mainly in coastal areas along the coastline from Tanga in the north to Mtwara in the south, and in the islands of Mafia and Zanzibar.

The Fisheries Division is the governmental agency responsible for the formulation, implementation, and enforcement of aquaculture policy and legislation. The Division conducts numerous workshops to create awareness in the communities on sustainable aquaculture, and provides low interest loans and a three-year tax-free period for investors in commercial aquaculture through the National Investment Center (NIC). Several institutions are involved in fisheries research, education, and training. The Tanzania Fisheries Research Institute (TAFIMA) has overall responsibility for all the research on fisheries; the Faculty of Aquatic Sciences and Technology (FAST) at the University of Dar Es Salaam and the Sokoine University of Agriculture (SUA) are both responsible for carrying out research and training on fisheries. Other government fisheries centers and institutes are involved in training as well.

In Tanzania, the fisheries sector contributes about 10% of the national GDP. Fisheries sector provides food, income, and employment for many people in Tanzania. It is estimated that the country's fish and fisheries products provide about 40% of animal protein supply. The supply of fish comes from two main sources: fisheries based on the natural water bodies and from fish farming. The major areas of fishing are the shores of Lakes Tanganyika, Victoria, and Nyasa where about 360,000 full time and occasional fishermen are engaged in fishing or fishery-related activities.

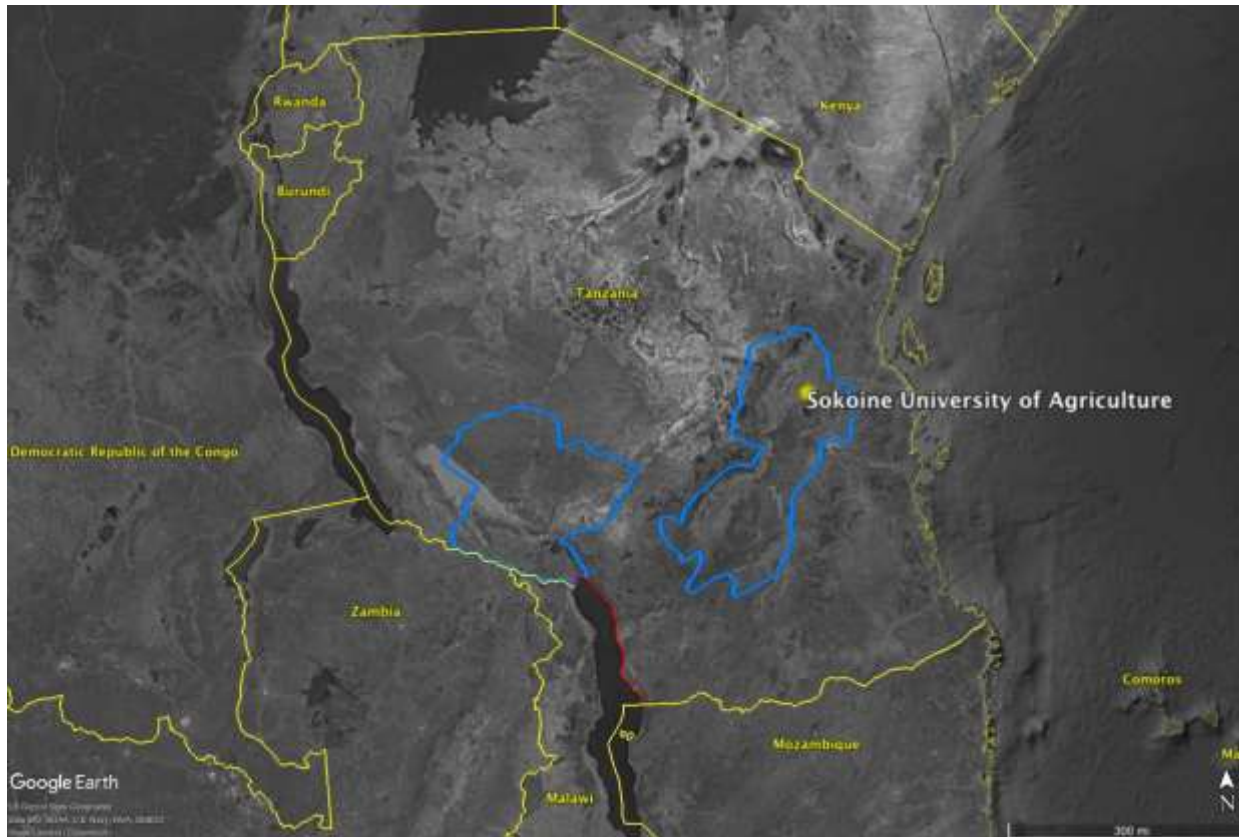
Although production from aquaculture accounts for only a small proportion of total fish produced at the national level, it provides vital animal protein to the population residing in areas which are located far away from the major fishery resources or where transport of fish is either difficult or too expensive. In some regions where protein intake per capita is low and where protein malnutrition prevails, the socio-economic benefit from aquaculture is high. Fish farming in Tanzania is done in dams, ponds and tanks by commercial farmers, smallholder farmers and institutions, mostly using tilapia species. The species widely cultured are *Oreochromis niloticus*, *Oreochromis leucostictus*, and *Oreochromis uroleptis*. Fish farmers obtain fingerlings from government fry centers and fisheries institutes.

For the past three decades, the government of Tanzania has recognized that the fisheries resources have been overexploited by local communities and other users. In realization of this, the government developed a policy and strategies for the fisheries sector in 1997. The policy emphasizes the need for change in attitude towards fisheries resource exploitation practices as well as the necessity to manage the resources sustainably and to conserve and develop the fisheries resources for the good and prosperity of all. The main goal of the national fisheries policy is to promote conservation, development, and sustainable management of the fisheries resources for the benefit of present and future generations. The policy recognizes the potential for increasing fish production through aquaculture to complement the capture fisheries. The policy has set management principles and guidelines for the development of aquaculture in order to ensure sustainability of aquaculture production in the country.

The primary Host Country site for AquaFish research is the Aquaculture Research Facility located at Sokoine University of Agriculture (SUA) in Tanzania and will be described in greater detail below. Other on-farm experiments will be done in Morogoro, Dar es Salaam, Coastal, Mbeya and Iringa regions of Tanzania.

In addition to partners at Purdue University located in the US and SUA in Tanzania, other collaborating partners are located at Oregon State University, Virginia Polytechnic Institute and State University, and University of Michigan in the US, University of Dar es Salaam Institute of Marine Sciences, located in Tanzania, and Kwame Nkrumah University of Science and Technology located in Ghana.

#### **Country Map**



*Map of Tanzania and indicating the location of Sokoine University of Agriculture.*

## SOKOINE UNIVERSITY OF AGRICULTURE AQUACULTURE RESEARCH FACILITY



*Kingolwira National Fish Farming Center Aquaculture Research Facility*



*Sokoine University of Agriculture Aquaculture Research Facility*

### **General Location**

Sokoine University of Agriculture is situated 3 km from the center of Morogoro Municipality, which is about 200 km west of Dar es Salaam. The university is located between 6 –7 °S and 37–38 °E.

### **DESCRIPTION OF AREA/REGION**

Freshwater aquaculture is concentrated in six regions in Tanzania: Arusha, Kilimanjaro, Morogoro, Iringa, Mbeya, and Ruvuma. Morogoro and Mbeya have the most fish farming activities.

The Morogoro Region is one of 20 regions in mainland Tanzania. The region lies between latitude 5°58" and 10°0" to the south of the Equator and longitude 35°25" and 35°30" to the east. It is bordered by seven other regions: Arusha and Tanga regions to the north, the Coast Region to the east, Dodoma and Iringa to the west, and Ruvuma and Lindi to the south.

The Mbeya Region is located in the southwestern corner of the Southern Highlands of Tanzania. The region lies between latitudes 7– 9 °S and between longitudes 32–35 °E. The region lies at an altitude of 475 m above sea level, with high peaks of 2,981 m above sea level at Rungwe. Mbeya shares borders with the countries of Zambia and Malawi to the immediate south, Rukwa Region to the west, and

Tabora and Singida regions to the north. The Iringa Region lies to its east, with Tunduma and Kasumulu in the Mbozi and Kyela districts, respectively, being the main points of entry into the neighboring countries of Malawi and Zambia.

#### *Mikindu Village*

Mikindu is a village in the mountainous areas of the Morogoro Region. Aquaculture is practiced extensively in this area with many fish ponds located near homes. Most farmers use animal and vegetable by-products to feed fish, which can reach more than 200 g in six months. Fish farmers in the area have organized themselves into fish farmer groups, which allows the farmers to actively participate in national extension programs.

#### *Kingolwira National Fish Farming Center (KNFFC), Morogoro*

Workshops and farmer-training programs are conducted at Sokoine University of Agriculture (SUA) and the Kingolwira National Fish Farming Center (KNFFC), Morogoro. KNFFC started in 1989 with funding from the United Nations Development Programme and FAO and the United Republic of Tanzania government. The center has a reliable water supply, an office building, a vehicle and two motorcycles, and 12 ponds. The center also has 18 round concrete tanks (4 m diameter size) in the hatchery/nursery section and 12 rectangular concrete tanks (1 x 0.5 m size). The center operates integrated fish farming with animal husbandry, whereby poultry pens, and pig and goat buildings are constructed adjacent to the earthen ponds. The center also has 10 earthen ponds that are off-site about 14 kilometers from KNFFC.

#### **Climate**

The climate is generally tropical with marked seasonal and altitudinal temperatures and high rainfall variations causing dry and rainy seasons.

#### **Temperature**

The mean annual temperatures in the Morogoro Region vary with altitude from the valley bottom to the mountaintops. The average annual temperature varies between 18°C on the mountains to 30°C in river valleys. In most parts of the region, average temperatures are almost uniform at 25 °C. In general, the hot season is from July to September. Temperatures in Mbeya range between 16 °C in the highlands and 25°C in the lowlands areas.

#### **Precipitation**

In the Morogoro Region, annual rainfall ranges from 600 mm in the lowlands to 1,200 mm in the highland plateau. However, there are areas that experience exceptional drought with less than 600 mm of rainfall. These areas are in Gairo and Mamboya divisions in the north of Kilosa District, and the Ngerengere Division in the east of Morogoro Rural District.

The Mbeya Region enjoys abundant and reliable rainfall. Annual rainfall varies between 650 mm in the Usangu Plains and up to 2,600 mm in Chunya on the northern shores of Lake Nyasa in Kyela District and highlands of Rungwe and the southern parts of Ileje District.

#### **Humidity**

Humidity is much higher on the coasts than inland and is particularly low during the winter months.

#### **Seasonality**

The area receives an average annual rainfall of 600 – 1,000 mm and has bimodal rainfall: The short rains occur between November and December, followed by a short dry spell between January and February. The main rainy season is from March to May. The period between June and October is a dry season. The soils around the university main campus are mainly oxisols, with scattered patches of sandy loams, with pH ranging between 5.5 and 6.0.

The rains in the Mbeya Region normally start in October and continue until May, with dry and cold spells occurring between June and September. The crop-growing season in most parts of the region begins in November and continues until May.



### Topography

The topography varies from the plains along the coast, to a plateau in the center of the country, and highlands in the north and south of the country.

### Geology/Soils

The dominant natural vegetation is that of *Hypertheria* spp. and *Sporobolus* spp. dotted with miombo and acacia bushes. However, established pastures have modified the vegetation and the dominant species are *Chloris gayana*, *Brachiaria* spp., and *Pennisetum purpureum*.

The regions lie at an altitude of 475 m above sea level with high peaks of 2,981 m above sea level at Rungwe. The major topographic features of the Mbeya Region are the low elevation of the Western Rift Zone, which covers Lakes Rukwa and Nyasa, and the Eastern Rift Zone, which covers the Usangu Plains and the neighboring parts of the Ruaha Trough. The lowlands within the Rift Valley lie between 500 m and 1,400 m above sea level. Of the regional surface areas, 61,868 km<sup>2</sup> is dry land, about 57,000 km<sup>2</sup> arable land, and 1,757 km<sup>2</sup> is covered with water.

### Soil and Water Data

In most arable areas, soils are commonly of moderate fertility, coarse or medium textured, and varying from sandy loams and alluvial solids to cracking rocks. Although large areas of the regions are cultivated, large tracks of land are still covered with natural vegetation such as miombo (*Broschystegion*, *Julbernardia*) woodlands. Areas with rains of 800 – 1,200 mm per annum favor the growth of miombo woodland, while areas with less rain, especially in the region's north, support the growth of wooded grassland and bush lands of dense thickets of acacias and thorny trees. Areas with higher rainfall support forests, often evergreen and bamboo except at the highest elevations, where afro-alpine grasslands occur.

### DESCRIPTION OF SITE

#### Map Coordinates

6° 49' 0" S, 37° 40' 0" E

#### Elevation

500 m

### General Background

The main campus of SUA, where the aquaculture facilities are located, lies on the slopes of the Uluguru Mountains at an altitude of about 500 – 600 m above sea level.

The aquaculture section is under the Department of Animal Science and Production. The department maintains 20 concrete cylindrical tanks with a diameter of 3 m and 10 earthen ponds with dimensions of 20 m x 15 m. The department also has an animal nutrition laboratory for analysis of feed samples. The laboratory has a capacity of carrying out proximate analysis, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) determination, and determination of mineral anti-nutritional contents of various feeds. In terms of human resources, there are many staff members in various fields of animal science (e.g., animal nutrition, animal breeding, and genetics) in the department who assist the aquaculture section.

### Water Supply

Water used for the aquaculture ponds and tanks at SUA originates from a stream located on Mount Uluguru. Water temperatures range from 25 – 29 °C. Dissolved oxygen ranges from 5.3 – 8.1 mg/L, and pH ranges from 6.7 – 7.2.

### Soils

The soils around the university main campus are mainly oxisols with scattered patches of sandy loams with pH ranging between 5.5 and 6.0.

### Support Facilities

The Tanzania Fisheries Research Institute (TAFIMA) has the overall responsibility for all the research on fisheries in the country, and the Faculty of Aquatic Sciences and Technology (FAST) at the University of Dar es Salaam and other government fisheries centers and institutes are involved in training as well.



<b>Primary Affiliations</b>	
<i>In-Country</i>	<i>US</i>
Sokoine University of Agriculture Morogoro, Tanzania	Purdue University West Lafayette, Indiana, US
<b>Current Contacts</b>	
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# NORTH CAROLINA STATE UNIVERSITY



## ENHANCING AQUACULTURE PRODUCTION EFFICIENCY, SUSTAINABILITY, AND ADAPTIVE MEASURES TO CLIMATE CHANGE IMPACTS IN BANGLADESH

### BANGLADESH

*(Information provided by Dr. Russell Borski, US Project PI, in 2013)*

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Bangladesh is a politically stable South Asian country lying in the Ganges Delta plain formed by the confluence of the Ganges (Padma), Brahmaputra (Jamuna), and Meghna rivers and their tributaries draining into the Bay of Bengal to the south. These highly fertile lands were developed through deposition of alluvial soils from the Himalayas. Much of the country is < 10 meters above sea level, with the coastal regions near sea level. About 10,000 square kilometers (1 million hectares) of the total area is covered with water, and large areas are routinely flooded during the monsoon season. Given these features, Bangladesh is one of the most highly suited countries for coastal and inland aquatic agricultural development. Fisheries and aquaculture are a mainstay for the livelihood of rural communities and most of the dietary animal protein (65%) consumed by its citizens comes from seafood. Accordingly, the Government of Bangladesh and USAID Feed the Future have made investment in aquaculture development a high priority towards improving food security and nutrition for its people. Carps, tilapia, *Pangasius* catfish, freshwater prawns, mud crab, and nutrient-dense fishes such as *Mola* and air-breathing catfishes, Shing and Koi, are the primary seafoods grown in Bangladesh. All species are indigenous or have been cultivated in country for over two decades. Several contain high levels of micronutrients that can help overcome mineral and vitamin deficiencies, particularly for women and children. Outside of nutritional benefits, these seafoods are also major sources of income for the rural poor. Therefore, there is a need to enhance production of popular cultivars through sustainable methods that limit environmental impact. Bangladesh is also considered the world's most vulnerable nation to climate change (Global Climate Risk Index, 2011). Adaptive measures are needed to mitigate the impacts through promotion of species tolerant of harsh environmental conditions and elevated hyposaline environments arising from increased sea levels.

The primary Host Country site for the AquaFish research will be at Bangladesh Agricultural University. The government established BAU in 1961 as the premier agricultural institute of higher education, research, and extension that serves a similar role as land grant research universities in the US. The government heavily supports the university and its mission, which has six branches (colleges) and 43 departments covering all aspects of agricultural education and research. The university's function is to increase the quality and standard of higher agricultural education and to produce the next generation of agriculturists, scientists, and researchers needed for developing agriculture in Bangladesh. The university confers MS and PhD degrees for many agriculture disciplines, including fisheries and aquaculture. Communication, transportation, and facilities for research and extension activities are very good. Transportation to regions for on-farm trials with cooperating farms is also adequate.

Outside of on-station research at BAU, there are several aquaculture systems that will be used for the purposes of field (on-farm) trials in the rural regions of the Patuakhali district and the greater Khulna and Barisal regions of Southwest and South Bangladesh, respectively. There will also be activities carried out on participating farms located in villages of Rangpur Union, Dumuria Upazila, Khulna District, and the surrounding region. Support facilities for water quality analysis are also located at Khulna University.

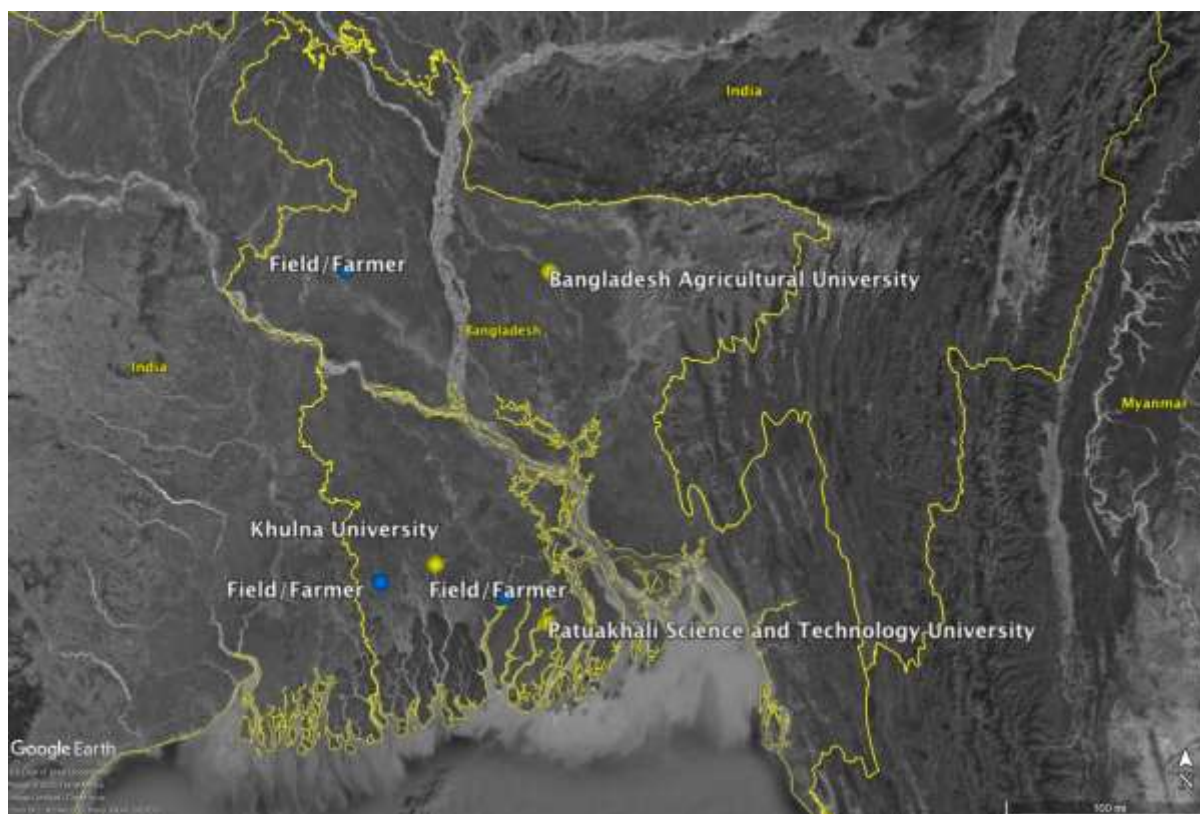
In addition to the partners at North Carolina State University located in the US, Bangladesh Agricultural University and Khulna University, other collaborating partners are located at Oregon State University in the US and Patuakhali Science and Technology University in Patuakhali, Bangladesh.

## BANGLADESH AGRICULTURAL UNIVERSITY (BAU)



*Bangladesh Agricultural University (BAU) on-station experimental ponds and the BAU water quality lab.*

### Country Map



*Map of Bangladesh indicating the location of Bangladesh Agricultural University and Khulna University. Additional support facilities (yellow) and on-farm trial locations (blue) are also included.*

### **General Location**

The primary Host Country site for the North Carolina State University (NCSU) project is Bangladesh Agricultural University (BAU). The BAU campus is located near Mymensingh, a city in the north-central region of the country, which is about 120 km (75 mi) north of Dhaka, the capital of Bangladesh. BAU is located on the western bank of the old Brahmaputra River, 5 km south from Mymensingh Railway Station.

### **DESCRIPTION OF AREA/REGION**

#### **Climate**

Mymensingh and the rest of Bangladesh are considered tropical wet and dry climate (Aw) under the Köppen climate index. It is generally cooler than Dhaka due to the close proximity to the Himalayan mountains. The cooler dry season ranges from November to February, and the monsoon season starts in May or June and continues until August, when it rains heavily and continues sometimes for days and even weeks.

#### **Temperature**

The average temperature ranges from 18 °C in January, increases to around 28 °C from April to October, and then steadily declines to an average temperature of around 20 °C in December.

#### **Precipitation**

The amount of rainfall is very high in Bangladesh because of its location in the tropical monsoon region. The winter season is very dry and accounts for only 2 – 4% of the total annual rainfall. Rainfall during the rainy season is caused by the tropical depressions that enter the country from the Bay of Bengal. These account for 70% of the annual total in the eastern part, 80% in the southwestern part, and slightly more than 85% in the northwestern part of Bangladesh. The amount of rainfall in this season varies, from 1,000 mm in the west central part to more than 2,000 mm in the south and northeast. Average rainy days during the season vary from 60 days in the west-central part to 95 days in the southeastern part and more than 100 days in the northeastern part. Overall average rainfall is 11 mm in January during the dry season and peaks to almost 500 mm in July during the monsoon.

#### **Humidity**

In the eastern areas, the lowest humidity occurs from January to March. The relative humidity peaks to around 80 – 85% from June to September. The average relative humidity for the whole year is 70 – 78%, depending on location.

#### **Seasonality**

Mild winter (October to March); hot, humid summer (March to June); humid, warm rainy monsoon (June to October)

#### **Topography**

Mostly flat alluvial plain; hilly in the southeast

#### **Soil and Water Data**

The soil is mostly alluvial and somewhat deltaic toward the south, sandy to silt/clay.

## Layout of the Site



BAU On-Station  
Experimental  
Ponds

*Experimental ponds at Bangladesh Agricultural University (BAU)*

### DESCRIPTION OF SITE

#### Map Coordinates

24° 43' 31" N, 90° 26' 8" E

#### Elevation

205m

#### General Background

The government established BAU in 1961 as the premier agricultural institute of higher education, research, and extension, and it plays a similar role as the land grant research universities in the US. The main task of BAU is to increase the quality and standard of higher agricultural education needed to produce the next generation of agricultural teachers, scientists, extension agents, and entrepreneurs. It is a residential university mandated to offer higher education and research in agriculture, including conducting examinations, conferment of degrees, and granting affiliation. The partnership between AquaFish and BAU is ideal for building capacity in the aquaculture and fisheries sector and for development of sustainable aquaculture practices that can enhance the food security and welfare of the people of Bangladesh. The university has the needed infrastructure, experience, and expertise to carry out productive research. There are 100 research ponds in the Fisheries Field Laboratory of BAU, for which 27 ponds will be dedicated to AquaFish activities. BAU also has a water quality and pond dynamics laboratory, nutrition laboratory, pathology/microbiology laboratory, and other facilities for undertaking research of international quality.

#### Water Supply

The BAU Fisheries Field Laboratory has a reliable year-round supply of water for culturing fish derived from groundwater pumped from deep tube wells and is supplemented with rainwater during the monsoon. The ground water is clean and has a neutral pH.

#### Soils

The soil is mostly alluvial and some deltaic toward the south, sandy to silt/clay.

### Support Facilities

Khulna University is a public university in Southwest Bangladesh. The Fisheries and Marine Resources Technology (FMRT) Discipline was established in 1992 with a mandate to establish an avenue for research and academic programs in all aspects of fisheries. The university is situated at Gollamari, Khulna, Bangladesh, by the river Moyur, beside the Khulna-Satkhira Highway. The teaching staff of the FMRT Discipline possess specialized knowledge in the areas of fish biology, marine science, aquaculture, fisheries management, genetics and fish breeding, ecology, oceanography, and post-harvest technology. Present research-oriented laboratories include a water quality lab, aquaculture nutrition lab, fish microbiology lab, fish genetics and biotechnology lab, and post-harvest and fish-processing lab. Some of the basic water quality analyses from on-farm trials in the region will be conducted in the FMRT water quality lab.

### Primary Affiliations

<i>In-Country</i>	<i>US</i>
Bangladesh Agricultural University Department of Fisheries and Management Mymensingh, Bangladesh	North Carolina State University Department of Biology Raleigh, North Carolina, US

### Current Contacts

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# AUBURN UNIVERSITY



## AQUACULTURE DEVELOPMENT IN KENYA AND UGANDA: ADVANCING COST-EFFECTIVE TECHNOLOGY, MARKET ASSESSMENT, AND END-USER ENGAGEMENT

### UGANDA

*(Information provided by Dr. Joseph Molnar, US Project PI, in 2013)*

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Uganda is located in the East African region (1 00 N, 32 00 E) along the equator line. It is a landlocked country bordering South Sudan in the north, Democratic Republic of Congo in the west, Rwanda in the southwest, Tanzania in the south, and Kenya in the east. Its surface area is 241,038 km<sup>2</sup> and the area under water (permanent and seasonal) is 43,938 Km<sup>2</sup> (~18% of total area). Kampala is the capital and political city of Uganda.

Uganda is a developing country in the sub-Saharan Africa region with a gross domestic product ranging 4 – 6% that is driven by public investment, agricultural output, and a conducive manufacturing environment. This economic growth has improved lives of many Ugandans, with households living in poverty declining from 24.5% (2010) to 22% (2013). Literacy levels were 73.2% for the total population with males at 82.6% and females at 64.6% in 2010. However, with a per capita income of US\$506, Uganda remains a very poor country with the majority of its non-poor population classified as vulnerable. The country is still off track on several millennium development goals for example, on health related services and the universal primary education. Nonetheless, there are signs of economic recovery with growth rates from 3.4% in 2012 to 5.8% in 2013, and most importantly the heavy rains experienced during the second half of 2013 are likely to lead to increased agricultural production.

Uganda's is about 30% arable land with a tropical climate; rainy with two dry seasons (December to February, June to August). The agricultural sector grew at 2.6 % in 2009 but these rates are below Uganda's population growth rate of about 3.2% per annum indicating a low per capita agriculture production. This is below the target rate of 6% per annum that was agreed by the African Union in Maputo, Mozambique, in 2003 under the Comprehensive Africa Agriculture Development Program (CAADP). Uganda Government is currently mobilizing farmers and increasing investments in agriculture through the Agriculture Sector Development Strategy and Investment Plan (DSIP), which will effectively reduce poverty in Uganda.

The Fisheries sector employs over 300,000 people with up to 1.2 million depending on resource for income and livelihood (PEAP, 2004). Through the DSIP intervention, fish production is expected to increase from 420,000 MT in 2009 to 530,000 in 2013, mainly through participatory management of natural water resources and intensification of aquaculture.

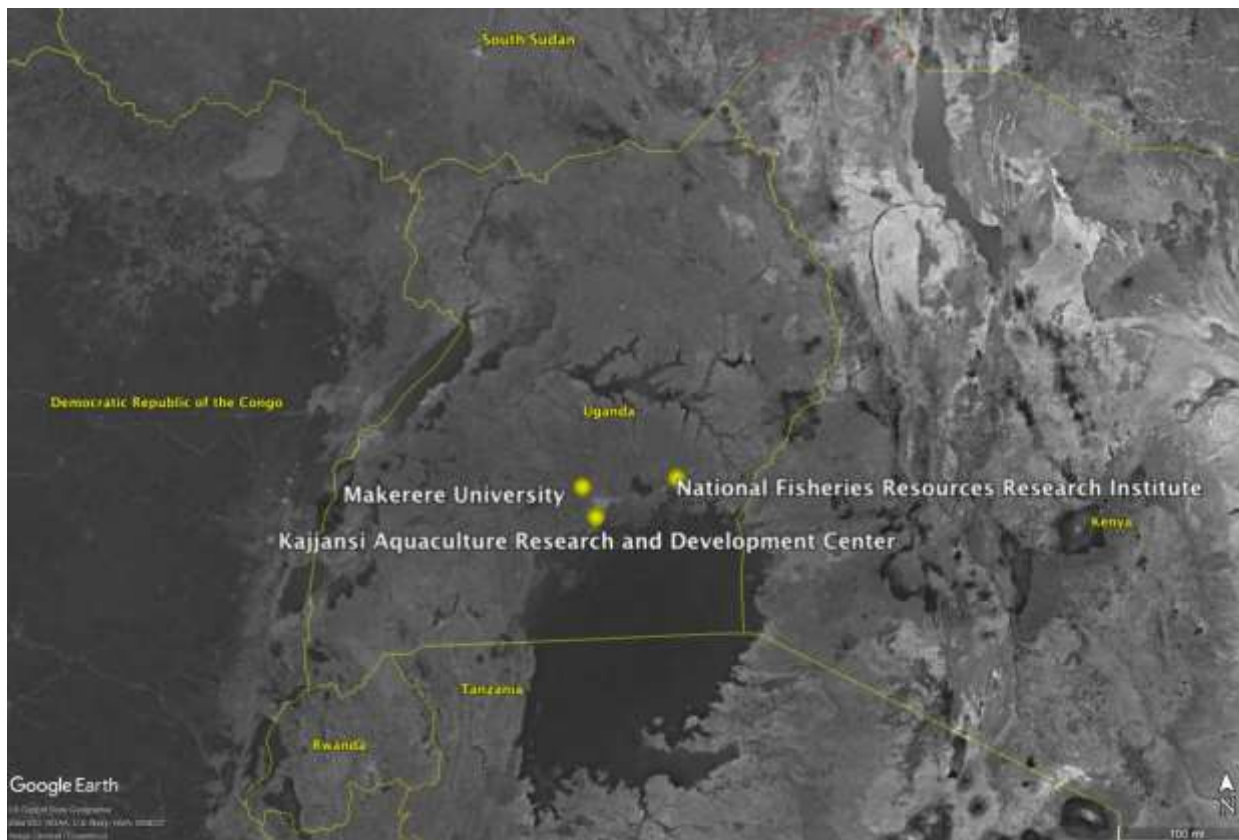
Aquaculture started in Uganda in 1953 (Balarin, 1985) when levels of kwashiorkor among children in the Central (Buganda) region were high. The Fisheries Experimental Station (now the Aquaculture Research and Development Center, ARDC) was therefore established in 1953 to develop appropriate technologies for fish production at subsistence levels in rural households. Until the late 1980s, fish farming was largely practiced by small-holder farmers whose prime objective was to ensure food security at subsistence level. From 2000, the demand for fish increased while fish stocks reduced and aquaculture production began to transform into a viable alternative for income, gainful employment, and food security. Hence, Uganda government policy promoted the commercialization of aquaculture.

The primary Host Country site for AquaFish research will be at the ARDC in Kajjansi and is described in greater detail below. This facility is under the National Fisheries Resources Research Institute (NaFIRRI)

which is a public research institute of the National Agriculture Research Organization. Being centrally located in the African great lakes region, ARDC is well positioned to serve as a hub for aquaculture research and development in the region. The ARDC-NaFIRRI-Kajjansi is within Wakiso District has conducive climatic and soil/vegetation for aquaculture production. The ARDC has 52 concrete tanks (49 – 60 m<sup>3</sup>), 51 earthen ponds (1100 – 3000m<sup>2</sup>), a hatchery, and laboratories (fish nutrition, water quality and fish health).

In addition to partners at Auburn University located in the US, collaborating partners on the Uganda projects are located at Alabama A&M University and Oregon State University in the US, as well as Makerere University and the Fisheries Training Institute in Uganda.

#### Country Map



*Map of Uganda indicating the location of the Kajjansi Aquaculture Research Development Centre, the National Fisheries Resources Institute, and Makerere University.*



**DESCRIPTION OF SITE****Map Coordinates**

0°13'19.1" N, 32°32'04.9" E

**Elevation**

1,190 m

**General Background**

ARDC is the largest and only research center in Uganda charged with developing technologies and information through research to improve aquaculture production and guide stakeholders in planning, investing, and developing aquaculture. ARDC is the national center responsible for aquaculture research and development and is a branch of NAFIRRI and is comprised of two locations: The main offices and ponds are located on about 49 acres, and the staff houses are one kilometer away on about two acres.

**Water Supply**

The main source of water is the Kajjansi River, but the center also is served by the National Water and Sewerage Cooperation.

**Soils**

Ferralitic

**Support Facilities**

Plan to work with Makerere University colleagues affiliated with the Nutrition Innovation Lab to plan and program a conference.

**Primary Affiliations***In-Country*

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Makerere University  
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*US*

Auburn University  
Department of Agricultural  
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**Current Contacts***In-Country*

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## KENYA

(Information provided by Dr. Joseph Molnar, US Project PI, in 2013)

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The Republic of Kenya lies astride the equator on the Eastern seaboard of Africa. It covers an area of approximately 582,600 km<sup>2</sup> of which 133 km<sup>2</sup> is water. Land use in Kenya is described in terms of ecological zones (I – VI), which are derived from a combination of climate, soil, topography, and vegetation type. Most land is either of high, medium, or low agricultural potential, depending on the ecological zone. Agricultural land use falls into two categories: either high-to-medium or low potential according to the amount of rain received and rates of evapotranspiration.

The high-to-medium potential arable areas are 26% of total humid to sub-humid areas that receive 75 – 1400 mm of rainfall. The low potential areas (74% of the total) are marginal agricultural lands where rainfall is unreliable and is often less than 750 mm. In the absence of irrigation or water conservation, they are suited only to livestock raising. The high-to-medium agricultural potential areas support 80% of the total human population (~33 million in 2007) while the remaining 20% live in the low potential areas (arid and semi-arid zones).

The government of Kenya development policy has always focused on alleviating poverty through increased food production and minimizing environment degradation. Consequently, a major priority development need of the government has been trying to introduce low-cost aquaculture, which will increase available protein to local communities. Mixed-sex Nile tilapia culture represents over 75% of fish produced through aquaculture. Polyculture of Nile tilapia and catfish produce about 15% of the national aquaculture production. Until year 2000, aquaculture in Kenya had stagnated at an annual production of around 1,000 tonnes. Since 1999, however, through consistent efforts in on-farm research and training, Kenya's aquaculture production has risen and is currently at about 3,500 tonnes. The focus is now on encouraging the development of private, commercial large-scale aquaculture, which is likely to increase Kenya's production to about 12,000 tonnes in the next three years. This development follows the efforts of the Department of Fisheries with development partners such as AquaFish to promote aquaculture as one of the means to eradicate poverty and hunger. During the preparation of the Poverty Reduction Strategy Paper in 2000, the Government identified aquaculture development as a core activity for funding through the current Medium Term Expenditure Framework Budgeting System. The period from 2000 until now has been marked by aggressive research, training and private sector involvement in aquaculture. Production in real terms has doubled and is set to grow by over 1,000 percent (ten times) in the next three years. The prevailing conditions combine good prices and high demand, which are likely to boost fish production from aquaculture.

Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) are the principal aquaculture species in Kenya and the region and are well adapted to local conditions. Other species include the air-breathing lungfish (*Protopterus ethiopicus*), ninju (*Labeo victorianus*), and other endemic fish species.

Tilapia species form about 90 percent of farmed fish in Kenya. Polyculture of the Nile tilapia (*Oreochromis niloticus*) with the African catfish (*Clarias gariepinus*) is often practiced to control the prolific breeding of the former and increase production per unit area. Aquaculture takes many different forms ranging from the small hand-dug 'kitchen ponds', to fairly large earthen ponds of 1,000 m<sup>2</sup>. Dams and other impoundments of stored water are often stocked with fish and harvested periodically. Aquaculture practices include the intensive, semi-intensive, and extensive systems. The semi-intensive systems form the bulk of aquaculture production in Kenya, contributing more than 70 percent of the total production from aquaculture. Intensive systems are few, while hyper-intensive systems are being set up and are projected to contribute as much as 90 percent of all farmed fish in Kenya by both volume and value.

Although there are many features of the Lake Victoria Basin, which are of interest to biologists, it is the fish that receive the most attention. The cichlids (including the Nile tilapia) in particular have had a remarkable burst of speciation in response to the environmental changes that have taken place in the basin and on Lake Victoria. One of the main events of importance to the Lake ecosystem in the past thirty years was the introduction of new species such as the Nile perch into the Lake. It is also important to note that the size of the fishery exploded from 1978 on, perhaps, a factor of five or more resulting from this introduction. Physical interferences, environmental degradation and change in land use have reduced fish catches, Aquaculture would therefore be a logical step in restoration of populations of selected and threatened species, improve fish supply to local riparian communities, return of delicacies to consumer markets and improved livelihood to fish traders and fish farmers.

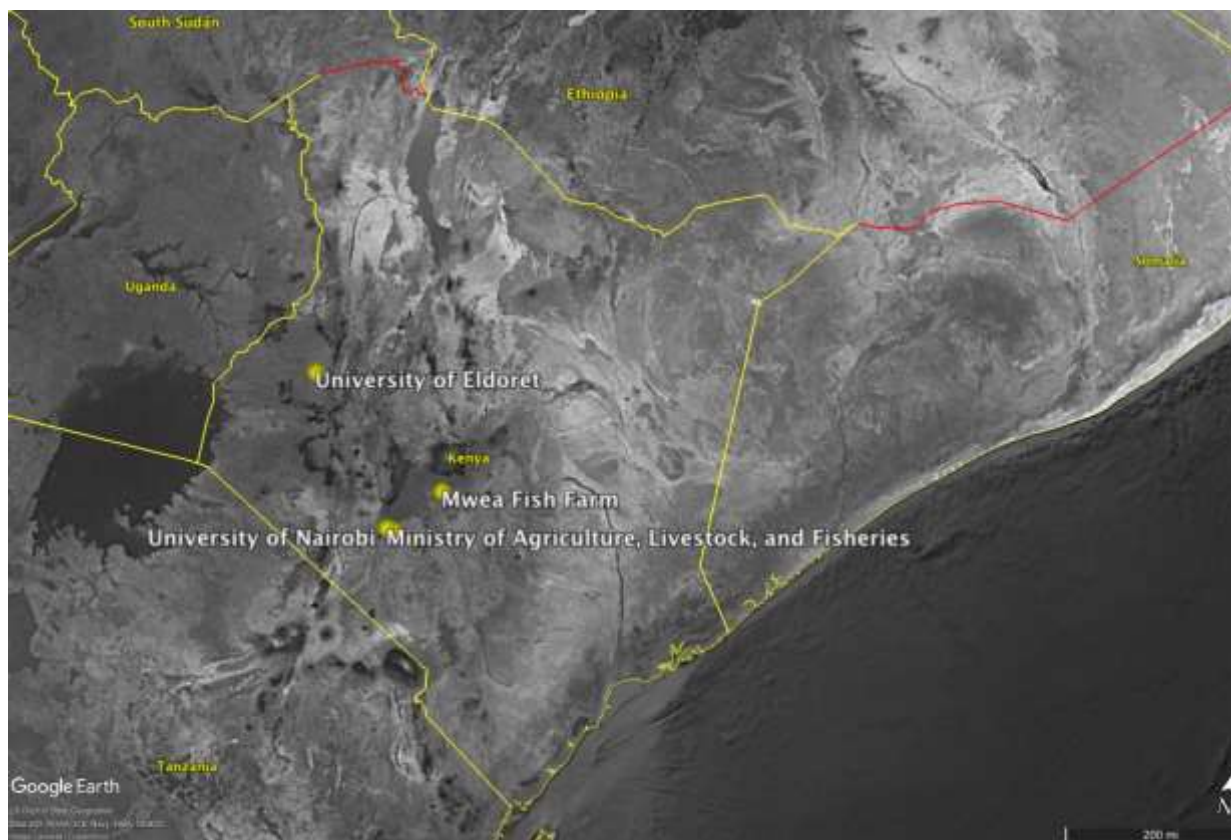
Fish farmers could diversify their fish production to serve as baitfish for Lake Victoria and avail basic human food for local and distance markets. The demand for catfish fingerlings is projected to grow further as the aquaculture potential of the Lake Victoria Basin is deemed enormous considering its water resources the geographic characteristics of the basin, demographic trends, fish eating culture and declines in Lake Victoria capture fisheries productivity. The domestic market for Nile tilapia is quite promising. Prices are high in major cities and other parts of the country. The major towns surrounding the aquaculture production centers constitute assured markets.

Aquaculture development among rural households with limited resources remains a challenge. The rural poor face many constraints to entry into aquaculture farming and subsequent adoption of improved technologies and management practices. Among others, availability of startup capital, operational resources, and reasonable prices are important in order to adopt, operate, and sustain improved fish farming practices and produce quality fish. Most developing projects are more concerned with increased production of fish. Producing more fish does not necessarily imply profitability of the fish farming business. Economic analysis is an important management tool necessary for business planning, seeking financial assistance from formal institutions, and identifying economically sustainable enterprises.

The primary Host Country sites and facilities for AquaFish research are the University of Eldoret and the Mwea Fish Farm, which will individually be described in more detail below. In addition to these two primary sites, another additional support facility includes the University of Nairobi located in Nairobi, Kenya.

In addition to partners at Auburn University in the US and the University of Eldoret, other collaborating partners are located at University of Arizona and Oregon State University in the US and the Ministry of Agriculture, Livestock, and Fisheries in Kenya.

## Country Map



*Map of Kenya indicating the location of the University of Eldoret, Mwea Fish Farm, the of University of Nairobi, and the Ministry of Agriculture, Livestock, and Fisheries.*

## UNIVERSITY OF ELDORET

### **General Location**

The University of Eldoret Aquaculture research facility is located 12 km outside of Eldoret Town, along the Eldoret-Ziwa-Kitale road.

### **DESCRIPTION OF AREA/REGION**

#### **Climate**

Tropical along the coast and arid inland

#### **Temperature**

The highest temperatures occur in March, and the lowest occur in July. The daily average varies between 16 – 22 °C. The cool season average varies between 13 – 19 °C. The warm season average varies between 17 – 25 °C.

#### **Precipitation**

Rainfalls average about 1223 mm. Rains are unimodal and fall from March to September. The “long rains” fall from March through May, with a single-month peak of 500 mm or more in April.

#### **Humidity**

Humidity in the highland region surrounding the campus ranges around 40 – 90% in the afternoon during the dry season and between 50 – 60% in the rainy season.

### Seasonality

There is a distinct cool season between June and August, when rainfall is at a minimum. Even though there is little rain, the skies tend to be overcast much of the day during this period. A rainy period known as the “short rains” occurs between October and December.

### Topography

The ponds are located on a gently rolling region that tapers into well-vegetated wetlands characterized by papyrus reeds and other aquatic macrophytes.

### Geology/Soils

Soils are igneous in origin and underlain by tertiary volcanic rocks (phenolites) characterized by low natural fertility. The soils in this region are acidic with soil pH ranging from 5.5 to 6.4. They are red friable over petroplinthite and are classified as rhodicferralsols. Clay content averages 30%, and the soils have a high water holding capacity. The area is characterized by brown loamy soil, and soil structures are mostly granular, indicating low water seepage due to small soil pores.

### Soil and Water Data

Water supply to the ponds is from a 1.2 ha spring-fed reservoir and is supplemented by municipal main water supply when necessary. Ponds were designed according to FAO recommendations with features such as inflow by gravity, drains with adjustable pipes, sloping sides, and a drainfield that intercepts effluent in a *Cyperus papyrus* swamp prior to entering the receiving water body.

### Layout of the Site



*Aerial photograph of University of Eldoret Aquaculture production and research facility*

### DESCRIPTION OF SITE

#### Map Coordinates

0°03' and 0°55' N, 34° 50' E

#### Elevation

2180 m

#### General Background

The University of Eldoret Fish Farm is operated by the Department of Fisheries and Aquatic Sciences, which is housed in the School of Natural Resource Management. Students from the university and several other institutions conduct field studies at the farm. Considerable attention was given to both the design and future operations of the fish farm. The main facilities are comprised of a hatchery, quarantine unit, and fish

ponds alongside supporting facilities of a seminar room, laboratories, workshop, and offices. Supplies of fertilizers, chicken feed, and feed ingredients, such as rice bran, are generally readily available, at least in Eldoret town.

The university offers MS and PhD degrees in Fisheries with an Aquaculture option. The university also offers a BS in Fisheries and Aquatic Sciences, a two-year diploma in Aquaculture and Fisheries Management, and other short courses in aquaculture. The university's fish farm has an area of about 10 ha, of which 5 ha are ponds. There are 47 fish ponds of various sizes, ranging from 100 m<sup>2</sup> to 0.2 ha in size. It was designed to fulfill a number of roles:

- To be a practical facility in support of fisheries students studying aquaculture;
- To act as a demonstration unit to promote the potential of freshwater fish farming to community leaders, government officials, extension workers, and entrepreneurs (to be achieved through practical training courses, visits, "open days," and the dissemination of information);
- To serve as a Regional Centre of Excellence for research into appropriate aquaculture methods and for the development and assessment of equipment, feeds, and husbandry practices, including economic evaluations of production methods;
- To function as a supplier of juvenile fish to farmers in the region in order to generate local revenue and assist fish farming development;
- To provide applied research opportunities for faculty members and visiting scientists.

#### **Water Supply**

Water supply to the ponds is from a 1.2 ha spring-fed reservoir, with a municipal supply providing supplemental water as needed.

#### **Soils**

Soils are igneous in origin and underlain by tertiary volcanic rocks (phenolites) characterized by low natural fertility. The soils in this region are acidic with a pH range of 5.5 – 6.4. They are red friable over petroplinthite, classified as rhodicferralsols, average 30% in clay content, and have a high water holding capacity. The area is characterized by brown loamy soil oil structures are mostly granular, suggesting low water seepage due to small soil pores.

#### **Support Facilities**

The experimental feeds will be tested for stability in water and proximate analysis at the University of Nairobi located in Nairobi, Kenya.

#### **Primary Affiliations**

<i>In-Country</i>	<i>US</i>
University of Eldoret	Auburn University
Department of Fisheries and Aquatic Sciences	Department of Agricultural Economics and Rural Sociology
Eldoret, Kenya	Auburn, Alabama, US

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## MWEA FISH FARM



*The Mwea Fish Farm in Kirinyaga County*

### **General Location**

Mwea Aquafish Farm is in Kirinyaga County, on the slopes of Mount Kenya. It is 110 km northeast of Nairobi on the Nairobi/Embu road and 1.5 km from Kimbimbi town and can be accessed throughout the year through a good all-weather road.

### **DESCRIPTION OF AREA/REGION**

This is a model fish farm where Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) are raised in earthen liner ponds and concrete tanks. It began in August 2009 on 3.5 ha of agricultural land. Initially, most ponds (measuring 300 m<sup>2</sup>) were constructed on sandy/loam/clay soils.

### **Climate**

TropTropical wet-and-dry with distinct dry and rainy season

### **Temperature**

The annual average maximum temperature is 28 °C with peaks in July, August, January and February, and with an average annual minimum temperature of 15 °C.

### **Precipitation**

The average annual rainfall at Mwea Experimental farm it is 890 mm (over 12 years).

### **Humidity**

Humidity ranges from 90% in early morning to 40% in the afternoon. Monthly averages of (pond-side) humidity are 63% in October and 79% in July.

### **Seasonality**

The warmest period occurs between February and April. There is a distinct cool season between June and August, when rainfall is at a minimum. Even though there is little rain, the skies tend to be overcast much of the day during this period. A rainy period known as the “short rains” occurs between October

and December. The “long rains” fall from March through May, with a single-month peak of 500 mm or more in April.

### **Topography**

1,050 m above sea level

### **Geology/Soils**

The area, like most of the Mwea volcanic plain, is underlain by the Thiba olivine basalts (a fairly uniform series of usually nonporphyritic, fine-grained gray basalts erupted from Mount Kenya), which are Pleistocene in age. Generally, the soils vary from reddish brown clays on ridges and upper slopes through very dark grayish brown clays on lower slopes to dark brown to very dark grayish brown compact clays in depressions. Also found are stony and gravelly soils.

### **DESCRIPTION OF SITE**

#### **Map Coordinates**

0°36.73' S, 37°22.84' E

#### **Elevation**

1,050 m

### **General Background**

Mwea Aquafish Farm produces about 100,000 Nile tilapia fry per month (or 1.2 million annually). This level is maintained for three years, with the hope that production will increase to 200 million fry produced annually after five years. To sustain this production, it is estimated that 200 females stocked will each produce 200 eggs each per spawn. The farm also maintains 3,000 African catfish brooders, a high-quality breed. Survival is usually low and to sustain production at 100,000 per month, the farm continues to hold 3,000 brooders (2,000 males and 1,000 females).

The farm integrates livestock with fish and crops with fish. The farm grows quality bananas, vegetables, and root crops alongside fish. Ponds serve as water storage structures and, as such, become a key asset of water supply to crops. Waste accumulated in pond as sludge is pumped, when draining a pond, into vegetable gardens to increase vegetable production. The farm operates a zero-discharge water policy and any water due for release is pumped back into the farm to irrigate crops. The farm has a classroom that can sit 40 – 50 students/farmers.

The hatchery has both Nile tilapia and catfish breeding units. It houses a conference room and a laboratory. This is an excellent facility for research and quality seed production. Annexed to the hatchery is a recirculating aquaculture facility, which runs on an 80 m<sup>3</sup> water holding tank feeding into 8 hexagonal rearing tanks, each holding 500 Nile tilapia, weighing about 150 g. The production capacity of each tank, which hold a volume of 20 m<sup>3</sup>, is 1,000 kg tilapia in a year, or two cycles of 500 kg per cycle.

### **Water Supply**

There are three water sources that supply the farm. The primary water source is the Nyamindi, a tributary of the Sagana River. A secondary water source is water pumped from three large reservoirs that were established next to a small stream that runs past the lower part of the farm. A third water source is a Borehold that extends 85 meters into the ground that discharges water at a rate of about 20 m<sup>3</sup> per hour; however, the farm is only pumping about 6 m<sup>3</sup> of water per hour from this source.

### **Support Facilities**

Students from the University of Nairobi, Moi University, and several other institutions conduct field studies at Mwea.

### **Primary Affiliations**

#### **In-Country**

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#### **US**

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