APPENDIX A: TASK SHEET FOR THE IAP 2027 PRACTICAL FIELD LAB IN NYERI, KENYA

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WHY FISH?

In 2024 the Practical Field Lab (PFL) directors scoped out central Kenya and identified aquaculture as a rapidly growing economic and land-use activity in the highlands and semi-arid regions of Central Kenya. The area concerned lies in Nyandarua, Nyeri, and Meru counties and is primarily Kikuyu-speaking. Constituting two-thirds of Kenya's landmass, it is severely impacted by climate change and dietary-induced non-communicable diseases (obesity, diabetes, and high blood pressure).

Historically, pastoralism has been the economic mainstay of Northern Kenya communities and the main source of meat consumed by Kenya's urban populations Recurrent droughts are decimating livestock herds, the unusually heavy rainfall leaving floods and crops failures in its wake. Warming temperatures on Mount Kenya are causing rapid glacial retreat, with projections suggesting glaciers could completely vanish before 2030, a decade earlier than elsewhere in Africa, accelerating reduced dry-season river flows, resulting in >30% drop in river water levels.

Meanwhile, NCDs (non-communicable diseases) like obesity, diabetes, and hypertension are claiming 40% of Kenya's adult lives annually, most severely in cities, characterized by sedentary lifestyles, less physical exertion, and high-calorie diets.

We chose fish because it is threatened by climate change on one hand and is a strong weapon in preventing NCDs. The demand for three terrestrial fish—tilapia, catfish, and trout—is rapidly growing and unmet by production as Kenyans become nutritionally and medically aware of the risks of high calorie and bad cholesterol. Significantly, Africa has exceeded its harvests from rivers, dams, and oceans and is a net fish importer.

THE TASK

The students will build a unique circular production system integrating aquaculture and agriculture, in which by-products from one process are inputs in another.

OBJECTIVE

Students will learn how to build solutions to climate and viability threats standing in the way of Kenya's freshwater fish farmers becoming frontline soldiers in combating obesity, high blood pressure, diabetes, and lifestyle-related cancers.

METHODOLOGY: "TASK GROUPS"

Students will build their solutions with and upon the innovations of farmers engaged in mixed agriculture and aquaculture. They will be placed into 7 task groups composed of up to 4 DeKUT, 2 Technical, Vocational Education and Training institutions (TVETs), and 2 MIT students, working and teams of instructors composed of MIT, DeKUT, and TVET faculty, and practicing fish farmers or their designates.

TASK SHEETS

Each task group will be handed a task sheet outlining: 1) The problem it must solve 2) Farmers' ideas or efforts at solving the problem, and 3) The task/assignment the group must execute to pass the PFL.

PFL SITES

All activities will be conducted on fish farms, selected for their owners' innovative solutions to aquacultural challenges. Each of the sites mutually reinforces learning-by-doing attributes of the other. It is the students' assessed task to build upon and add further capacity to those innovations. The PFL sites have been selected because of their uniqueness in innovating at the very edge of survival to obtain the most from limited resources. The sites have demonstrated ways of overcoming environmental, energy, and social challenges.

BRIEF OVERVIEW OF TASK GROUPS

1. THE SCIENCE, TECHNOLOGY, AND SOCIETY GROUP

Problem: There is a danger of science names and jargon contributing to Africans abandoning their self-invented idioms and equipment and the comfort and confidence they lend to their innovative spirit, while adopting entirely alien(ating) idioms and tools of science from other cultures. The local histories, cultural beliefs, cuisines, diets, preservation techniques (salting, drying, smoking), etc. constitute firm foundations for understanding the place of fish among the Kikuyu, who historically did not eat fish but cattle.

Farmers' Science and technology: Farmers are smoking, drying, cooking, farming, harvesting, and creating spaces for fish by fusing ancestral and European traditions. They constitute historical foundations upon which to build ethical and culturally cognizant approaches to fish farming and the values to be attached to incoming technology such as AI and its applications.

Task 1: To work closely with these farmers—all of them indigenous knowledge practitioners—to record, archive, and train locals (through doing) how to store, access, and protect their ancestral and everyday fish knowledges and practices. The group will therefore serve as the advisory group on historical and cultural perspectives to structure every task group's assignment.

Task 2: Document indigenous histories of fish cuisine, diets, fishing, and post-harvest processing as critical resources for innovations in fish farming and post-harvest value addition. Notably: simply because fish lived in rivers does not mean the river was "wild" (untamed) and not a fish farm. Among others, the task group will focus on fish harvesting methods, preservation techniques, extracts, uses of non-eaten parts of fish, rivers/ponds as crop-fields.

2. THE WATER TEMPERATURE GROUP

Team 1: Artificial Heating (Tilapia and Catfish)

Problem: Pond water too cold and polluted to sustain tilapia and catfish farming at all stages from hatchery to point of sale. Fish larvae and fry are highly sensitive to water temperature and

quality, while warm water species like tilapia and catfish experience stymied growth under cold water conditions, and trout dies quickly.

Farmers' Solution: 1) Growing tilapia in greenhouses to raise the water temperature in ponds utilizing harvested rainwater, recycled to overcome dry winter scarcity.

Task: a) Build and deploy an AI-augmented thermostat system for regulating the greenhouse pond water temperature for tilapia and catfish fish; and b) photovoltaic-solar and biogas heated catfish hatchery in which the water temperature remains within a narrow range suitable for fry and adult tilapia and catfish.

Team 2: Artificial Cooling (Trout)

Problem: Trout can only grow in cold, flowing water and is hyper-sensitive to 1) warm and 2) polluted water.

Farmers' Solution: None so far

Task: Build and deploy 1) sensors and systems to measure turbidity and temperature on mobile devices in real-time and 2) artificial water-cooling systems (chillers) ideal for smaller operations.

3. THE WATER QUALITY GROUP

Problem: The gases that impact fish health are dissolved oxygen (O_2) (essential), carbon dioxide (CO_2) from fish breathing, ammonia (NH_3) from decomposing organic waste, hydrogen sulfide (H_2S) and methane (CH4) from mud/sludge, and nitrogen ($_2$). Other than oxygen, all these gases suffocate or poison the fish.

Farmers' solution: Growing duckweed on the pond edges to removing urea and ammonia. Duckweed can grow to double its volume in 48 hours.

Task: Build and deploy a) sensors and systems to measure, gather, and transfer data on dissolved oxygen, ammonia, and pH for real-time display on mobile devices; and b) automated pond water cleaning and recirculating system based on the unique capacity of duckweed to rapidly remove large quantities of urea and ammonia. The system will be applied in tilapia and catfish, and the duckweed will be harvested for fish feed production.

4. THE LUNGFISH GROUP

Problem: Climate change is driving indigenous fish species into extinction. There are, however, species like lungfish that adapt to climate change by hibernating during extended dry seasons. In 2025 the PFL started an experiment of catching and breeding them under pond conditions and releasing offspring into natural water reservoirs. The challenge: high mortality due to the fish's sensitivity to even the slightest changes in habitat.

Farmers' Solution: N/A: farmers are too busy dealing with production challenges to save non-core fish species from climate change.

Task: Use already gathered data to build and deploy IoTs to collect, store, transmit, and analyze data about the lungfish's behavior in a controlled environment and its natural habitat.

5. THE CIRCULAR AQUA-AGRI GROUP

Problem: Lack of high quality and affordable feeds is the biggest barrier to entry into fish farming. Feeds are usually contaminated and become afflatoxic during storage, while imported ingredients exponentially drive-up costs.

Farmer solutions: The most spectacular circular aqua-agriculture innovations in rural central Kenya are happening at farm level, where byproducts of livestock and crops feed fish, and those of fish fertilize crops. Some enterprising farmers are: 1) pelletizing feed from their farm produce, but affordable machinery is a serious challenge. They also have no capacity to test materials that could replace expensive and imported ingredients; 2) growing insects like black soldier flies (BSF) and aquatic plants like duckweed, azolla, zooplankton, and leaf vegetables (spinach, romaine lettuce, kale, bok choy, and collards) using livestock waste. However, they lack capacity to accurately detect, characterize, and quantify toxicity of liquid and gas emissions, thereby over- or under-estimating the efficacy of their methods.

Tasks: Since January 2024, a group of alumni from the PFL pilots have successfully completed the design-build of a farm-scale pelletizer. The group will 1) Test-run the machine and manufacture 6 months' supply of tilapia, catfish, and trout feed 2) Develop and commission an IoT system to accurately detect, characterize, and quantify toxicity of liquid and gas emissions, and 3) Develop and commission a portable system for scientifically testing prospective feed ingredients for purposes of import substitution.

6. THE RENEWABLE ENERGY SOLUTIONS GROUP

Problem 1: Electricity: Africa loses 40-50% of produce each year to rotting in storages or at marketplaces. While farmers have refrigerators and a highly efficient *matatu* (public transport) courier system to deliver orders to customers, the major problem is electricity to power farm refrigeration and by extension pelletizers. The entire operation is dependent on erratic grid electricity prone to load-shedding.

Farmers' Solution: Farmers have refrigeration but no electricity to power it.

Task: Design and install low-cost off-grid solar energy to supplement or replace grid.

Problem 2: Water Heat: How then to heat water and maintain temperatures favorable to fry and adult warm water fish?

Farmers' solution: Use LPN gas, but it is very expensive.

Task: Build and commission a bag biogas plant using a combination of biomass materials and cow dung. It must be equipped with a tamper-proof air quality monitor to detect, meter, and monitor sulfur, a toxic emission harmful to humans and animals. It should also incorporate in the bio-digester an auxiliary system for foliar fertilizer/bio-pesticide manufacturing.

7. THE HATCHERY GROUP

Problem: The "fingerling problem" in Africa is a critical bottleneck in the aquaculture sector.

Farmers' Solution: Farmers are operating their own hatcheries, but heat, clean water, and no mechanism to monitor and warn of infections and temperature hazards until it is too late. Total wipe-outs of fry are common.

Task: The group will 1) learning-by-doing egg striping from females, milk extraction from males, egg fertilization and incubation process, pond cleaning and fry management; and 2) having understood the process, they will design a hatchery equipped with monitoring and early warning systems tailored to larvae and fry characteristics and detecting dangers before they happen.

8. THE FISHY BUSINESS GROUP

Problem: Small-holder fish farmers suffer three major business problems: 1) lack of technical support and training; 2) dependence on middlemen for marketing, which reduces small-holder farms' profits; 3) limited access to empathetic or patient credit; 4) Lack of value addition, with most fish sold fresh.

Farmers' solutions: 1) Farmers have relied on international non-governmental organizations' (NGO) support and their own creative resilience; the former has diminished since USAID was shut down. 2) Aquaculture cooperatives were established in the 2010s with minimum business training and discipline. They failed. 3) Credit has proven difficult to access; the few farmers still standing have survived through true grit, not credit access.

Task 1: Develop effective training and technical support, business management, marketing, and fintech strategies tailored to aquaculture.

Task 2: Create a fintech model drawing from the cooperative and indigenous models of savings like *susu*, augmented by digital banking.

Task 3: Develop a roadmap, timeline, funding, and business model for fish value addition.