WORKING TOWARDS SUSTAINABILITY: A CASE STUDY OF A TROPICAL MONTANE FIELD STATION

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Abstract: La Estación Biológica de Cuerici in the San Jose province of Costa Rica is a center for ecological conservation and biological education. The private owners have protected 200 hectares of oak and alder forest while conveying the importance of conservation and sustainability to all visiting groups. The station is funded by income from visiting student groups. The food and water networks are highly integrated into the natural environment and the surrounding human community, focusing on reuse, recycling and sustainability. The integrated systems at the station have some vulnerabilities and limitations, including dependence on a single hydropower system and current reliance on outside food sources. Despite these limitations, the station system demonstrates that a practical balance can be attained between conservation and human needs.

Key Words: sustainability, resource cycle

INTRODUCTION

Seventy years ago, the grandparents of Carlos Solano acquired land near Cuerici Mountain in the Talamanca ranges of Costa Rica. Because there was no access road to the property, the family was unable to sell timber. Instead, the family created pastures and agricultural land using slash and burn methods. They hunted animals from the mountain and raised cows. Later, after an access road was built, they began to produce charcoal from dominant tree species, such as oaks (*Quercus copayensis* and *Q. costarricenses*). In the 1970's, the Costa Rican government passed strict laws that made deforestation illegal. A farmer was required to obtain a permit for any tree removal. The family no longer had a livelihood, and his grandparents decided to sell the land as cattle pastures. Although Carlos spent his childhood catching birds and hunting tapirs, he valued the mountain forest and saw it disappearing rapidly. He decided, with the help of eight friends, to buy the land from his grandparents, along with some additional neighboring property.

With his co-owners, Carlos designed a set of laws for the land. He divided up the land for different purposes: a blackberry farm, a small cow pasture, a site for reforestation, a site for forest conservation, and residential space. He preserved riparian buffers by building barbed wire fences to keep cows from disturbing the vegetation near

streams and possibly contaminating the water supply with their feces. He prohibited tree cutting and the use of fire. It was not difficult to convince the small surrounding community to support fire control after a large fire in 1992 spread upslope, destroying farm crops and part of the oak forest. The fire united the citizens with a common goal of conservation. Carlos created La Estación Biológica Albergue Cuerici to save the mountain habitat in which he was raised.

Although Carlos supports nature conservation, he believes a balance between conserving nature and maintaining human needs is more important. According to Carlos, this balance entails using only what is necessary from the land. He has just enough crops to make a small profit to support his family and just enough cows and chickens to supply his family with milk and eggs. He abhors the ideas of silviculture and export agriculture as he believes that greed and exploitation destroy the forest. His life is now devoted to the sustainable use of the land.

Human land use is inevitable. However, sustainable development can allow humans and the environment to coexist healthily. We defined sustainability as a self-propagating system in which resources are provided locally and wastes are contained and recycled. Sustainable living is especially important in the rain forest, where biodiversity is high but is potentially decreasing due to rapid deforestation (Evans 1999). For example, in Costa Rica in 2005, only 7.5% of primary forest remains, and of that, 75% is privately owned (F.A.O. 2005). Carlos and other private landowners like him may become the driving force in protecting new land in Costa Rica. In 1991, Carlos built La Estación Biológica Albergue Cuerici to share his ideas of sustainability with visiting students and teachers (Fig. 1). Students come from around the world to study Cuerici's tropical forest habitat. However, when they leave the station, they take with them not only a biological understanding of the forest, but also an understanding of how people like Carlos survive and successfully conserve.

We explored the central networks of this field station. We conducted personal interviews (Solano *et al. personal communications*) and collected data on the two central resource cycles: water and food. These systems are fundamental to the station's growing resource independence. We interviewed Carlos Solano (trout farmer and station manager), Albert Torres (station administrator and friend of Carlos), Maydou Cordoba Delgado (wife of Carlos and farm manager), Elisa Cordoba Delgado (chef and

relative of Carlos), and Dacia Mena Rojas (chef and neighbor).

WATER SYSTEM

The water system at Cuerici has three main source inputs: a stream to the West, an underground spring to the West, and another underground spring to the East. Incoming water is used in the sewage system, potable water system, trout farm, and the hydroelectric station (Fig. 2). All incoming water is from high in the watershed (>2600 m), and therefore does not contain significant bacterial or toxin contamination.

Drinking Water. The underground spring to the East provides the station and the surrounding homes with all necessary water. This water comes in from the spring and immediately flows through a mesh filtering screen into a sediment tank. Within the tank, the sediment settles to the bottom and water continues through another filtration tube into a holding tank. From this tank, the water is distributed to the station and three surrounding homes that are a part of the station complex.

After water is used by the station, there are two output trajectories. Sewage water (from the toilet system) goes into a series of septic tanks. Two are needed to accommodate the volume of sewage coming from the station. Within the tanks, bacteria and other microbes decompose the organic matter. When water leaves the tanks, it travels to a rock and soil filtration system. The system is covered in plastic on the surface to prevent leaching of unprocessed organic matter. He placed the septic tank away from ground water and stream beds, and artificially raised the land at least 2 meters to increase the distance of rock and soil filtration.

All grey water (from showers, kitchen, sinks), goes directly to a separate rock and soil filtration system comparable to the system previously described. It is important that these two water outputs are kept separate because the soap and other chemicals in the grey water would drastically decrease the efficiency of decomposition in the sewage system, leading to a system backup. Each individual house within the station complex also has its own septic system.

Trout. The underground spring and the stream to the West both feed the trout farm, which currently has ca. 50,000 fish. Both the stream and spring waters are from a similar geographic location. The incubation tank directly uses groundwater, while the trout tank water comes from a stream near the groundwater system. These two water sources are kept separate both in the holding tank and all delivery tubes because eggs and hatchlings must be kept in pure spring water.

The source of the spring is covered with plastic to exclude organic matter and sediment. The incubated trout require sediment-free water because they are born with their mouths open, and any small particles in the water could cause suffocation. The spring feeds directly to the incubation tanks at approximately 0.48 L/sec. Water flow was measured by taking five measurements of the surface velocity (using a floating stick). The area of output was then calculated (width of transect and depths at 10 cm intervals were used for these calculations). Incubation pipe inputs were measured using one-liter container fill rates. We decided to quantify as many water inputs and outputs as possible to better understand water cycles of the station complex. The Western stream feeds all other trout tanks, including the four large outside holding tanks and the trout trenches (Fig. 1). Water enters the four holding tanks at a rate of approximately 8.50 L/sec.

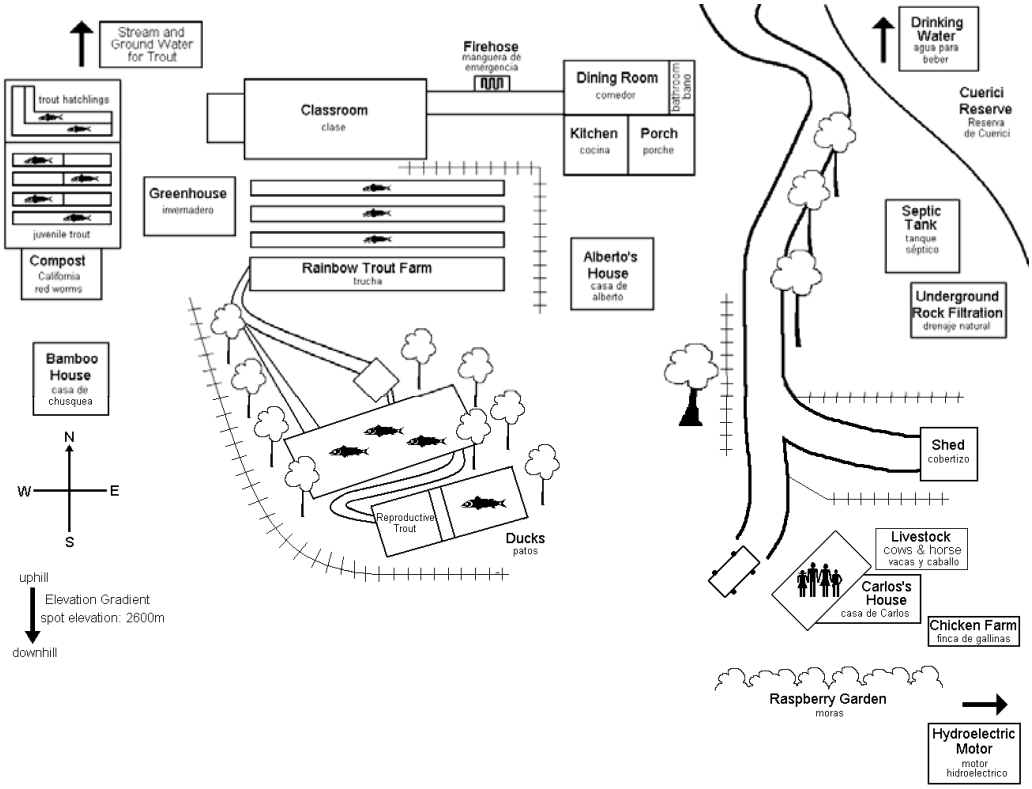

Figure 1. Map of Cuerici Biological Station and all surrounding components. This includes the station and resources used by Carlos, Carlos's daughter, and Alberto.

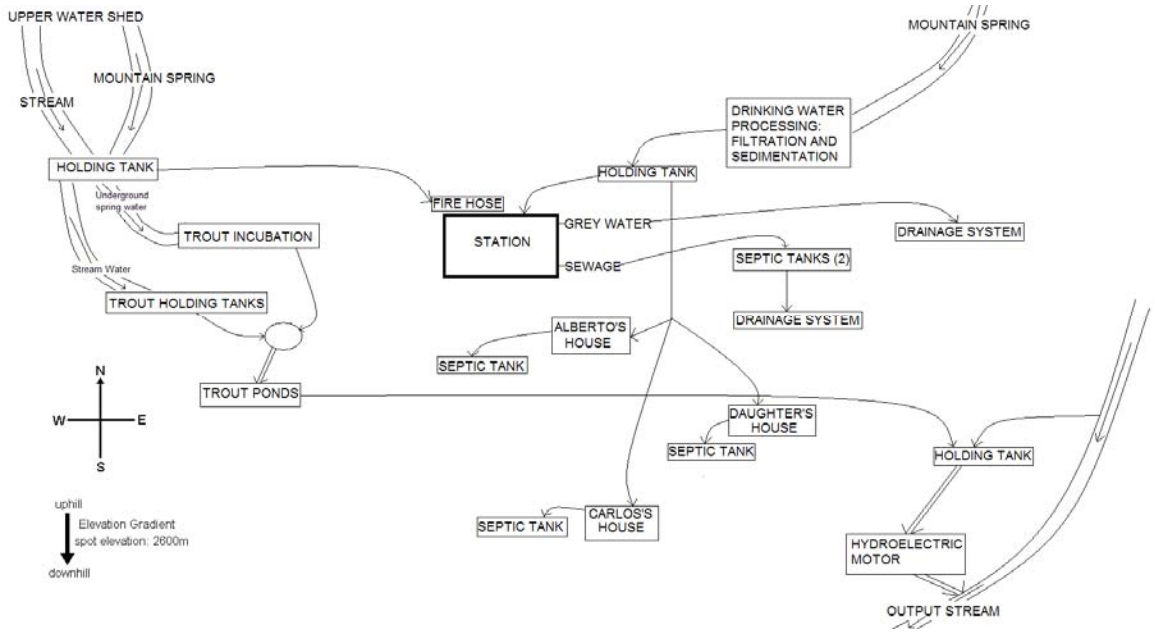

Figure 2. Map of water inputs and outputs throughout the trout farm, water delivery system, and hydroelectric pump.

Incubation begins in the pure, oxygenated spring water. Eggs experience about 50% mortality. The two main causes of mortality are suffocation from the weight of the yolk sac on the embryo and fungal infections of the egg. Although two fungicides are used by the government to control fungal infections (azul de metileno and verde malaquita), Carlos instead picks out dead, infected eggs by hand to prevent water contamination that could harm downstream aquatic cycles and aquatic organism health. This is a very time-intensive process, but is important for maintaining water quality. All incubation occurs in an enclosed room, keeping the eggs protected from outside elements.

After trout incubation, which lasts 25-30 days, the fish are moved to inside tanks, where they grow to three centimeters in length. They are then moved to one of four holding tanks for trout up to approximately four cm in length. Carlos has ca. 7500 fish in each holding tank, and most of these will be sold to other farms. Tanks are arranged by size class to minimize cannibalism of smaller trout. However, within-tank cannibalism still occurs frequently. Small trout (2-4 cm) also die easily during transferring and sorting. Total mortality of small trout is roughly twenty percent. Tanks are cleaned twice a week to remove fish

excrement and to prevent bacterial buildup, which depletes the dissolved oxygen.

Most fish are sold at ca. four cm, but those that are especially large and healthy for their age class are kept for breeding. Trout kept for breeding or consumption are moved to four ground trenches which contain various sizes of fish. Around two years of age, they are moved from these trenches to larger ponds where reproductive trout of all age classes are combined. Trout reproduce annually, usually between September and December, and each female produces 1000 to 3000 eggs. Trout instinctively migrate upstream to lay their eggs. Fish will wait at the gate which leads upstream from the reproductive pond. Here, the fish are collected for egg and sperm extraction. Each fish is removed from the water and eggs or sperm are manually extracted into separate collection jars. The largest eggs and sperm from the healthiest individuals are matched to produce the best possible offspring. Fertilized eggs of many mating pairs are used to maintain genetic variability in each generation. Roughly ten adult trout die every reproductive season from competition and natural causes. This completes the life cycle within Carlos's trout farm.

Hydroelectric System. Water from the stream in the immediate station watershed, water that bypasses the drinking system, water that bypasses the trout system, and trout outputs combine in a holding tank south of the station (Fig. 2). The holding tank is equipped with a large mesh filter in the bottom to prevent leaves and other objects from damaging the hydroelectric turbines. The pipes to the electrical motor are placed at the base of the holding tank to prevent any air from entering the system, which could cause system failure. The water flows through this entrance pipe approximately 25 meters in slope distance downhill to the hydroelectric motor at approximately 5.49 L/sec.

The hydroelectric system provides power to the station, the three surrounding houses in the station complex, and the trout farm. The system is composed of a Baldor 5000 W high efficiency electric motor, a Thomson and Howe Energy System and small hydro controls (which measure water flow, amperes, voltage, and hertz through a Siemans sensor system), and a General Electric converter. There is a small transformer in the hydroelectric pump house which supplies 110 V electricity to a light and an outlet box for use within the pump house. All energy traveling to the houses and station leaves the pump house at 440-460 volts (59-59.5 Hz). Voltage is lost en route to the converter at the station, where it is then transformed to either 110 or 220 V. The water heater and other large

appliances require 220 V. After transformation, the energy passes through a sensor which allocates the energy to different resources throughout the station and to each of the three houses. Because there is no storage device for energy (e.g. battery or generator), the water heater is a buffer for inputs of energy. When there is a change supply, the water heater is able to receive excess power, or shut off, allowing electricity to flow to more critical devices. If the energy input goes outside the range of 50-150 V, the entire system shuts down and must be restarted at the pump house. Carlos was not able to estimate the total power generated, the power used, or the amount of excess energy lost to water heating because the station lacks a battery or generator.

FOOD CYCLE

When we (19 students and faculty) arrived at Cuerici, we became part of an intricate food web (Fig. 3). To prepare a typical meal, many resources are used. Alberto imports approximately 85% of the food from San Jose and San Isidro, including rice, beans, sugar, meats, and condiments. The other 15% of the food is supplied locally. Carlos's trout, his son's blackberries, and his uncle's carrots and potatoes are also part of the menu. Per day, for 19 people, the chefs use about three kg of dry rice, three kg of dry beans, two kg of meat, and 50 pieces of fruit for juice. The kitchen staff includes Carlos's cousin and close neighbor. They use a propane stove to cook three meals a day.

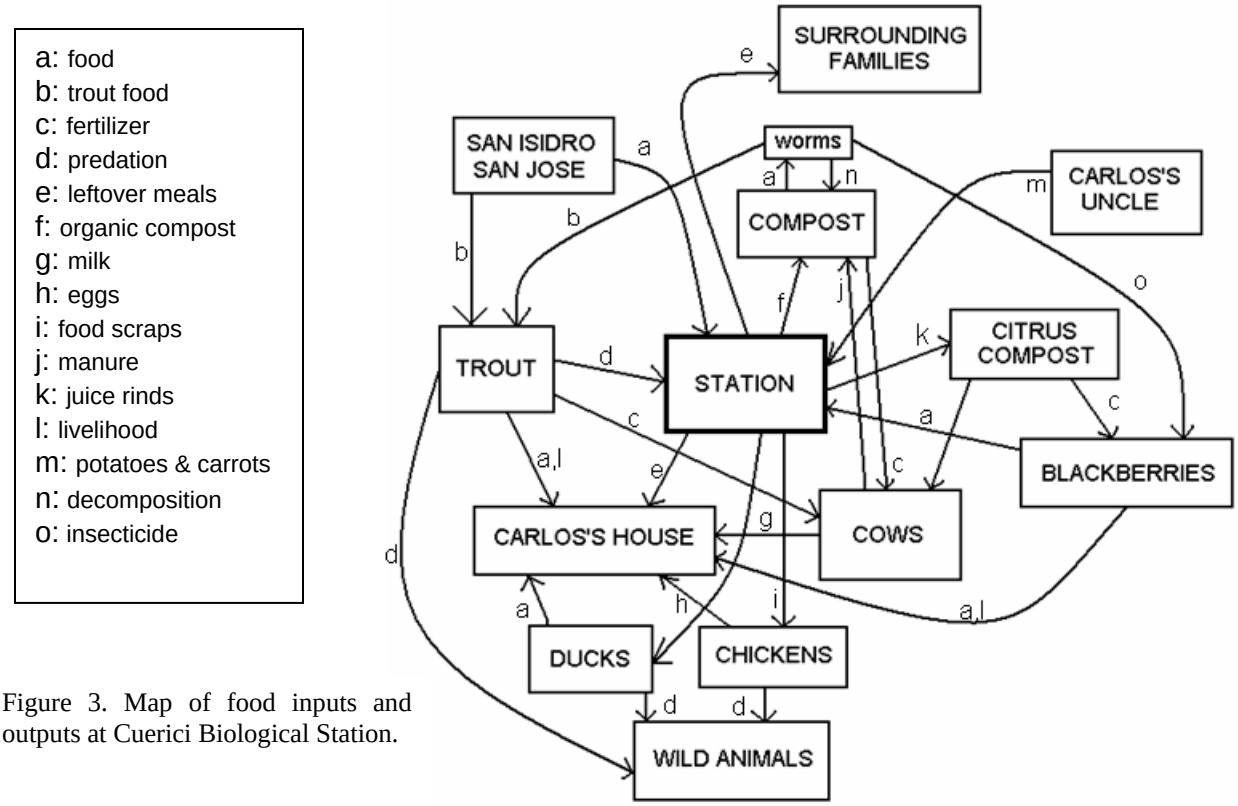

Figure 3. Map of food inputs and outputs at Cuerici Biological Station.

After each meal, students place their remaining food scraps into an organic compost collection bowl. The plates are washed by hand to conserve water. The cooked food that was not served is given to the chefs and surrounding families. It is likely that they eat a portion of it, although some of it is given to the farm animals as feed. Carlos's family has one milk cow, three other cows, thirteen chickens for eggs, six ducks, and one horse. The resources from the animals support only Carlos's family. Occasionally, predators such as pumas, vultures and coyotes eat the ducks and chickens.

To quantify the destination of food at the station, we weighed food before and after each meal for an entire day (29 January 2007), including amount eaten, leftover food, and organic compost. We found that our group of 19 individuals ate 27.63 kg of food, produced 11.66 kg of organic food waste, and left 12.37 kg of food uneaten, totaling 51.66 kg of food per day (Fig. 4).

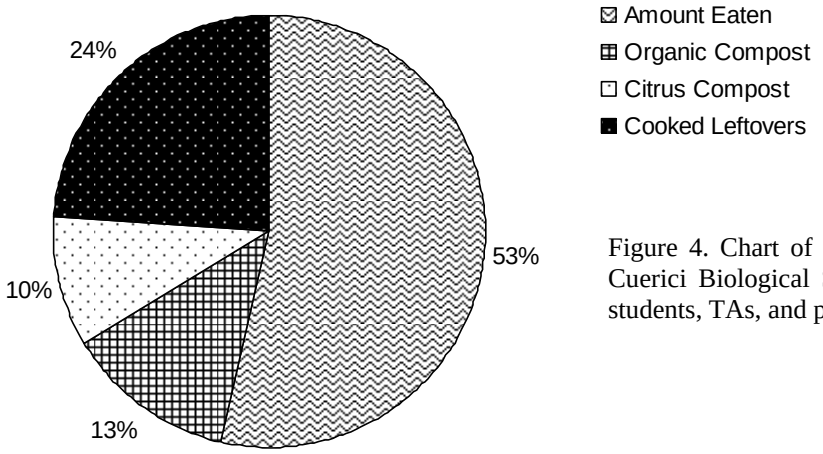

Figure 4. Chart of food consumption over one day at Cuerici Biological Station by group of 19 Dartmouth students, TAs, and professors.

The organic compost is broken down into two categories: citrus (which worms cannot process) and non-citrus (which they can). The non-citrus waste is kept in the juvenile trout building, where California red worms break down the material and also produce a natural insecticide and fungicide used on the blackberry farm. Carlos originally received a small bag of worms from a visiting organic agriculture professor, and now has thousands of them. He uses the worms not only to accelerate the decomposition process, but also as food for the juvenile trout, because the worms have high protein content. The trout give back to the compost through their sediment (i.e.

fish carcasses and excrements), which Carlos cleans from the trout ponds once every three years. Horse and cow manure are also added to the compost, and the final product is then used to fertilize the pasture, and blackberry farm. The small profit from the blackberries is invested in Carlos's trout farm. The trout are sold for profit or used at the station to feed students and expose them to his passion and project.

ECONOMICS

La Estación Biológica Albergue Cuerici is financially distinct from Carlos's rainbow trout farm. The station is under the umbrella organization Explornave. The station currently hosts 8-10 groups of approximately 20 students each per year, and requires the generated income to support its community development goals, including providing jobs for local people and purchasing local fruits and vegetables. Cuerici maintains a strong focus on sustainability; however, its budget is extremely tight. Cuerici charges approximately US$41 per person per night (as of 2007); however, only ca. 10-15% of this is available for investment in new projects because of high overhead costs such as yearly taxes and fees, maintenance costs, and salaries. The 11 business partners are conservationists and any profit feeds directly into the further development of the station. The cost distribution is approximately 30% food products, 30% property maintenance, and 40% salaries, taxes, and fees. To minimize losses from the overhead costs and maximize station development, Cuerici would ideally host 15 student groups per year. With increased visitation, they would be able to invest in another 30-bed bunkhouse and a larger dining room, which would allow the station to host two groups simultaneously.

In hopes of increasing the number of groups visiting the station, Carlos and the reserve administrator, Alberto Torres, have planned an advertising campaign, including a website with articles, pictures, and a video clip of the station. The main marketing areas include the US, Spain, Japan, Germany, and England. Investing in a large advertising campaign is costly; however, the station needs publicity to acquire new student groups. Large, well known institutions such as Dartmouth College and La Organización para Estudios Tropicales could also be important in generating publicity to other institutions that have programs returning to Costa Rica year after year.

Along with the station, one of Carlos's long term investments is his trout farm. He is currently raising the trout to feed both his family and visiting students, and to sell to other farms and fisheries. Although the

trout are not yet profitable, Carlos hopes to profit very soon after his high initial investment. The trout are an integral part of his farm and have the potential to be his main source of income. Carlos has built a reproductively self-sustaining trout hatchery that provides his family with food and future financial support.

DISCUSSION

La Estación Biológica Albergue Cuerici is a center of innovation and responsibility in environmental engineering and conservation. The station uses natural water sources for all processes and effectively prevents downstream contamination. The food cycle efficiently recycles all unused organic matter inputs. However, not all food cycle resources originate within the system, which prevents complete sustainability.

In the future, a planned large-scale (50 M x 18 M) hydroponic greenhouse may provide food to visiting groups. An experimental, smaller scale model is now being used to determine if the greenhouse can tolerate the temperature variations of the montane system. This project is currently the highest priority as it would greatly reduce food costs to the station. Students would be able to pick their own vegetables, connecting them directly to the resources that sustain them while at the station. Although requiring a large initial investment (3-4 million colones; $6000-8000), the greenhouse would both increase resource independence and contribute to the environmental education.

All station electricity is currently self-produced; however, replacement parts for the hydroelectric system are no longer available. Predicting when the system will breakdown is impossible, and the station does not have a generator or battery to provide backup power when the existing system fails. Electricity is essential for the trout farm's water pumps. In addition, reliable electricity is important for student groups who return year after year. The government has recently provided power further up the mountain, but it would be expensive to access the grid (6 million colones; $12000). Because a replacement hydroelectric motor is also expensive (3 million colones; $6000), the government grid may be a good investment as a permanent source of power. The station managers will have to decide between the resource-independence of self-produced alternative energy and the security of government-provided energy.

Sustainable development is very complex on the regional or national scale, and often involves great suffering when projects (e.g.

dam building) for energy sustainability destroy ecosystems and local communities (Isaacman and Sneddon 2000, Murphy 2002). However, La Estación Biológica Albergue Cuerici demonstrates that small-scale sustainable development can produce food, water, and energy while having a low environmental impact.

The station serves as a structural model for other stations and an ideological model for environmentally conscious development. The elevation gradient and clean water sources are central to the system's engineering. Therefore, any developing station in a mountainous environment could base their water and food networks on the described systems. A station in a different habitat may require a different alternative-energy source and more complex water treatment systems; however, Cuerici's engineering still serves as a functional blueprint of food and water networks. For students and conservationists, the station is a model for balancing human needs with conservation, in a community which both employs and protects the land that gives it life.

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