Restoration Cases Flagship Collection

Naturally regenerating 30-yr old ACG dry forests surrounding a 4-centuries-old pasture plot maintained by annual burning for education and training. Photo credit: Felipe Chavarría.

Case #11:

Bio-cultural restoration of Área de Conservación Guanacaste, Costa Rica

RESTOR

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Contents

In brief

Overview

Área de Conservación Guanacaste (ACG) in northwestern Costa Rica encompasses 169,000 ha of protected land and sea and extends from 19 km in the Pacific Ocean to about 105 km inland, including the Caribbean slopes of the Volcanic Cordillera de Guanacaste. The area includes four major tropical ecosystems: marine/coastal, dry forest, rain forest, and cloud forest and spans an elevational range from sea level to 1,916 masl. In 1985, individuals, government agencies, and non-governmental organizations initiated a joint effort to create a regional conservation unit to reduce threats to biological integrity and survival by preventing fires, hunting, farming/pasturing, and logging, by purchasing agroscape properties to restore native ecosystems and by increasing habitat connectivity for resident and seasonally migrating species. Over 35 years, forest extent in the protected area increased more than 10-fold, entirely through fire prevention and natural regeneration. Enhanced protection of marine areas and coastal mangrove ecosystems is promoting their recovery. More than 80,000 ha of former pasture and croplands are on their way to becoming forests through natural seeding from adjacent forest patches.

Exemplary practices

The formation of ACG required a paradigm shift toward a local-based conservation and management approach based on strategic land purchase and government permissions, elimination of fires, local employment at all administrative levels, and field-based biological education. These actions created and protected sufficient habitat to sustain native species, thereby providing goods and services to local communities to compensate them for their engagement in wildland conservation and restoration and promoting and assisting the natural forest regeneration process to restore and connect forest ecosystems within a heterogeneous landscape. Local communities were engaged in ACG through educational programs, training of local naturalists to conduct biological inventories, voluntary fire-fighting brigades, government employment, and regional and national advisory councils.

Key lessons learned

- *Long-term conservation and restoration cannot succeed without the cooperation, participation, and engagement of local to global stakeholders.*
- *Protect remaining habitats and harness nature's resilience to reestablish native biodiversity.*
- *Grow protected areas strategically to achieve regional socioeconomic and ecological integrity, climate change resilience, and connectivity.*
- *Commit to innovative actions focused on long-term objectives and local engagement.*
- *Bioliteracy education programs create knowledge about uses and values of biodiversity to society.*

4

Restoration narrative

"To save what dry forest we still have, we are going to have to give some land back to it."

—Daniel H. Janzen (1986, p. 11)

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IArea de Conservacion Guanacaste/Costa Rica

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RESTOR

Geography and ecological setting

Área de Conservación Guanacaste (ACG) in northwestern Costa Rica is one of eleven regional conservation units within the National System of Protected Areas (SINAC). ACG encompasses 169,000 ha of protected land and sea (Figure 1), extending from 19 km out in the Pacific Ocean to about 105 km inland, including the Caribbean slopes of the Volcanic Cordillera de Guanacaste. This area includes the four major tropical ecosystems: marine/coastal, dry forest, rainforest, and cloud forest, spanning an elevational range from sea level to 1,916 masl. Three national parks—Parque Nacional Santa Rosa, Parque Nacional Guanacaste, and Parque Nacional Rincón de la Vieja—originally separate protected areas, are now fused into one continuous piece by substantial land purchases (Figure 1; Pringle, 2017). In 1999, ACG became a UNESCO World Heritage Site (Janzen, 2001).

Before the Spanish arrived, ACG was inhabited by the Chorotega people and several other indigenous groups. The lowland areas are part of a belt of tropical dry forest that once extended across 55 million ha along the Pacific Coast of Mesoamerica, from

Mexico to Panama. Less than 2% of these dry forests remain standing as relatively intact “wildland” ecosystems (Janzen, 1986).

The Province of Guanacaste, where much of ACG lies, is bounded on the east by the volcanic Cordillera de Guanacaste and the non-volcanic Cordillera de Tilarán. As moisture-filled trade winds from the east and northeast ascend these slopes, their moisture condenses out into the headwaters of the Río Tempisque and other major drainages. The winds continue west and southwest to create a rain shadow that encompasses the dry forest of ACG (Janzen and Hallwachs, 2016). Soils in this region are largely volcanic with major ancient serpentine and marine portions (Powers et al., 2009). The upper plateau areas of Santa Rosa have poor rocky soils derived from pumice and ash (Arroyo-Rodriguez et al., 2005).

Guanacaste’s economic and cultural heritage is based on beef cattle ranching and agroindustry, with much of the flatland agroscape covered by small patches of forest, isolated trees, and extensive pastures of exotic African grasses where Brahman cattle graze. Sugar cane, cotton, oranges, pineapple, melons, and rice are also grown in the region. Since the late 20th century, tourism has emerged as the new and growing economic activity (Calvo-Alvarado

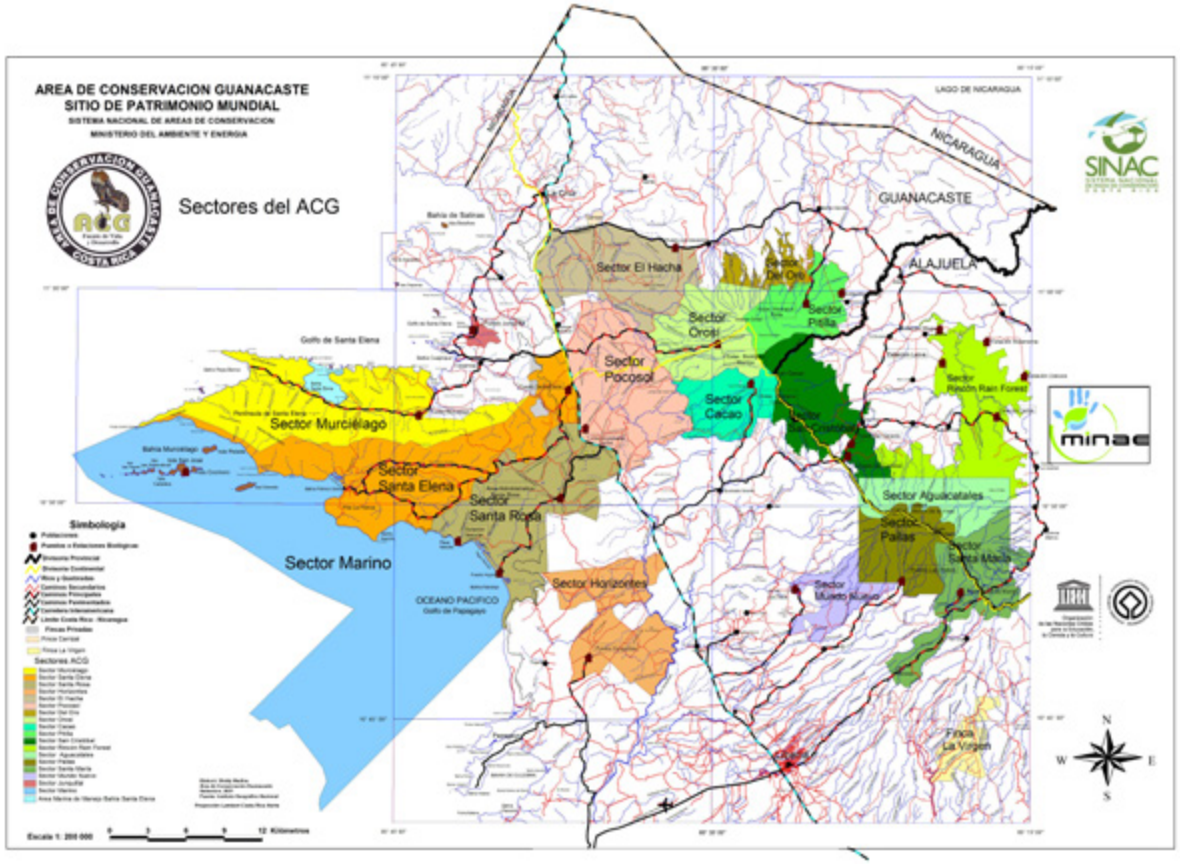

Figure 1. Map of Área de Conservación Guanacaste (ACG) sectors, as described in this document, including terrestrial and marine ecosystems. Officially, these sectors are the Área Silvestre Protegido of the government’s named conservation area, ACG, with the white area being private landscapes. Source: Waldy Medina, ACG

et al., 2019), valued at almost US$4 billion annually prior to the Covid-19 pandemic.

Four centuries of ranching, logging, road building, hunting, and anthropogenic fires gave rise to the heterogeneous landscape matrix that now composes ACG and its diverse sectors (Figure 1; Janzen and Hallwachs, 2020). The establishment of Parque Nacional Santa Rosa in 1971 (now Sector Santa Rosa in Figure 1) was a key step in recognizing and protecting the region's cultural and biological heritage.

Deforestation history

Hacienda Santa Rosa was established in the late 1500s as part of a mule-production area for a cross-isthmus international transport system when the Guanacaste region was part of the Spanish colony of Nicaragua (Janzen, 2000). Guanacaste became a province of Costa Rica in 1824, three years after Costa Rica's independence from Spain. In later centuries, the region's dry forests were largely converted to pasture and the Hacienda Santa Rosa was also used for timber, wild meat, croplands, and water for irrigation (Janzen, 2000).

The savanna grass *jaragua (Hyparrhenia rufa)* was introduced from East Africa during the 1920s to support the cattle industry, because the native grasses of Costa Rica have low forage quality and are poorly adapted to large-scale grazing (Janzen and Hallwachs, 2016). Its high flammability allows dry-season fires set by ranchers to quickly spread into nearby forests. Hacienda Santa Rosa was an extensively managed cattle ranch until the mid-1960s when a major portion of it was expropriated from the Somoza family to create a national historic site and recreation area in 1966 (Figure 2; Janzen, 2000; Pringle, 2017).

Topography, climate, and accessibility eased the transformation of Guanacaste's dry forest to pasture and agricultural land (Arroyo-Mora

et al., 2005). The initiation of beef exports to the United States in 1957 provided a major economic boost to the industry (Arroyo-Mora et al., 2005), encouraged by the Costa Rican Government and supported by policies of the World Bank, the US Aid for International Development, and other international development institutions. By 1972, Guanacaste Province became the center of Costa Rican cattle ranching (Ibrahim et al., 2000). In the Tempisque Northeast basin (620,600 ha)—where ACG lies—continued cattle ranching and fires reduced forest cover to less than 25.6% by 1979 (Calvo-Alvarado et al., 2009).

Figure 2. Santa Rosa in 1967 dry season with jaragua-dominated pastures (yellow vegetation) and remnant patches of old secondary dry forest. Photo credit: Daniel Janzen

The tipping point

After Santa Rosa became a National Park in 1971, the National Park Service removed more than 2,000 head of cattle as an active conservation measure. Without grazing or active fire-control practices, the *jaragua* grew to heights of 1–2 m, and annual rancher-set dry season fires extended further into remnant forest areas. By 1984, it became clear that the stands of variously aged secondary dry forest and even the tiny fragments of old-growth forest in the dry forest sectors would be totally eliminated by fires if actions were not taken (Janzen, 1988b). In response, visiting research biologists and Santa Rosa staff initiated a fire elimination program (Janzen and Hallwachs, 2016). Pastures in Santa Rosa began turning back into forests. As a neighboring rancher said in 1986, "Of course the forest will come back if you let it. Why do you think we burn the pastures?" (Janzen and Hallwachs, 2016, p. 331).

Tiny, isolated, and threatened forest remnants create risky conditions for protection and recovery of native biodiversity, particularly if local communities are not engaged in conservation efforts. During the 1970s and 1980s, scientific concern over deforestation in the tropics became a pressing societal concern, but restoration was viewed by some conservation NGOs and Costa Rican government officials as a "dangerous distraction" from protecting and conserving intact forests (Allen, 2001; Woodworth, 2013). ACG staff, some governmental and non-governmental organizations, and researchers invested in the long-term protection and maintenance of regional biodiversity supported by local community engagement proposed a new vision that extended conservation well beyond the original borders of Parque Nacional Santa Rosa. A paradigm shift toward a regionally-based conservation and management approach was founded on three main components (Janzen, 1996):

- Enlarge the protected area to sustain populations and ecosystems of hundreds of thousands of species through a strategic and pragmatic land-acquisition purchase program.
- Provide goods and services (including public education and employment) to integrate ACG neighbors with the wild area and convert them to stakeholders.
- Promote and assist the natural forest regeneration process to restore functioning and interconnected forest ecosystems across the region.

Two long-term, semi-resident researchers from the University of Pennsylvania, Drs. Daniel Janzen and Winnie Hallwachs, were the architects and passionate leaders for this novel and bold conservation concept. They launched a major campaign in 1986 to create a new protected area 7-fold larger than Santa Rosa's terrestrial extent of 9,900 ha (Janzen, 1986). The vision was to create a continuous swath of interconnected ecosystems from the Pacific Ocean, across the lowland dry forest, up to the cloud forests on the Cordilleras and over to the Caribbean rain forest slopes (Janzen, 1986). By this time, Parque Nacional Rincón de La Vieja had become established, protecting 14,100 ha of forest and other natural ecosystems on the slopes of an active 3,000 m high volcano. The initially conceived 70,000 ha Parque Nacional Guanacaste (PNG) was envisioned as something in between a wildland and a garden, built on the foundation of Parque Nacional Santa Rosa, at an estimated price tag of US$11 million (Janzen, 1997). Achieving the PNG goal— and ultimately, creating ACG—required a major shift from the existing classical centralized administrative model of National Parks to a decentralized model based on local engagement, leadership, and decision-making power aimed at specific objectives.

The election of Óscar Arias as President of Costa Rica in 1986 ushered in a new era for conservation in Costa Rica. Arias created the Ministry of Natural Resources, Energy, and Mines (MIRENEM), today known as the Ministry of Environment and Energy (MINAE) and appointed Alvaro Umaña as the Minister, a cabinet-level position. By 1987, the notion of land purchase and management for conservation through restoration, alongside the conservation of old-growth areas, gradually became more palatable to both the donor and NGO communities (Janzen, 2000) as well as to government officials. Innovations in government organization further paved the way towards decentralizing the administration of conservation units (Basurto and Jiménez-Pérez, 2013).

Actors and arrangements

The growth of ACG from the 9,904 terrestrial ha of Parque Nacional Santa Rosa to ACG's current extent of over 126,000 terrestrial ha (169,000 ha total) involved a complex and concerted effort by a host of actors—private individuals, donors, national and international governments, and non-governmental agencies—that collectively changed legislation and national policy for conservation and restoration landscape in Costa Rica (Guanacaste Dry Forest Conservation Fund, 2021).

During the first five years of the PNG proposal, national support and leadership was critically needed. In 1986, Professor Rodrigo Gámez, biodiversity advisor to then President Óscar Arias, and Minister Umaña provided essential national leadership and first championed the idea to the government. Creating PNG would mean decentralizing the functions and administration of the National Park Service, newly moved from the Ministry of Agriculture and Cattle into its own Ministry. It also meant raising funds to purchase strategically located private lands, which would then be turned over to the government as public lands within the protected area system. Fundraising would be the responsibility of Janzen and Hallwachs and would be sourced from donors and organizations outside of Costa Rica. A group of Costa Rican biologists and conservation actors banded together with Daniel Janzen and Winnie Hallwachs to make the Guanacaste Project happen (Allen, 2001). Together, they chartered new and uncertain terrain for the Costa Rican government and conservation establishment. Two Costa Rican conservation NGOs, Fundación Neotrópica and Fundación de Parques Nacionales (FPN), offered critical support and helped to navigate the complexities of land transfers and donations in support of PNG (Evans, 2010).

By mid-1987, about half of the government-owned lands within PNG had been declared national park and half were in *zona protectora* status, a legal designation in which logging and other destructive activities are banned (Allen, 1988). New funding mechanisms were applied through nimble negotiations. In 1989, a debt-for-nature swap orchestrated by Minister Alvaro Umaña and the New York investment company Salomon Brothers, leveraged a US$3.5 million debt swap donation from Sweden to provide US$17 million in government bonds for long-term support for the Guanacaste project (Allen, 2001), managed by the FPN.

In 1989, the vision of PNG became a reality

when it was officially incorporated into a newly formed Regional Conservation Unit by the new Ministry of the Environment (MIRENEM). The unit officially became ACG in 1991. This novel experience with a decentralized conservation unit was a testing ground for the creation of the National System of Conservation Areas in 1994 (Janzen, 2000). Also in 1989, a portion of a 7000-ha donated ranch adjacent to Sector Santa Rosa was deliberately designated as the Horizontes Forest Experiment Station (EEFH) (Sector Horizontes, Figure 1) to provide examples of forest restoration and reforestation for Guanacaste province (Allen, 2001; Hulshof and Powers, 2020). The consolidated conservation area then included 88,000 ha on land and 43,000 ha on sea. The southern portion of the Santa Elena Peninsula (15,800 ha) (Sector Santa Elena, Sector Murcielago, Figure 1) did not become incorporated into ACG until 2018, when it was expropriated by the Costa Rican government. No other areas of ACG were expropriated; they were either donated or purchased on the open market (Janzen and Hallwachs, 2020).

The Guanacaste Dry Forest Conservation Fund (GDFCF) was established as a US non-profit NGO organization in 1997, dedicated solely to ACG. GDFCF activities are closely coordinated with ACG within SINAC. Activities sponsored by the GDFCF include biological research, conservation, restoration, fire control, education, science-based management, and biodiversity development (Guanacaste Dry Forest Conservation Fund, 2021). The GDFCF owns about 14,000 ha within ACG and receives Payments for Environmental Services (PSAs) for a portion of these lands from the Costa Rican government for their protection (Monique Gilbert, personal communication). As of 2021, GDFCF employs 54 people of which 50 are Costa Ricans living in Costa Rica.

A small non-profit organization, Investigadores ACG, was founded in 2007 to advance research and data sharing (Figure 3). They hold annual open house events and organize databases for ACG. Dr. Jennifer Powers, an ACG researcher since the 1990s says, “Working in ACG makes you want to give back.” (J. Powers, 2021, Personal communication). ACG staff feel the same way, and they give back heavily in-kind.

The institutionalization of ACG was a gradual process, led by a committed group of Costa Ricans (Allen, 2001). Some are public servants and GDFCF employees, researchers, teachers, forest managers, administrators, police, fire-fighters—all are local residents. As stated by Roger Blanco, Co-Director of the ACG Research Program with Maria Marta Chavarria, “ACG is a living institution in our country, and it is not only supported by

money; it is supported by people." (R. Blanco, 2022, Personal Communication). Governance arrangements are unconventional and evolving. As described by Janzen, "ACG is a decentralized portion of the Sistema Nacional de Áreas de Conservación of the Ministerio del Ambiente y Energía (MINAE) of the government of Costa Rica. Its administration is an irregular and still adjusting government-private alliance conducted on land owned by the State but paying almost half its own bills and guided by principles more common in the private sector than in State bureaucracies" (Janzen, 2001, p. 43).

Since its incorporation in 1989, ACG has incorporated local and regional civil society in decision-making, through the permanent establishment of a Regional Council (Consejo Regional) consisting of people representing the society in which ACG is immersed. Beginning in 2002, these councils are mandated by the Biodiversity Law in all of the Conservation Areas. The Regional Council works to support administrative programs and activities and to ensure broad engagement of local communities and interests. The director of ACG, MSc. Alejandro Masis, is co-hired by the Consejo Regional and MINAE.

Figure 3. (top) International and Costa Rican ACG researchers gather for the 2019 open house event. Photo credit: Jennifer Powers. (bottom) Assembled group of the entire ACG staff and GDFCF parataxonomists in 2003. Photo credit: Daniel Janzen

Planning and engagement

Early on, decisions regarding planning and land purchases were largely made by Janzen, Hallwachs, and local government administrators of different sectors to address urgent conservation needs. Later, these responsibilities have become shared by the GDFCF, ACG staff, and the Regional Council. The history of ACG is one of persistent civic and political engagement to achieve what Janzen termed "biocultural restoration" (Janzen, 1988; Allen, 1988; Pringle, 2017). "The goal of biocultural restoration is to give back to people the understanding of the natural history around them that their grandparents had," said Janzen (Allen, 1988). From the beginning, the plan was to build a staff of caring stewards who specialized in carrying out specific ACG management specialties including police, teachers, biological surveyors, tourism entrepreneurs, fire fighters, and community relations experts (Guanacaste Dry Forest Conservation Fund, 2021).

In 1987, six managers of local farms that were purchased to become part of the nascent ACG were hired as Sector and Biological Station managers. They cultivated a small portion of their fields as a salary supplement, transformed their houses into biological stations, mapped vegetation on the farms, and received training from a local game warden on handling poachers and public relations (Allen, 1998).
Local people came to handle all fire control (Allen, 1988). From 1986 on, fires were controlled by hiring a small crew of former farmers and ranch hands from the area. They were also given the freedom to design fire breaks and fire lookouts and to plan their own work schedules. They purchased their own equipment, including trucks, pumps, brooms, binoculars, and radios. The crews extinguished 30–75 anthropogenic fires per year in or near ACG (Janzen, 2002).

ACG became a "living classroom" through educational field-based programs for grade school, secondary school, and university students, civic groups, and tourists from Costa Rica and internationally. In 1986–1988, local rural adults from the boundary zone of ACG were hired and trained to help collect insects for an inventory of about 100,000 ha (Janzen et al., 1993). This training program led to the first parataxonomists course in 1989 and the development of a formalized training program as part of Costa Rica's National Biodiversity Inventory Program (Janzen et al. 1993; Janzen and Hallwachs, 2011; Figure 3). Many of the participants in these programs have taken on leadership and training roles within ACG, in other conservation areas in Costa Rica, and in other biodiversity-related employment throughout the country.

Costs, funding, and other support

From 1985 to 2019, ACG/GCFCF raised at least US$107 million from national and international sources, including a still-growing endowment of US$14 million that is central to the long-term self-sufficiency of essential ACG and GDFCF programs that are not covered by the government's annual allocation of about 75% of the ACG budget (Janzen and Hallwachs 2021; Pringle, 2017). GDFCF was initially funded by donations and the proceeds from a 50-million-yen (US$430,000) Kyoto Prize to Janzen, in addition to other prizes. GDFCF serves as ACG's primary charitable-support arm, owns and co-oversees approximately 14,000 ha within ACG, and manages the growing endowment that is intended to confer financial sustainability in perpetuity. Costa Rica's Fundación de Parques Nacionales (FPN, a government-private hybrid) provided key financial support since 1986 and continues to support ACG as the direct employer of many ACG and GDFCF staff and as a landowner of key portions of ACG. The Nature Conservancy US was an important financial partner during the first 12 years of ACG life.

ACG functions today as a hybrid NGO-government organization with a staff of 150 resident Costa Ricans and an annual budget of approximately US$6 million, with about US$4 million paid by the Costa Rican federal government (before COVID emergency) and US$2 million by its supporting charitable group, GDFCF. The federal government pays for administration, police and fire protection, much facility maintenance, and the bulk of the children's education program. The portion contributed by GDFCF goes primarily toward an intensive and ongoing inventory of species and their natural history via the work of the resident parataxonomists and the use of DNA barcoding to know what is actually being protected. The cost of the parataxonomist program of about US$800,000/year is the largest single activity supported by GDFCF. GDFCF also supports a marine biological inventory program, sea turtle and migratory bird research, and cost-shares a portion of the education program. GDFCF also contributes to ACG operations and land management costs. ACG is managed by federal and GDFCF employees within the national system of protected areas (SINAC) and with guidance by the local Regional Council. GDFCF has an independent pro bono board of directors, with key advisors and collaborators from senior ACG staff and the GDFCF directorate (M. Gilbert and E. Palola, personal communication).

Implementation

Implementation of restoration and conservation activities in ACG first focused on reducing threats to the remnant forest ecosystems by stopping logging and hunting and extinguishing escaped dry season fires that were traditionally set by farmers. Creating local "ownership" and stewardship by local communities was seen as essential for the long-term survival of ACG's ecosystems and biota. The plan to reduce these threats began in 1985, based on seven key steps: 1) raising the money to purchase degraded ranchland, cloud forest, and rain forests to be restored; 2) extinguishing fires on properties inside and outside of ACG; 3) reaching out to the community through field-based basic biology instruction for 4th–6th graders in 42 neighboring schools (2,500 students per year); 4) employing only local staff; 5) establishing an endowment fund to meet annual operations costs not met by government or further donations; 6) inspiring and training staff to be accountable and responsible for their particular specialization; and 7) placing the overall decision-making policies of ACG in the hands of a local board of directors who share power with the central government, GDFCF, and ACG staff (Janzen, 2001).

From 1986–1988, ACG planted thousands of native trees in small pastures in two sectors, but natural regrowth quickly overtook the planting efforts (Janzen, 2002). As stated by Janzen and Hallwachs, "It became immediately obvious that when confronted with 60,000 ha of pasture with scattered dry forest remnants, the correct use of budget and administrative resources was not in planting trees, but rather in stopping the fires and letting nature do the reforestation" (Janzen and Hallwachs, 2016, p. 332). The success of assisted natural regeneration (removing obstacles to promote natural forest regrowth) allowed funds and effort to be directed toward other essential programs and activities, such as fire control, biological education, building park infrastructure, and purchase of additional areas of degraded ranchland (Janzen, 2002).

Three main methods were used for fire control: 1) generating 24-hour/7-day commitment and motivating resident members of the government and NGO fire crews to put out fires; 2) creating firebreaks and back-fires to prevent spread; and 3) leaving cattle in former pastures after land was purchased to reduce grass competition and dry season fuel accumulation. In the late 1980s, as many as 7,000 head of cattle were reintroduced

into overgrown pastures to serve as "biotic mowing machines" and seed dispersal agents (Janzen and Hallwachs, 2016, 2020). Fire control was essential during the first 3-5 years, after which the woody regeneration was sufficiently established to begin to shade out the dry forest jaragua grass. Once the woody vegetation became firmly established, cattle were removed as they can deflect the progression of regrowing forest (Janzen and Hallwachs, 2016).

ACG developed the "bioliteracy" program (PEB) in 1986 to provide elementary school children in grades 4–6 with field-based natural history and science education (Cruz and Blanco, 2010). In 1988, PEB established legal agreements between the Ministry of Education and ACG to secure permission to take children to nature's classrooms within ACG's diverse habitats and ecosystems (Cruz and Blanco, 2010; Figure 4). "We focus on young people because they will inherit in one way or another the power to make the decisions that will impact ACG and the environment in their communities and the country" (Cruz and Blanco, 2010, p. 194). With additional financial support from the GDFCF, the program now serves 30-53 elementary schools surrounding the ACG protected area (Cruz and Blanco, 2010; GDFCF, 2021). Currently, the program employs six full time teachers and two drivers. Each student has the opportunity to take at least four field trips each school year, with a total of 12 outings over the three years of involvement in the program. Similar to the PEB, ACG's Marine Bioawareness Program focuses on educating children, parents, teachers, and neighbors from the small coastal town of Cuajiniquil, neighboring ACG Sector Marino. This town has relied on fishing in what are now protected ACG waters for the past 40 years, leading to overfishing and near extinction. The program aims to raise awareness among the community to allow the Sector Marino restoration (in progress) and to protect all ACG mangrove and coastal ecosystems. The Costa Rica-Benin Mangrove Project in Bahía Tores in ACG began in 2017 as a collaboration between SINAC, MINAE, and the Fundación Neotrópica with technical support from Mexican researchers (Figure 5). The project involves participation of over 75 people from Cuajiniquil and regular monitoring by ACG staff. Both planted and naturally regenerating mangroves seedlings are establishing well in the restoration site.

In 2015, the inventory of marine species of ACG (BioMar-ACG project) started as a focused project carried out by ACG, the University of Costa Rica Centro de Investigación en Ciencias del Mar y Limnología, the Museo de Zoología, the Herbario de Biología, and GDFCF (Cortés and Joyce, 2020). Information generated by

Figure 4. (above) Parataxonomist Carolina Caro introduces a caterpillar to school children from communities surrounding ACG. Photo credit: PEB educator Rosibel Elizondo Cruz. (right) PEB educator Eduardo Artavia Durán and a student study the role of mutualism on an Ant Acacia tree (Vachellia collinsii). Photo credit: Monique Gilbert

this project will be used by ACG to define management and conservation strategies and for their bioliteracy programs (Janzen, 2010). The Restoration and Silviculture Program of ACG began in 1986 and was formalized in 1989 with the creation of EEFH on 7,000 ha Sector Horizontes (Figure 1). The program has five major goals: 1) to conduct forestry research on native dry tropical forest species; 2) to serve as a demonstration area for reforestation in dry forest ecosystems; 3) to be a source of genetic material for forestry development projects in the region; 4) to promote and test reforestation techniques in degraded ranchlands within and outside of the protected area; and 5) to develop ecotourism in harmony with protection and restoration of tropical dry forest ecosystems (ACG, 2021).

Initial tree planting trials in 1989 covered 11 ha and included 12 native important timber species: Mahogany (*Swietenia macrophylla*, Figure 6), Black laurel (*Cordia gerascanthus*), Roble savanna (*Tabebuia rosea*), Guanacaste (*Enterolobium cyclocarpum*), Cenízaro (*Samanea saman*), Black bark (*Tabebuia impetiginosa*), Guachipelin (*Diphysa americana)*, Charcoal (*Acosmium panamense*), Cortez amarillo (*Handroanthus ochraceus*), Cocobolo (*Dalbergia retusa;* Figure 6), Aceituno (*Simarouba amara*), and Ateleia (*Ateleia herbert-smithii)*. These trials expanded during

Figure 5. Mangrove restoration site in Sector Murcielago, Bahia Tomas Cuajiniquil, La Cruz, Guanacaste in May 2020. The site was deforested and used for salt production and has required construction of canals to provide suitable flooding levels to support regeneration of native mangroves. Photo credit: Felipe Chavarría

Figure 6. (left) Fruits of Mahogany (Swietenia macrophylla) collected for planting trials. Photo credit: Milena Gutierrez (right) Seed orchard for Cocobolo (Dalbergia retusa) at Horizontes Experimental Forestry Station. Photo credit: Robin Chazdon

1991–1993 to 64 ha and 14 species with high potential for commercial timber plantations in the dry forest. Trials were also conducted using multiple-use species such as Madero negro (*Glyricidia sepium*) and species of high commercial value such as Guayacán real or Lignum vitae (*Guaiacum sanctum*). More than 700 trees of 26 species of native and potentially valuable dry forest trees provide seed sources. The program also supports research on tree-planting based restoration techniques, including planting tree clusters and enrichment planting in both dry and rain forest ecosystems, complementing native species trials in other regions of Costa Rica (Butterfield, 1995).

Since 1985, Área de Conservación Guanacaste (ACG) has been a testing ground for innovative forest restoration approaches, including the use of cattle and horses to control grasses and disperse seeds. ACG managers successfully restored forests on exhausted forest pastures in the 2,800 ha Rincón-Cacao Biological Corridor by planting them with living stakes of the exotic, small tree Gmelina arborea, which effectively killed pasture grasses by shading them. Plantings established during 1999–2000 were left unmanaged after 1–2 years, allowing natural colonization to begin building young native forests (Figure 7). During 1999–2000, this approach was used across 30 ha and continued with hundreds more, involving the planting of over 33,000 stakes. An evaluation 18 years later confirmed that the Gmelina plantations and cluster plantings were successful tools for accelerating the regeneration of tropical humid forest and were far less costly than planting native tree seedlings grown in a nursery (Sierra Parra et al., 2021).

In 1996, Janzen and Hallwachs arranged to deposit 100 dump truck loads of orange peels, from which the toxic essential oils had been extracted, to be spread on an ancient and exhausted pasture in exchange for the Del Oro Orange Juice company preparing to donate 1,600 ha of important original forest to ACG. They bet that “among its 235,000 estimated species (Janzen, 1996) there would be some that would dearly love to eat orange peels” (Janzen, 2000), thus converting this agricultural waste to soil. Based on initial success of this pilot experiment, in 1998 an estimated 12,000 Mg (1000 dump truck loads) of processed orange peels and pulp were applied to a 3-ha portion of a former cattle pasture with compacted, rocky, nutrient-poor soils characteristic of prolonged fire-based land management and overgrazing in ACG, as part of an innovative agricultural waste disposal service contract (Figure 8). After 16 years, this experimental plot showed a three-fold increase in woody plant species richness and a 176% increase in aboveground woody biomass compared to an adjacent untreated plot (Treuer et al., 2017). Deposition of orange waste significantly elevated levels of soil macronutrients and important micronutrients during 2–16 years after the initial orange waste application. Although legal actions by commercial competition based on unfounded concerns forced a halt to further applications in the government-owned terrain (Escofet, 2000), this pioneering study showed the way for accelerating forest regeneration through applications of agricultural waste, including coffee berry waste (Cole and Zahawi, 2021).

Box 1. Experiments with exotic trees and agricultural waste

Figure 7. Gmelina arborea *plantings in sector San Cristóbal, in 1999 (top left), 2001 (middle left), 2004 (bottom left) and 2017 (right). Photo credits: Programa de Restauración y Silvicultura, ACG (1999-2004) and Robin Chazdon (2017)*

Figure 8. Forest regeneration at the pilot orange peel site in 2009. Photo credit: Milena Gutierrez

Outcomes and impacts

Early successes of ACG project became evident during the first 14 years.

"It has stopped its fires. It has flipped 40,000 ha of old pastures to young regenerating forest. It has staffed itself with self-perpetuating and involved resident custodians who balance their internal "protectionist" mission with the beginnings of a "production" mode compatible with their conservation mission. It trains itself for the challenge at hand, as well as confronts challenges it was trained to expect. It teaches basic biology to all school children in a 20–30 km radius. It has built and managed an endowment that gives stability to staff and allows the application of performance-based employment criteria."

—Daniel Janzen (2000, p. 12-13)

Figure 9. Dry season prescribed burn of a jaragua pasture fire break in Sector Santa Rosa of ACG. Photo credit: Monique Gilbert

Now, after 36 years, ACG's "pilot project" protects the largest block of tropical dry forest in Central America (Segura, 2018), and local ACG staff and community volunteer fire brigades control and manage seasonal fires (Figure 9). Altogether, ACG's Sectors protect 80,000 ha of dry forest, 30,000 ha of moist forest, 10,000 ha of cloud forest, 43,000 ha of marine areas, and 150 km of protected coastline.

In addition to these local impacts and decentralized management authority (Basurto and Jiménez-Pérez, 2013), the experience gained by restoring and protecting native biodiversity in ACG has been widely disseminated to all social sectors within Costa Rica and internationally. As ACG demonstrates, society at large can benefit from knowledge and identification of local species (Janzen and Hallwachs, 2016). More than 90% of the decisions and applications made within ACG are by resident employees of the government, GDFCF and FPN, and the regional board of directors (Blanco, 2018). Over 30 years, the PEB program has brought 35,000 local school children to ACG ecosystem classrooms (GDFCG, 2021), some of whom have gone on to become parataxonomists, teachers, university students, research assistants, and senior government administrators. Even during the Covid-19 pandemic, students participated in "online" field trips.

Over 35 years, the vision of consolidating multiple conservation areas and ecosystems into a single management unit has been largely fulfilled, based on themes of biocultural restoration and biodevelopment—using native biodiversity to contribute to the intellectual and cultural advancement of people. Consolidation and connectivity among the region's ecosystems, including the cloud and rain forests along the Cordilleras provide critical dry season refugia and seasonal migration routes for birds, insects, and mammals (Janzen,1987).

The parataxonomist program expanded from 2 in 1984 to 36 in 2020 (Janzen and Hallwachs, 2011, 2020; Figure 3). The participants are drawn from a pool of working adults in the countryside (Figure 10). They have one foot in the world of science and one foot in their neighboring communities (GDFCF, 2021). This linkage reinforces the bond between ACG, its staff, and its broader social and cultural mission.

ACG's outward focus improved the 190,000 ha of agroscapes surrounding protected areas, encouraged through a range of activities developed by different government and NGO actors, including subregional offices in Liberia, Costa Rica; Forest and Wildlife Control Brigades in collaboration with law enforcement

authorities; and the Costa Rican payments for ecosystems services progam (PSA). Regional partnerships created a solid base for future activities addressing local needs and concerns. Prior to the Covid-19 pandemic, ACG had become a popular destination for ecotourists, creating more jobs for local communities and spreading knowledge through informal education. Guanacaste's population is now more urbanized, more economically focused on tourism, and less invested in cattle production and small land-holdings, providing an example of a forest transition driven by economic development and fueled by both spontaneous and assisted natural regeneration (Calvo-Alvarado et al., 2019). The number of ecotourists doubled from 80,000 in 2000 to 160,000 in 2019 (ACG, 2021). During 2020, the Covid-19 pandemic led to a 59% decrease in ecotourist visitation, reaching the lowest level in 20 years, but the numbers have since begun recuperating.

Figure 10. Parataxonomist Gloria Sihezar (as in Figure 12 below) replacing old leaves with fresh ones to rear caterpillars in the biodiversity inventory, BioAlfa (Janzen and Hallwachs, 2019), at Estación Biológica San Gerardo, Sector Rincón Rain Forest. Photo credit: Daniel Janzen

Key challenges

Early on, the formation of ACG was challenged by the prevailing attitude within governmental and non-governmental organizations that restoration approaches were poorly aligned or even in conflict with conservation in protected areas. When he led efforts to purchase exhausted ranchlands in late 1985 and 1986, Janzen was negatively received by conservation NGOs for expounding a restoration focus (Janzen, 2000). Narrow conceptualizations of conservation slowly began to include restoration, but entrenched views still persist. Local ACG decisions such as dumping orange peels on pastures or planting exotic *Gmelina* (Box 1) were not viewed favorably by some national-level administrators. Negative reactions also emerged locally when farms were being purchased and wildlife began to proliferate, attracting hunting and displacing farmworkers (Janzen, 2000). The most consequential innovation was the concept and practice of on-the-job training of poorly educated but highly intelligent and enthusiastic resident farmhands, park guards, and housewives to implement field-based biodiversity studies and species inventories (e.g., Janzen, 1991; Janzen and Hallwachs, 2011, 2019). In 1989, these activities were normally reserved for university graduates and international Ph.D.s.

Today, climate change and its consequences for forest species of all taxa are the greatest challenges facing ACG. The dry season now lasts for six months instead of four in 1963 (Janzen and Hallwachs, 2021). Janzen and Hallwachs (2021) have documented clear trends in the decline of insect species in ACG in both young and old forest ecosystems that are a consequence of climate change (Figure 10). “Climate change distorts much more than temperature and rainfall patterns. The entire temperature–rainfall blanket is sliding up the Pacific slopes of the volcanic 1,400- to 2,000-m Cordillera Guanacaste” (Janzen and Hallwachs, 2021, p. 3). The clouds that created cloud forests at the top of Volcán Cacao are vanishing. Climate change hinders species migration during the dry season, increasing local extinction risk for large numbers of insects, birds, and mammals. In recent years, coral bleaching has been observed in the marine sector of ACG and efforts are being made to identify which coral species are the most resilient to the impacts of climate change (IUCN, 2020). As stated by Milena Gutierrez, director of AGC’s Silviculture and Restoration Program, “Climate change is an important threat. It is not sufficient to protect forests. We must help them to adapt.” (M. Gutierrez, 2021, Personal Communication).

Figure 11. Costa Rica's white morpho butterfly, Morpho catalina (Nymphalidae)*, endemic to Cordillera Guanacaste. On top is caterpillar 04-SRNP-35053-DHJ84953; on bottom is a reared adult 97-SRNP-1624-DHJ97682. This species is among the very largest of the day-flying butterflies in ACG. Caterpillars feed on Inga* (Fabaceae)*and a few other plants in the heavily shaded understory of ACG mid-elevation rainforest on the Pacific slopes of the Cordillera. Photo credit: Daniel Janzen*

Struggles continue despite earlier battles won to decentralize decision-making and spending authority to ACG (Janzen, 2001). ACG staff now face many challenges on a daily basis to maintain the programs and budget allocations they have fought for over many years. Continuing their work in ACG is a 24/7 labor of love that often requires resistance to an increasingly bureaucratic national administration that emphasizes narrow legal constructs. In reality, there are two ACGs, one that includes only ACG sectors and is the World Heritage Site (Figure 1) and one recognized as the official governmental unit that includes all of the region from Liberia to the Nicaraguan border (Figure 1). The local vision of what ACG needs is not perfectly aligned with the nation-wide priorities for conservation areas, agroscapes, and the National Parks that lie within them.

Numerous threats still confront ACG, including illegal resource extraction (e.g., illegal hunting, fishing, and capture of some species for the pet trade), fires, and agrochemical pollution from surrounding agricultural areas (IUCN, 2020). Active marine protection efforts for natural restoration have only been politically possible since 2005, and these are still hampered by insufficient staffing and resources (Janzen and Hallwachs, 2020).

Enabling factors and innovations

Although in some ways, the development of ACG was ahead of its time, the timing was also opportune. The 1980s brought major changes to Costa Rica—the fall of international beef prices, the intensification of agriculture and improved management practices for cattle, the surge of the tourism industry, the establishment of regional conservation areas, and implementation of innovative laws and environmental policies (Calvo-Alvarado et al., 2019). These background conditions created favorable socio-economic and political conditions for the ACG process of large-scale forest recovery and consolidation. As stated by researcher Jennifer Power, “ACG’s outward focus has contributed to their success.” (J. Power, 2021, Personal Communication).

For local landowners who were seeing loss of income from cattle ranching, selling their land to become part of ACG was an acceptable economic alternative. Other enabling factors aligned to move the ACG agenda forward, including low population density in the region, poor soils, and isolation from central political forces in the capital city, San José (Janzen and Hallwachs, 2020). ACG was far from markets, had steep volcanic slopes, lacked big navigable

rivers, and lacked a source of exploitable indigenous labor (Janzen and Hallwachs, 2016). Natural regeneration of the dry forests in ACG was facilitated by four main factors: 1) more than 100 species of common dry forest trees, vines, and shrubs in ACG have wind-dispersed seeds; 2) vertebrate frugivorous seed dispersers in ACG are accustomed to moving through the hot and dry pastures and readily disperse seeds there; 3) spores of mycorrhizal fungi that develop mutualistic relations with roots are readily dispersed by wind; and 4) seedlings of dry forest trees are adapted to hot and dry conditions presented by pastures (Janzen and Hallwachs, 2016). Cloud and rain forests in ACG also showed rapid recovery during natural regeneration because of effective seed dispersal by native fauna (Sierra Parra et al., 2021).

The unique partnerships developed during the formation and institutionalization of ACG have been critical to its continuing success. “The hybrid model of partnerships between ACG staff, FPN, and GDFCF has allowed us to leverage stability, flexibility, and visionary thinking to create and maintain ACG,” said Roger Blanco, Co-Director of ACG Research Program (R. Blanco, 2021, Personal Communication).

Parting shot

"It was a surprise, with so many years in this work; we are filled with pride and satisfaction. We are very grateful to Dan and Winnie and ACG, because without them it would not have been possible…We all feel pride because our work is silent every day but today it was seen and recognized."

—Gloria Sihezar, Parataxonomist

Figure 12. Gloria Sihezar received an award in 2019 for her contribution to biodiversity conservation. Gloria has been a parataxonomist in ACG for 27 years. Photo credit: GDFCF

Key lessons learned

- *Conservation and restoration are strongly aligned and cannot succeed without the cooperation, participation, and engagement of resident neighboring communities and stakeholders.* These constituencies must be compensated for their labor, their opportunity costs of purchase, and restoration (and larger scale conservation) in currencies that are appropriate for each context (Pringle, 2017).

- *Protect remaining habitat fragments and harness nature's resilience.* Due to the persistence of remnant populations in the landscape matrix of ACG, initiating ecological recovery did not require aggressive micromanagement nor sophisticated techniques. Suppressing anthropogenic fires and reducing fuel loads were sufficient actions to launch dry forest regeneration, aided by seed dispersal by wind and animals (Pringle, 2017).

- *Grow protected areas strategically to achieve regional socioeconomic and ecological integrity and connectivity that directly benefits local communities.* Remnant forest areas can be upgraded and upsized in a strategic way to consolidate larger units, connect isolated areas, and rescue degraded or poorly protected areas to support effective biodiversity conservation and provide economic benefits to local and national communities through ecotourism. Strategic acquisition of properties in ACG plugged key gaps between three national parks representing the three major tropical terrestrial ecosystems (Pringle, 2017).

- *Commit to actions focused on long-term objectives and local engagement.* A small number of people have made lifelong commitments to projects that will be sustained beyond their lifetimes and form the core of the efforts to restore ACG.

- *Develop creative financial strategies.* Heterogeneous and innovative financing can drive the upgrading and consolidation of protected areas. Innovations include partnerships between governments, non-profit organizations, and private citizens that channel intellectual and financial capital towards landscape-scale recovery and protection.

- *Learning about biodiversity creates knowledge about its uses and value to society.* The concept of conservation within ACG includes the importance of knowledge, education, and improved management of natural systems.

- *Engage and empower young people.* Protecting nature involves creating a bioliterate society and reawakens dormant biophilia by stimulating children's interest, as well as their parents' interest, in nature as early and as often as possible (Pringle, 2017).


AREA DE CONSERVACION GUANACASTE
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Learn more

Further information and resources

Guanacaste Dry Forest Conservation Fund website
https://www.gdfcf.org/

Map of major ecosystems in ACG
http://www.gdfcf.org/rain-forest

SINAC Área de Conservación Guanacaste Website
https://www.acguanacaste.ac.cr/index.php

Video: Guanacaste Conservation Area (2018)
https://www.youtube.com/watch?v=7neGyHymk1k

Video: Costa Rica: Paradise Reclaimed
(1987 WNET Nature Episode)
https://archive.org/details/CostaRicaParadiseReclaimed

Video: ACG Fire Protection Program
https://www.youtube.com/watch?v=XwcXhMGXzk4&t=6s

Video: Restoration of Mangroves in Bahía Tomas
https://www.youtube.com/watch?v=mbhHmgELO50&t=311s

Video: Mangrove Restoration in Cuajiniquil
https://initiative-mangroves-ffem.com/en/restoration-of-the-cuajiniquil-mangrove-already-impressiveresults/

Video: ACG Restoration and Silviculture Program
https://www.youtube.com/watch?v=MvAr0wSvv40&t=14s

Digital repository for ACG
http://copa.acguanacaste.ac.cr/

Vegetative key and descriptions of tree species of the tropical dry forests of upland Sector Santa Rosa, Área de Conservación Guanacaste, Costa Rica. 2001. Brian J. Enquist and Jon J. Sullivan
https://www.acguanacaste.ac.cr/paginas_especie/plantae_online/EnquistSullivanTreeKey.pdf

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