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The Galapagos Verde 2050 Project






Volume 1
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GALAPAGOS VERDE 2050

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Foreword

In 2013, the Charles Darwin Foundation (CDF), in close collaboration with the Galapagos National Park (GNP), began the 'Galapagos Verde 2050 Project (GV2050)'. This initiative intended for the development of a project of applied science, which encompasses two research components: the ecological restoration of Galapagos and the development of sustainable agricultural practices. Both components have their own long-term designs and objectives, but with the ultimate aim of contributing to the conservation of the archipelago, and supporting the well-being of the human population until the year 2050.

Over time, other public and private institutions have become involved in this scientific endeavor. In July 2016, the CDF renewed the agreement with the Ecuadorian Government to continue its work generating research and contributing to the local and national conservation and sustainable development for the next 25 years. Within this context, this atlas of the Galapagos Verde 2050 Project is not only an atlas for the project itself, but also a document that gives insight into the details and dimensions of the current conservation actions being implemented in Galapagos and Ecuador.

The project aims to restore degraded habitats and endangered species, and therefore recover the ecosystem services of these habitats, as well as assess the influence of water-saving technologies in the restoration of these degraded areas and in the development of sustainable agriculture practices. Even though such areas are highly altered, there is always space to plant plants and generate an environment that favours the presence of fauna such as birds, reptiles, insects and other invertebrates. By doing this, the GV2050 project produces information and research that can then contribute to the conservation of Galapagos and sustainable use of its natural capital. Furthermore, it enhances the role urban areas can have in improving the wellbeing of the local human population and contributing to the recovery of native biodiversity lost due to urban development in the Galapagos.

Ultimately, I direct you all towards the contents of this document, and to take advantage of the knowledge provided herein, as an example of a collaborative work and scientific endeavors that aim for a better future here in the Galapagos.

We believe that investment in a project of this nature is crucial in order to counteract the effects of a growing human population. The ecological efforts and long-term sustainable practices that will stem from the GV2050 project will secure the natural capital of the Galapagos, and protect endemic ecosystems and critical species.

Dr. Arturo Izurieta Valery
Charles Darwin Foundation Executive Director

Project Leader

Leader of the Galapagos Verde 2050 Project and General Coordinator of the Natural History Collections

Patricia is an Ecuadorian researcher who arrived in the Galapagos in 1996 to work on her doctorate thesis on the 'human impact on native, endemic and introduced flora on the Galapagos Islands'. She later became part of the CDF staff as curator of the CDF Herbarium has since initiated a project for the conservation of threatened species.

She is a specialist in ecology and conservation biology, and has developed numerous applied biology projects on threatened plant species, animal-plant interactions and ecological restoration.

She was professor of botany at the Central University of Ecuador and is currently leader of the project Galapagos Verde 2050 as well as General Coordinator of the Natural History Collections of Galapagos at the CDF.

"Galapagos Verde 2050 contributes to two key objectives of the National Park's 'Management Plan for the Protected Areas of Galapagos'. This project mainly targets the objectives '1.1 Conservation and Restoration of Ecosystems and their biodiversity, and 5.1 Science for Sustainability.' This project, through both ecological restoration and sustainable agriculture, represents an applied research initiative. This initiative supports the conservation of Galapagos and improves economic opportunities for local communities, through the use of technology and the development of sustainable practices. I firmly believe that investment in these strategies is very important for the reestablishment of endangered species, the restoration of ecosystems, the socio/ecological enrichment of urban areas, and the recovery of ecosystem services in rural areas in the Galapagos Islands."

Fundación Charles Darwin Foundation GALAPAGOS

Proyecto GALAPAGOS VERDE 2050 Project

Dr. Patricia Jaramillo Díaz
Biodiversity and Restoration Senior Researcher, Charles Darwin Foundation.

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Executive Summary

The Galapagos Verde 2050 (GV2050) project started with a collaboration between the Fuente de Vida of Ecuador (representing the Dutch organization Groasis), and the Charles Darwin Foundation (CDF), with initial financing for the pilot project generously donated by the COmON Foundation. The objective of this pilot project was to 1) test the effectiveness of a water-saving technology on the growth of key native and endemic plants in degraded ecosystems (ecological restoration) and 2) to test the production of cultivated plants in local farms in the Galapagos (sustainable agriculture). Considering the potential use of water-saving technology as a widespread conservation tool for the flora in the Galapagos, the CDF coordinated with the Galapagos National Park (GNP) for this initial study beginning in 2013.

During 2013, a local farm on Floreana Island was used as a model to test the effectiveness of the water saving technology Groasis Waterboxx® (Groasis) for ecological restoration in rural areas, before implementing these methods in protected GNP areas. Another initial study site was established on Santa Cruz, where the technology was tested in a small touristic site called "Los Gemelos", an infamous area for the spread of the invasive invasive blackberry species (*Rubus niveus*) (Buddenhagen & Jewell, 2006; Gardener *et al*., 1999; Rentería & Buddenhagen, 2006). As a part of urban ecological restoration, invasive species were eliminated and both endemic and native species were planted in the Harbor Captaincy premises on Santa Cruz, and the Galapagos National School gardens. Restoration of a former waste landfill was also implemented on Baltra Island.

After the success of the pilot project, Galapagos Verde 2050 was officially structured as a three-phased long-term initiative of applied science, restoration, adaptive management, and conservation beginning in 2014 and planned until 2050 (Figure 1). It focuses on two primary components: 1) ecological restoration of urban, rural and protected areas, and 2) the development of sustainable agriculture.

PHASE 1: June 2014 – November 2017

Ecological restoration began in Santa Cruz, Baltra, Plaza Sur and Floreana Islands. The project worked to restore keystone species on these islands, including *Opuntia echios* var. *echios* on Plaza Sur, and emblematic species such as *Scalesia affinis* ssp. *affinis* on Santa Cruz.

Furthermore, restoration began in 'special use zones'(SUZs), such as waste landfills on Floreana and Baltra Islands, and a gravel mine and cemetery on Floreana. In urban areas, the project worked with the local community to create ecological gardens in the towns on Santa Cruz, Floreana and Baltra Islands. In rural areas, the project worked in the restoration of agricultural areas invaded by introduced plant species, removing and replacing them with endemic species. The first example of this was in a farm on Floreana where *Scalesia pedunculata* var. *pedunculata* was planted with other native and endemic species of that vegetation zone.

Within the sustainable agriculture component, the project worked with water-saving technologies in farms on Floreana and Santa Cruz, growing plantain, papaya, tomato, cucumber, watermelon, bell pepper and others. It was found that plants grown with the water-saving technology had increased net production compared to those grown with traditional irrigation techniques, providing an overall positive monetary return. This reduces dependence

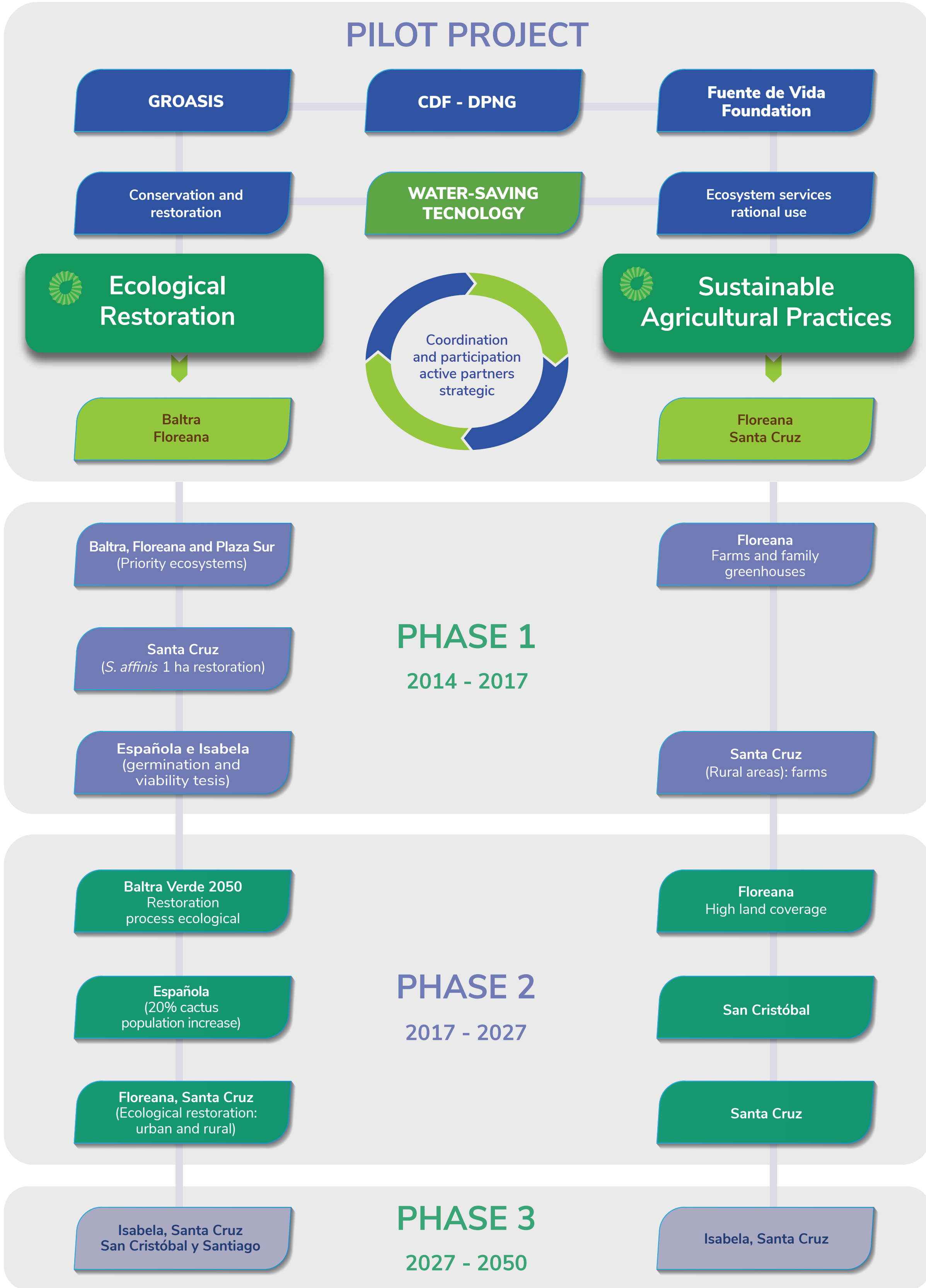


Figure 1. A framework timeline of the GV2050 project over its three phases.

on imported products, reduces the risk of introducing invasive species, and saves water. This part of the project showed how an initial investment in technologies as such can lead to productive and ecologically-sustainable farming in the future.

PHASE 2: November 2017 – July 2027

The project is currently in phase 2 and continues to work on the sites selected during phase 1, monitoring the plants, replacing dead ones, updating the technologies and removing invasive species. The results obtained from phase 1 are being analyzed to prioritize study sites and to identify which technologies should be used for each site, terrain type and with which plant species. For example, the subproject of 'Baltra Verde 2050' is being developed to test which technologies and plant species are best for restoring ecosystems under highly arid conditions.

The project currently has more than 15 gardens located in the towns of Santa Cruz, Floreana and the Ecological Airport of Baltra, contributing to the recovery of the ecosystems and their ability to generate ecological services such as increased pollination. These gardens also improve the general landscape aesthetic for local populations and provide opportunities to educate locals about the endemic and native flora of the archipelago. Within this second phase, ecological gardens have also been created in the town of San Cristobal.

Restoration has been extended to Isabela and Española Islands. In Isabela, the restoration of the threatened endemic species *Galvezia leucantha* sp. *leucantha* has begun, and in Española, the project is working to restore the population of the keystone species *Opuntia megasperma* var. *orientalis* and *Lecocarpus lecocarpoides*.

In the sustainable agriculture component, the work of phases 1&2 is being continued on farms in Santa Cruz and Floreana. Based on the successful results thus far, the project plans to increase the participation of farmers on inhabited islands.

PHASE 3: August 2027 – December 2050

The final and most extensive phase of the project will continue the work of phases 1 and 2. The project plans to extend work to the uninhabited island of Santiago where invasive species continue to threaten its ecosystems. This phase will also introduce further restorative actions across San Cristobal and Isabela.

Within the sustainable agriculture component, the project plans to extend the use of technologies across the farmlands of the four inhabited islands to help ensure Galapagos is less dependent on imports from mainland Ecuador. It is therefore critical that enough materials and funding are available to ensure the use of these sustainble technologies, so that long term goals can be met.

The Project

Background

The unique biodiversity of the Galapagos Islands is recognized worldwide and is the reason why the archipelago has been listed as a UNESCO World Heritage Site. However, the impacts of growing human populations, increasing tourism and introduced species threaten the endemic and native diversity of its ecosystems (Nash, 2009; Toral-Granda *et al*., 2017; Trueman *et al*., 2010). Thus, it is especially critical that efforts be made to protect the extraordinary flora and fauna of the Galapagos Islands.

While many of the threats of introduced herbivores, such as feral goats, have been eradicated from some of these islands, populations of many keystone endemic plant species remain low and may not recover without intervention (Cruz *et al*., 2009; Lavoie *et al*., 2007). Prior to GV2050, restoration efforts have been sporadic and have been conducted at an insufficient scale which has prevented the impact needed for successful ecosystem restoration and population recovery (Jaramillo *et al*., 2015a). The fast rate of ecosystem degradation, in comparison to the slow and complex restoration process creates a challenge, especially when working with fragile ecosystems such as those in the Galapagos archipelago (Gardener *et al*., 2010b; Hobbs, 2008; Hobbs *et al*., 2009). Periods of drought and lack of freshwater sources have made previous restoration efforts especially difficult (Kastdalen, 1982; Trueman & d'Ozouville, 2010). Furthermore, the degradation of ecosystems due to land use has also been a fundamental problem that inspired the GV2050 project.

What is Galapagos Verde 2050?

Galapagos Verde 2050 (GV2050) is a multi-institutional and interdisciplinary project of the CDF which actively contributes to the conservation of the natural capital of the Galapagos archipelago and the well-being of its human population.

GV2050 works to restore ecosystems and promote sustainable agricultural practices that allow the community to live in harmony with nature. GV2050 aims to use recently developed technologies designed to overcome the barrier of limited freshwater availability. These include various water-saving technologies that have already been successfully used around the world to increase the survival and growth of endemic and native plant species by increasing water availability in arid environments. The use of these technologies can accelerate ecological restoration, increase agricultural productivity and reduce the watering costs required in the arid conditions of the Galapagos archipelago.

GV2050 is a tri-phase project that currently, in phase 2, has established more than 80 study sites on seven islands: Baltra, Española, Floreana, Isabela, Plaza Sur, San Cristobal and Santa Cruz. The project is divided in two main research components: 1) ecological restoration of degraded ecosystems and 2) the development of sustainable agriculture. Both components of the GV2050 project address relevant issues in the conservation of the Galapagos Islands; the former, restoring native and endemic plants in degraded ecosystems and the latter using water saving technologies to increase crop production. All of the project's work is executed by the Charles Darwin Research Station (CDRS) of the Charles Darwin Foundation (CDF), with the collaboration of strategic partners; most notably, the Galapagos National Park (GNP), Biosecurity Agency for Galapagos (ABG) and the Ministry of Agriculture in Galapagos (MAG).

Threats to Galapagos Ecosystems

Change in land use

Human population growth has increased exponentially during the last decades and along with this, land use is progressively a more outstanding problem (Hardter & Sánchez, 2007). Naturally, a growing population comes with an increasing amount of basic needs that must be met and provided by local authorities, such as education, food, health and waste management (Hardter, 2008). Projections show that the amount of waste generated in the Galapagos archipelago doubles every ten years. This is not only due to the increasing population, but to increasing consumption levels (Hardter *et al.*, 2010). This waste has to be managed and/or stored somewhere; therefore, land dedicated to such management has caused significant levels of ecosystem degradation in the Galapagos Islands (Ragazzi *et al.*, 2014).

For example, all inhabited islands in the Galapagos have waste landfills that present extensive ecosystem degradation within their area and surrounding areas. These areas have been defined by thee GNP as 'special use zones' (SUZs) (Jaramillo, 1998b). Other SUZs are gravel mines, created for extraction of material for the construction of houses, buildings, roads, etc., (Jaramillo, 1998; Jaramillo *et al*., 2015a; Jaramillo *et a*l., 2015b). Thus, the GV2050 project has selected SUZs as study sites in order to carry out ecological restoration efforts using water-saving technologies (Jaramillo *et al*., 2015a).

Another remarkable example of the degradation of ecosystems due to land use is Baltra Island itself. This island was used as a military base by the U.S. during World War II and the lasting impacts of this to the natural ecosystems of the island remain visible today (Idrovo, 2013). Therefore, the GV2050 project works towards the ecological restoration

of Baltra on different study sites, including the old waste landfill (Jaramillo *et al*., 2013a; Jaramillo *et al*., 2017).

Limited freshwater sources

Freshwater in the Galapagos Islands is scarse, representing one of the major problems for the human population (d'Ozouville, 2008; Delgado & Loor, 2017). In particular, agricultural productivity is affected by the limited availability of this essential resource. There is an urgency to implement actions to mitigate this issue, especially in the face of an exponentially increasing human population and its higher food demand (Jaramillo, 2015; Jaramillo *et al*., 2014).

Consequently, the use of water-saving technologies represents a promising way to save water and increase food production, while saving money (Hoff, 2014; Land Life Company, 2019). It is important that an applied science project such as GV2050 looks to benefit the natural capital of the archipelago, but also the development of the human population. The GV2050 project exemplifies a model of applied science, community and adaptive management, as it considers conservation priorities as well as human needs and major problems such as limited freshwater availability (Jaramillo, 2015; Jaramillo *et al*., 2015b).

Invasive species

Invasive species constitute the greatest threat to the Galapagos biodiversity. Currently there are around 810 introduced plant species, of which at least 270 are naturalized and 113 are invading the natural areas of the archipelago (Buddenhagen *et al*., 2004; Causton *et al*., 2018; Guézou & Trueman, 2009; Jaramillo *et al*., 2018b; Toral-Granda *et al*., 2017).

Table 1. Total area (ha) and percentage of area degraded by human activities (in parentheses) of the vegetation zones on the four inhabited islands of the Galapagos Archipelago. Adapted from Watson *et al.* (2009).

	VEGETATION TYPE		
ISLANDS	Humid	Transition	Arid
Floreana	1.170 ha (38%)	72 ha (2%)	57 ha (0,5%)
Isabela (South)	8.173 ha (21%)	2.185 ha (4%)	162 ha (0,2%)
San Cristobal	5.552 ha (94%)	1.015 ha (24%)	888 ha (2%)
Santa Cruz	8.381 ha (88%)	3.121 ha (25%)	319 ha (0,4%)

On inhabited islands, the highlands (humid vegetation zone) are the most degraded ecosystems in the archipelago. About 94% of the highlands on San Cristobal have become degraded due to the presence of invasive plant species, and 21% on Isabela (Table 1) (Gordillo, 1990). The ecosystems of the highlands have not only been transformed by invasive species, but also by the expansion of agriculture. The establishment of agricultural land has nearly caused the complete loss of some unique natural ecosystems, such as a Scalesia forest, which currently covers less than 1% of its original distribution on the island of Santa Cruz (Gardener *et al*., 2010a; Gardener *et al*., 2010b; Mauchamp & Atkinson, 2009; Rentería & Buddenhagen, 2006).

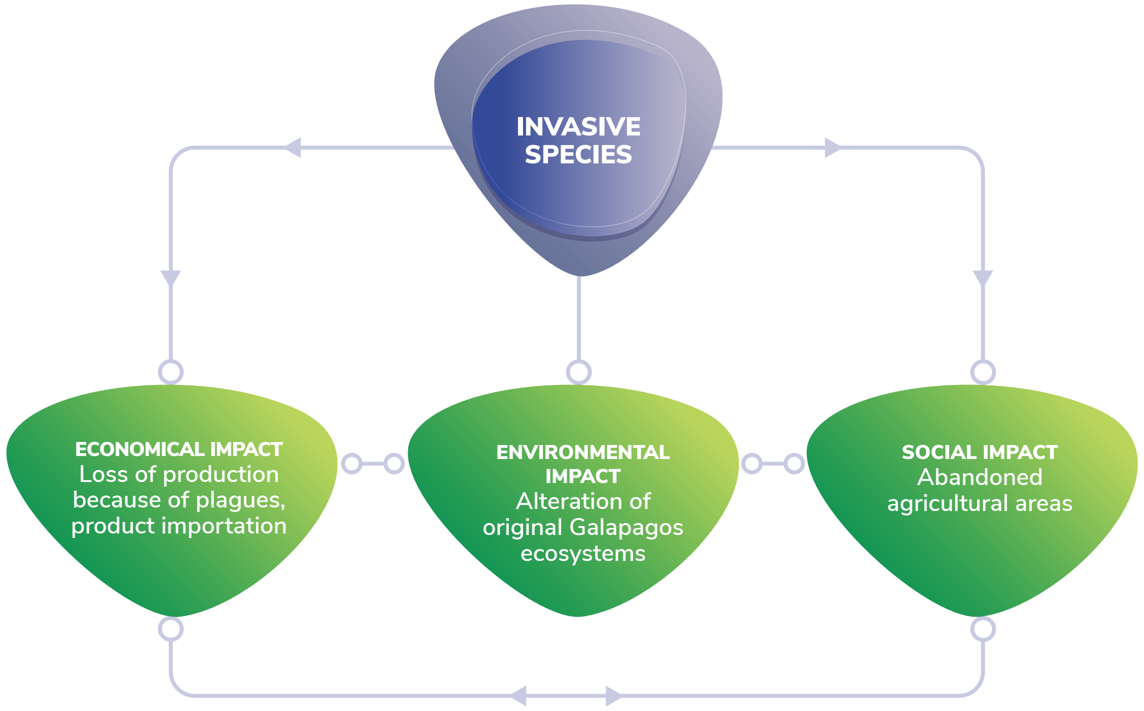


Figure 2. Positive feedback cycle of the impacts of invasive species in the Galapagos archipelago.

Furthermore, the arrival of invasive species has had negative socio-economic impacts on a provincial scale. The spread of invasive species can lead to the loss of crops, and even to the abandonment of farmland, leading to a greater dependence on the imports of food products from mainland Ecuador to answer the demand from the growing human population. This dependence further increases the risk of invasive species introduction into Galapagos, via the packing and shipment of mainland products. Overall, these elements create a positive feedback cycle that further enhances negative environmental, social and economic impacts (Figure 2). GV2050 aims to mitigate these impacts by removing or preventing the spread of invasive plant species where possible, which will in turn aid ecological restoration.

Why is GV2050 Important to Galapagos and to the World?

The Galapagos Islands are part of the Republic of Ecuador and consist of a network of islands that make up a globally significant ecosystem and a famous UNESCO World Heritage Site. In this unique territory, management requires a balance between the development of the local community and the conservation of its natural capital. This natural capital is ultimately the basis for the development of local communities and must continue to provide the best conditions to support human well-being, at present and in the future (DPNG, 2014; González *et al*., 2008; Tapia & Guzmán, 2013; Tapia *et al*., 2009; Tapia *et al*., 2008).

The GV2050 project is currently implemented at a regional level in Ecuador. However, the project was designed to consider its impacts at national and global levels. The objectives and visions of the project align on a regional level with the National Park's 'Management Plan for the Protected Areas of Galapagos' (DPNG, 2014). At a national level, it aligns with the National Plan for Good Living of Ecuador (SENPLADES), and at a global level with The Sustainable Development Goals of the United Nations (Naciones Unidas, 2018; SENPLADES, 2013).

Conceptual and Theoretical Framework

Linking GV2050 with the Management Plan for the Protected Areas of Galapagos

The Management Plan for the Protected Areas of Galapagos was published in 2014 by the Galapagos National Park. The plan outlines an 'Action Strategy', which acts as a basic guideline for programs or projects related to the application of conservation and/or restoration (DPNG, 2014).

The two main components of the GV2050 project, ecological restoration and sustainable agriculture, were created in correlation to the objectives 1.1 Conservation and Restoration of Ecosystems and their biodiversity, and 5.1 Science for Sustainability, respectively (Figure 3).

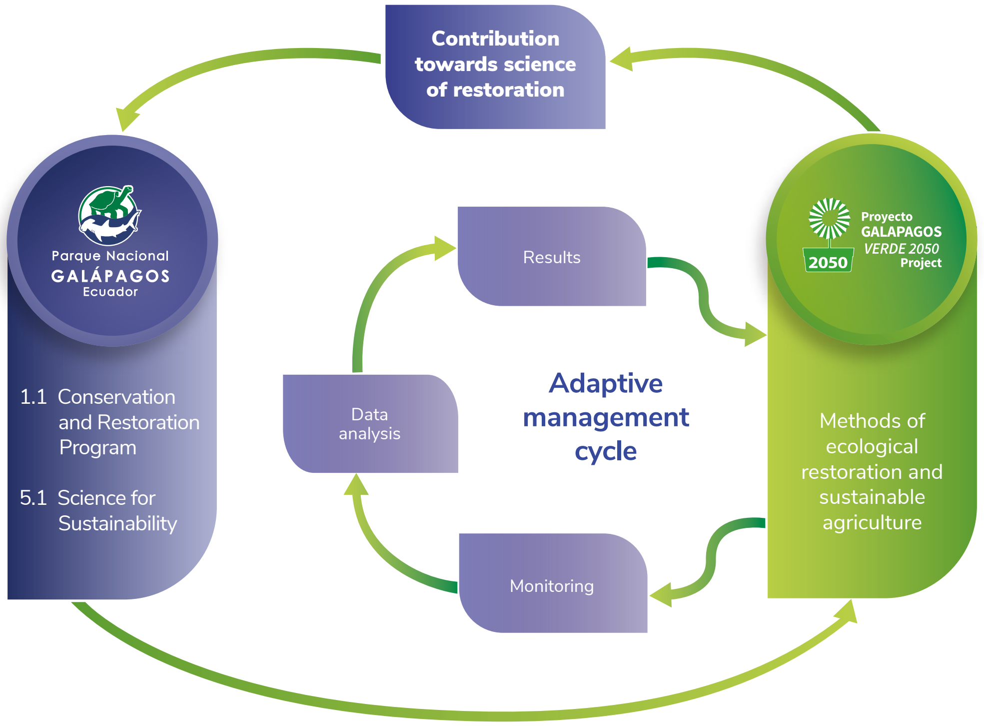


Figure 3. Galapagos Verde Project linking to the Management Plan for the Protected Areas of Galapagos (DPNG, 2014).

Four returns of the GV2050 Project

GV2050 works in accordance to a theoretical framework known as "the four benefits or returns," which is also widely applied by the Ecosystem Return Foundation (ERF). This framework promotes the recuperation of degraded ecosystems and landscapes through ***environmental***, ***social***, ***economic*** and ***inspirational*** benefits, or returns (Brasser & Ferwerda, 2015; Ferwerda, 2015; Ferwerda & Moolenaar, 2016). All of the work carried out by the GV2050 project, and every study site established, always seeks to contribute to at least one of these returns. In addition to the principal environmental benefits of ecosystem restoration and sustainable agriculture, the project's work also produces other social, economic and inspirational benefits, which are outlined as following:

Social

Keeping a close link with the local community is of great importance to GV2050. We recognize the value of sharing the research and knowledge we generate by involving local community members in the activities of the project. This not only benefits people by learning more about Galapagos and the research done, it also benefits the project because the communities' ecological awareness increases so does their cooperation with the project activities themselves. This is the primary reason behind working with local school students in the creation of ecological gardens and educating them about the native and endemic species of the archipelago.

These social benefits also occur on a political level. GV2050's work in special-use zones (SUZs), has set an example of how conservation can be incorporated into the inevitable expansion of human infrastructure on the islands. For example, waste landfills are necessary for disposal of human waste, however our implementation of study sites in these areas shows that conservation efforts can be incorporated into non-environmental decision-making. Furthermore, GV2050's research into sustainable agricultural practices will be used directly by the Ministry of Agriculture in Galapagos (MAG) to work towards a system for sustainable agriculture in the Galapagos Islands. The results collected from GV2050 will help contribute to the management of these islands, which is carried out by the GNP—the largest governing body in Galapagos (Figure 4).

Economic

The cost-benefit analysis of using water-saving technology for selected crops has so far shown a positive monetary return. This has large implications in the farming community of the Galapagos, and contributes to the self-sufficient alimentation, thus decreasing the dependency on mainland imports. Furthermore, the use of water-saving technologies reduces the amount of water used in farming, compared to traditional irrigation methods, which saves an additional expense. Rural ecological restoration on farms that cater to tourists, and the creation of ecological gardens both contribute as important tourist attractions, which help fuel the largest financial sector of the Galapagos in a sustainable way. This restoration of degraded areas or integration of plants within farms reduces the vulnerability of areas to invasive species, which are costly to remove.

This is why an initial investment in technologies and the implementation of GV2050 efforts is crucial to ensure this long-term economic gain.

Inspirational

The conservation of emblematic native and endemic species is a matter of pride for the people of Ecuador and citizens of the Galapagos, but also for the world as a whole (DPNG, 2014). Galapagos is a Natural World Heritage site, making it an international cultural landmark. By contributing to the preservation of the natural beauty and diversity of this site, GV2050 is directly benefitting the 271,238 tourists who visited the GNP in the last year (DPNG, 2019). One of the unique aspects of the Galapagos population is that despite being part of a developing country, it prioritizes the values of conservation beyond that of more developed countries (Tapia *et al*., 2008). Continuing to instill this passion for nature in the younger generations is a fundamental essence of the Galapagos culture that GV2050's work with children directly contributes to.

Figure 4. GV2050 working with local high school students to restore the degraded areas surrounding their school, an activity that aligns with the 'four benefits or returns'.

Objectives

GENERAL

Contribute to the conservation of the Galapagos terrestrial ecosystems and to the well-being of the human population through the restoration of degraded ecosystems, the recovery of endangered plant species populations and the development of sustainable agricultural practices.

SPECIFIC

1. ***To restore degraded ecosystems and species in the Galapagos Islands***

   - Restore endangered plant species populations.
   - Restore degraded ecosystems within protected, rural and urban areas.
   - Control and limit the arrival of invasive species in urban and rural areas of high ecological value.
   - Assess the effectiveness of water-saving technologies on the recovery process of endangered plant species.

2. ***To promote and enhance the uptake, development and continued use of sustainable agricultural practices***

   - Study the effectiveness of water-saving technologies on agricultural productivity.
   - Assess the economic costs and benefits of using water-saving technologies in agricultural practices.
   - Integrate local stakeholders (i.e. farmers) in sustainable practices that will conserve natural rural areas for human wellbeing.
   - Improve productivity and ecosystem recovery of the landscape by planting perennial crops together with native and endemic tree species.

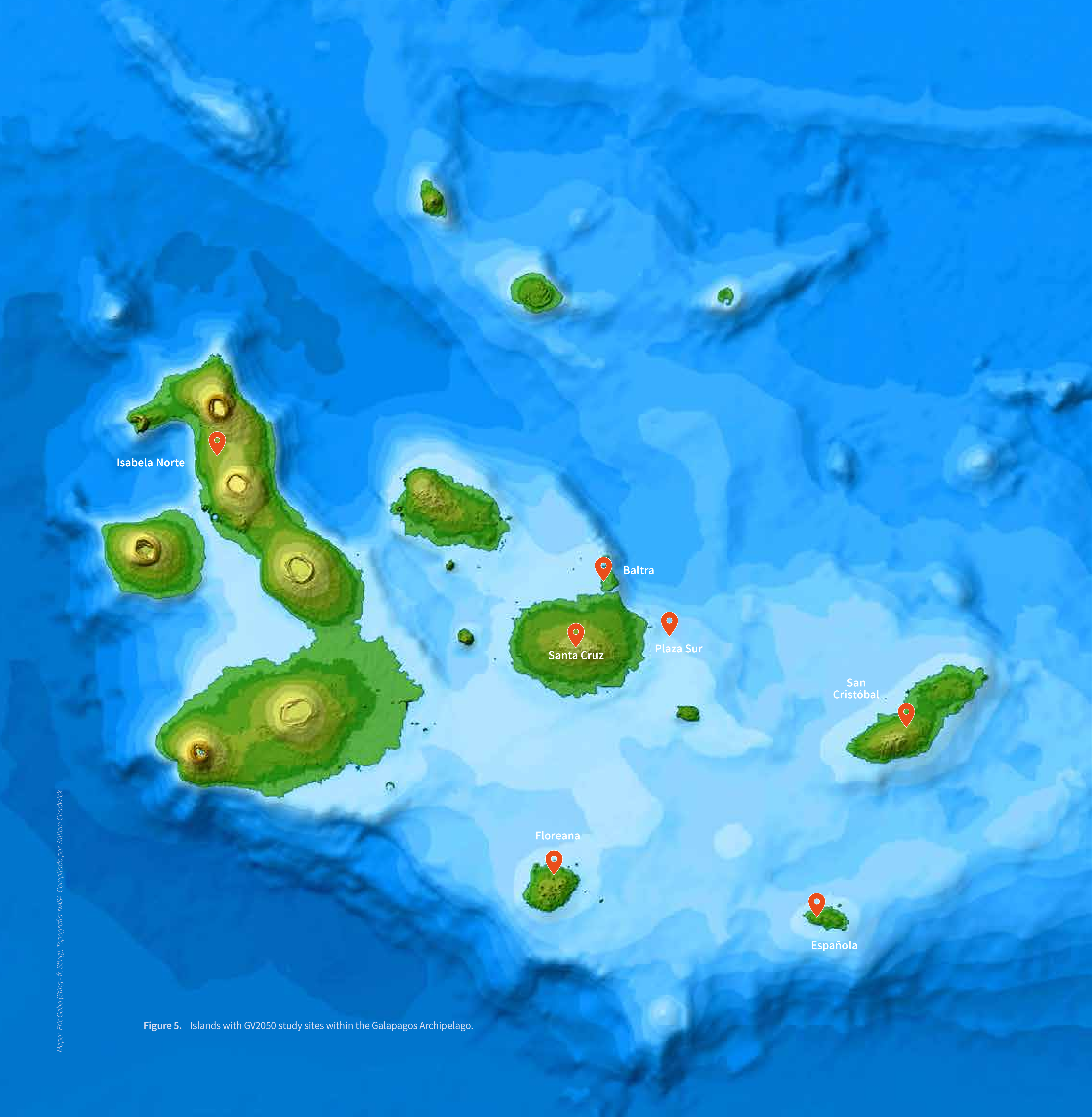


Figure 5. Islands with GV2050 study sites within the Galapagos Archipelago.

Where are we?

The Galapagos archipelago is located in the Pacific Ocean, 1000 km west of mainland Ecuador (DPNG, 2014). The GV2050 offices are based within the Charles Darwin Research Station on Santa Cruz Island, and the fieldwork study sites of the project currently cover seven islands: Baltra, Española, Floreana, Isabela, Plaza Sur, San Cristobal and Santa Cruz.

The ecological restoration component includes: Española, Plaza Sur, Floreana, Santa Cruz, Isabela, San Cristobal and Baltra, while the sustainable agriculture component includes the islands of Santa Cruz, Floreana and San Cristobal (Figure 5).

Research Components

Ecological restoration

Research on the current status of plant species in the island's humid zone concludes that the loss of endemic species is attributed to habitat degradation (Adsersen, 1990; Atkinson *et al.*, 2008; Buddenhagen, 2006; Buddenhagen & Yanez, 2005; Bungartz *et al.*, 2012; Jaramillo & Tapia, 2015; Liu *et al.*, 2012; Mauchamp & Atkinson, 2009; Moll, 1990; Traveset *et al.*, 2015; Trueman, 2008; Watson *et al.*, 2010).

Restoration actions in the past, however, have been small-scale initiatives and too sporadic, and have not effectively made the impact vital for successful restoration (Gardener *et al.*, 2010a; Trueman, 2008; Trueman *et al.*, 2010). This is due to the relative ease and speed of restoration varies depending on factors such as the level of degradation (Dobson *et al.*, 1997; Hobbs *et al.*, 2006) (Figure 6).

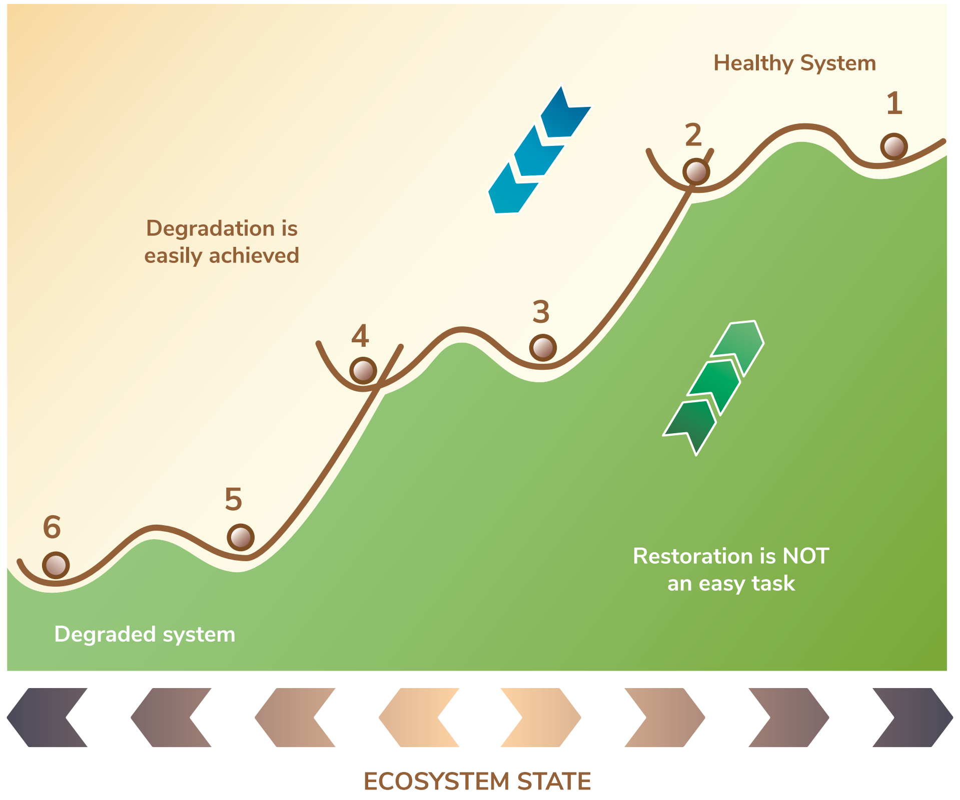


Figure 6. A visual representation of ecosystem resilience towards the process of restoration. Adapted from Whisenant (1999).

This is why more initiatives that efficiently counteract the rapid rate of degradation are needed. However, periods of drought and lack of freshwater sources make freshwater a scarce resource in the Galapagos archipelago. This project, thus, integrates the use of water-saving technology, as a means to counteract the water scarcity issue within the degraded zones. The use of water-saving technologies has been implemented successfully elsewhere in the world (Spain, Africa, Morocco, México), generating up to 90% of seedling survival on reforestation projects (Hoff, 2014; Land Life Company, 2019). Using this technology with endemic and native plants can accelerate the success rate of ecological restoration efforts and reduce the watering costs required in the arid conditions of the Galapagos archipelago (Jaramillo, 2015; Tapia *et al.*, 2019).

Rural ecological restoration

One of GV2050's priorities is the collaboration with local farmers to establish native and endemic plants amongst crops. These polycultures are of great economic value as the association creates organic matter that improves the soil structure, nutrient availability and microorganism presence. In addition to creating a vegetative cover, preventing soil erosion and maintaining moisture, polycultures also facilitate the flow of pollinators, between areas of human settlement and GNP land, contributing to the general recovery of the landscape (Linsley *et al.*, 1966; Traveset *et al.*, 2015). These features also provide economic incentives to farmers such as enhanced opportunities for agriculture-driven sustainble tourism (Gerzabek *et al.*, 2019).

Natural ecological restoration

Although 97% of Galapagos land cover is protected National Park land, some of this land still calls for restorative action. Degradation of these protected lands mainly comes from the risk of invasive species, land use and the loss of biodiversity that came from before the park was established in 1959 (Corley-Smith, 1990).

The GV2050 project works to restore whole ecosystems using a range of key native and endemic species of each area. However, sometimes restoration efforts of just one or a few keystone species may help restore whole ecosystems (Gibbs *et al.*, 2008). Therefore, the GV2050 project prioritizes species based on their ecological role and level of threat.

Urban ecological restoration

GV2050 recognizes the importance of including ecological restoration amidst the ever-growing urban areas of the Galapagos. The project works to ecologically restore SUZs, urban areas that have been completely altered by human activity and often neglected by conservation work. It is important to restore these places as the local human population continues to grow and more sites like these are likely to arise across the archipelago.

The creation of ecological gardens within towns of populated islands can engage and educate local people and visitors about the native and endemic flora of the islands, as well as increase the presence of pollinators and add to overall landscape enjoyment.

Where and why do we implement the ecological restoration component?

1. Baltra

The ecological restoration of Baltra Island is focused on zones with high priority ecosystems defined by the GNP. This project's plan is to restore five hectares as a model for the future restoration of the rest of the island.

Baltra Island has been devastated by human impacts and introduced species. The vehicle traffic and the large airstrip construction severely disturbed the soil surface and compaction (Jaramillo, 2009). Introduced species such as goats and cats have caused great changes to the ecosystem and the populations of endemic keystone species, such as land iguanas and *Opuntia* cacti, and other less visible but equally important species of lizards, birds and insects (Balseca, 2002; Gibbs, 2013a; Jaramillo *et al*., 2013a; Sulloway & Noonan, 2015). These populations began to decline in the early nineteenth century due to habitat destruction by introduced goats (*Capra hircus*). During the 1940s, the population of iguanas disappeared due to a combination of this habitat destruction and the construction of a U.S. military base during World War II (Cayot & Menoscal, 1994). The repopulation of land iguanas and eradication of feral goats constitute important first steps in the ecological restoration of Baltra (de Vries & Black, 1983; Phillips *et al*., 2005; Sulloway & Noonan, 2015).

2. Plaza Sur

Plaza Sur forms approximately 13 hectares of National Park land and was once home to a striking population of the emblematic tree cactus *Opuntia echios* var. *echios*. However, recent decades have seen a dramatic decrease in the population (Figure 16) (Snell *et al*., 1994; Snell & Snell, 1988; Sulloway & Noonan, 2015).

The Galapagos Hawk (*Buteo galapagoensis*), land iguana (*Conolophus subcristatus*) and *Opuntia echios* form a key food chain on the island (Christian & Tracy, 1980; de Vries, 1989). The 1920's and 30's human settlement in Santa Cruz subsequently caused the extinction of the hawk from Santa Cruz, and a poaching ban was placed on land iguanas. Together this caused a disproportionate growth of the land iguana population. The *Opuntia* fruits and cladodes that fall from the adult plants are being eaten by the iguanas at a faster rate than they can establish as new plants, resulting in a large decline in the *Opuntia* population as old individuals senesce without regeneration (Jaramillo *et al*., 2017; Sulloway & Noonan, 2015). The population decline has also been linked to the introduction of house mice (*Mus musculus*) and harsh El Niño weather events (Campbell *et al*., 2012; Snell *et al*., 1994). This is why GV2050 aims to restore the population of *Opuntia* to historic distribution and numbers (Jaramillo *et al*., 2017).

In turn, the restoration of this population should contribute to re-establishing the ecological integrity of the island and the capacity to sustain its ecosystem services (Anderson, 1995; DPNG, 2014; Sayer *et al*., 2004; Watson *et al*., 2010).

3. Santa Cruz

During the first phase, the project focused its efforts on the restoration of populations of *Scalesia affinis*. Until 1974, this species was considered abundant in Santa Cruz. However, *S. affinis* has dramatically declined with the expansion of urban settlement, human population and infrastructure. By 2007, only 68 individuals were found in the areas surrounding the main town of Puerto Ayora (Atkinson *et al*., 2010; Jaramillo, 2007; Jaramillo *et al*., 2018e; Jaramillo & Tye, 2006).

4. Floreana

Human use of natural resources is the primary driver of the degradation that jeopardizes the ecological integrity of Floreana. To mitigate this issue, the GNP and Floreana GADP requested that restoration be focused on 'special use zones' (SUZs), such as a gravel mine, a cemetery and a waste landfill. Previously, the GNP had conducted reforestation programs in these sites with unsuccessful results. Additional sites were selected based on a prioritization plan of the ecosystems in Floreana created together with two of the project's strategic partners.

Black gravel mine Floreana

5. Española

Similarly to Plaza Sur with *O. echios*, Española once had a large population of *Opuntia megasperma* var. *orientalis*. However, humans almost completely eliminated the giant tortoise (*Chelonoidis hoodensis*) and the introduced goats caused a decline in the population of *O. megasperma* (Jaramillo *et al*., 2018d). Both the cactus and tortoise are keystone species for the ecosystem and have a very important relationship on the island (Estupiñan & Mauchamp, 1995; Gibbs *et al*., 2014). The cacti are an important food source for recovering tortoise population and the tortoises promote cactus establishment by aiding with seed dispersal. The reduced population of cacti on Española presents a major obstacle for the full recovery of the endemic tortoise species—the target of a dedicated conservation effort over the last 50 years (Gibbs *et al*., 2014; Gibbs *et al*., 2008; Jaramillo *et al*., 2018d; Tapia, 2016).

6. Isabela

The endemic species *Galvezia leucantha* has a distribution now restricted to small populations of three subspecies: *G. leucantha* sp. *pubescens*, *G. leucantha* sp. *porphyrantha* and *G. leucantha* sp. *leucantha* present on Rabida, Santiago and Fernandina, and Isabela islands respectively (Guzmán *et al*., 2016; Jaramillo & Tye, 2018). *G. leucantha* is on the Red List of threatened species of Ecuador due to a limited geographic distribution and the threats of introduced invasive herbivores (Elisens, 1989; Guzmán *et al*., 2016; Jaramillo *et al*., 2018f; Jaramillo & Tye, 2018; León-Yánez *et al*., 2011; Wiggins, 1968). In particular, the subspecies *Galvezia leucantha* sp. *leucantha* is only found on Isabela and Fernandina islands. In 2015, the population was represented by only four individuals in a coastal area called Tortuga Negra beach (Jaramillo & Tye, 2018).

7. Ecological Gardens: Santa Cruz, Floreana, San Cristobal and Baltra

Understanding Galapagos as a unique socio-ecological system means that ecosystems and society must be managed as a single entity (González *et al*., 2008; Tapia *et al*., 2009; Tapia *et al*., 2008). From here onwards, the dichotomy between environmental conservation

and the human community development needs to be removed. GV2050 recognizes that the rate at which the population and its infrastructure spreads across the archipelago is not slowing down. Therefore, the future of conservation science in the Galapagos calls for work that integrates both the environment and humans (DPNG, 2014). This is why GV2050 works with the local population and institutions in the creation of ecological gardens as part of the urban ecological restoration component.

Highlighting the values of biodiversity and educating the ~30,000 Galapagos residents about conservation and sustainable lifestyles is a key responsibility for GV2050 since the conservation of the Galapagos archipelago beyond the year 2050 will be in their hands. This is a principal reason for working with local school students in creating ecological gardens, and educating them about native and endemic species of the archipelago.

These gardens are tools and means to inspire, engage and motivate local and visiting residents about the importance of enjoying the beauty of healthy urban and rural environments. The gardens of native and endemic flora of the archipelago offer spaces where social and natural systems coexist. Ecological gardens also help increase the number of pollinating species—contributing to an essential ecosystem service.

Sustainable Agriculture

The development of farmland through clearcutting not only removes endemic and native flora in the area, but also makes the land more vulnerable to the introduction and establishment of invasive species. Consequences vary; first, these abandoned plots by local famers become focal points of dispersion for invasive species to protected areas, intensifying the need for management by Galapagos National Park. Second, the abandonment of farming activities requires the island populations to be more dependent on the importation of crops and products from the mainland. Third, this importation becomes a prevailing mechanism by which invasive species arrive on the islands (Donald & Evans, 2006; Lundh, 2006; Pywell *et al*., 1995; Rosenthal, 2003; Weiss, 2018).

Given the geological, hydrological and climatic characteristics of the Galapagos Islands, there is limited availability of freshwater, in comparison with other tropical islands such as Hawaii (d'Ozouville, 2008; Guyottéphany *et al*., 2012). The lack of freshwater is a latent problem in agriculture too, making it difficult to have agricultural production all year round, this limitation decreases competitiveness in terms of quantity and quality with products entering from the continent, and this can diminish the quality of life and food security of the inhabitants of Galapagos (Sampedro, 2017).

Water-saving technologies are an innovative way of promoting sustainable agricultural practices by improving water use efficiency in crop production. GV2050 works with local farmers encouraging them to be more competitive and to make their farms self-sustainable. The use of water-saving technologies can aid the survival and productivity of crops while minimizing the water use, compared to traditional irrigation systems. For example, Groasis has been shown to save water consumption by 98% more than other common agricultural irrigation practices (Jaramillo, 2015; Hoff, 2013).

Methodological Framework

Implementation Framework for Restoration and Agriculture Activities

The GV2050 project was created based on the experiences and results obtained from the pilot project (Jaramillo *et al*., 2013b), that determines which institutions, priority areas and strategies need to be put in place. The framework of its strategic execution is as follows:

1. Institutional roles

Before the development and initiation of each phase, it is necessary to clearly establish the roles and competencies of the institutions involved. This coordination of activities and prioritization of common objectives optimizes resources and can lead to the application of results towards policymaking.

2. Priority areas and plant species

The study sites for the ecological restoration component were selected and established according to conservation priorities in the archipelago. One of the fundamental bases for the GV2050 project is the Management Plan for the Protected Areas of Galapagos.

This plan states that "the conservation of functional biodiversity acts as a buffer against anomalous disturbances ensures a natural long-term maintenance of ecosystem services that also benefit human systems. From this concept, not all species of an ecosystem have the same role in determining their functionality but there are ecologically essential species that acquire a main role in biodiversity conservation programs". This plan also states that, "any restoration project must take into account and meet the following requirements in sequential and hierarchical order before being carried out: (a) scientific viability, (b) territorial viability, (c) technical viability, (d) economic viability, (e) legal viability, (f) social viability, and (g) political viability" (DPNG, 2014). In that context, for the implementation of the three phases of the GV2050 project on remote and populated islands, GV2050 developed a specific Action Plan under which it has been executing the ecological restoration process in Galapagos (Jaramillo *et al*., 2015a; Jaramillo *et al*., 2017).

The selection of study sites within the sustainable agriculture component has been carried out in coordination with the Ministry of Agriculture (MAG), association of farmers in Galapagos and independent farmers through mutual planning and based on the Galapagos Bioagriculture Plan (Guzmán & Poma, 2015; MAGAP, 2014).

The key plant species selected for the ecological restoration process have mainly been chosen based on the ecological function that they have within their ecosystem (Gibbs & Grant, 1987; Jaramillo *et al*., 2018b; Jaramillo *et al*., 2015a; Vargas *et al*., 2014) and also based on their distribution within their own island and specific vegetation zone (Bungartz *et al*., 2013; Watson *et al*., 2010). The IUCN status of each species is also taken into account, that is, Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species, which are grouped as threatened and species in risk of extinction for the Galapagos Islands (Jaramillo, 2000; Jaramillo *et al*., 2018a; Jaramillo *et al*., 2018b; IUCN, 2017).

Implementation of Strategies for Restoration and Agriculture Activities

1. *Ex situ* activities before planting

In the case of ecological restoration, we extract seeds from land iguana and/or giant tortoise excrements collected *in situ*. We germinate these seeds in our laboratory at the Charles Darwin Research Station. We take care of the young plants until they are big enough to be returned to their island of origin and planted using water-saving technologies (Figure 7).

The life-cycle of an *Opuntia* cactus in GV2050 Project

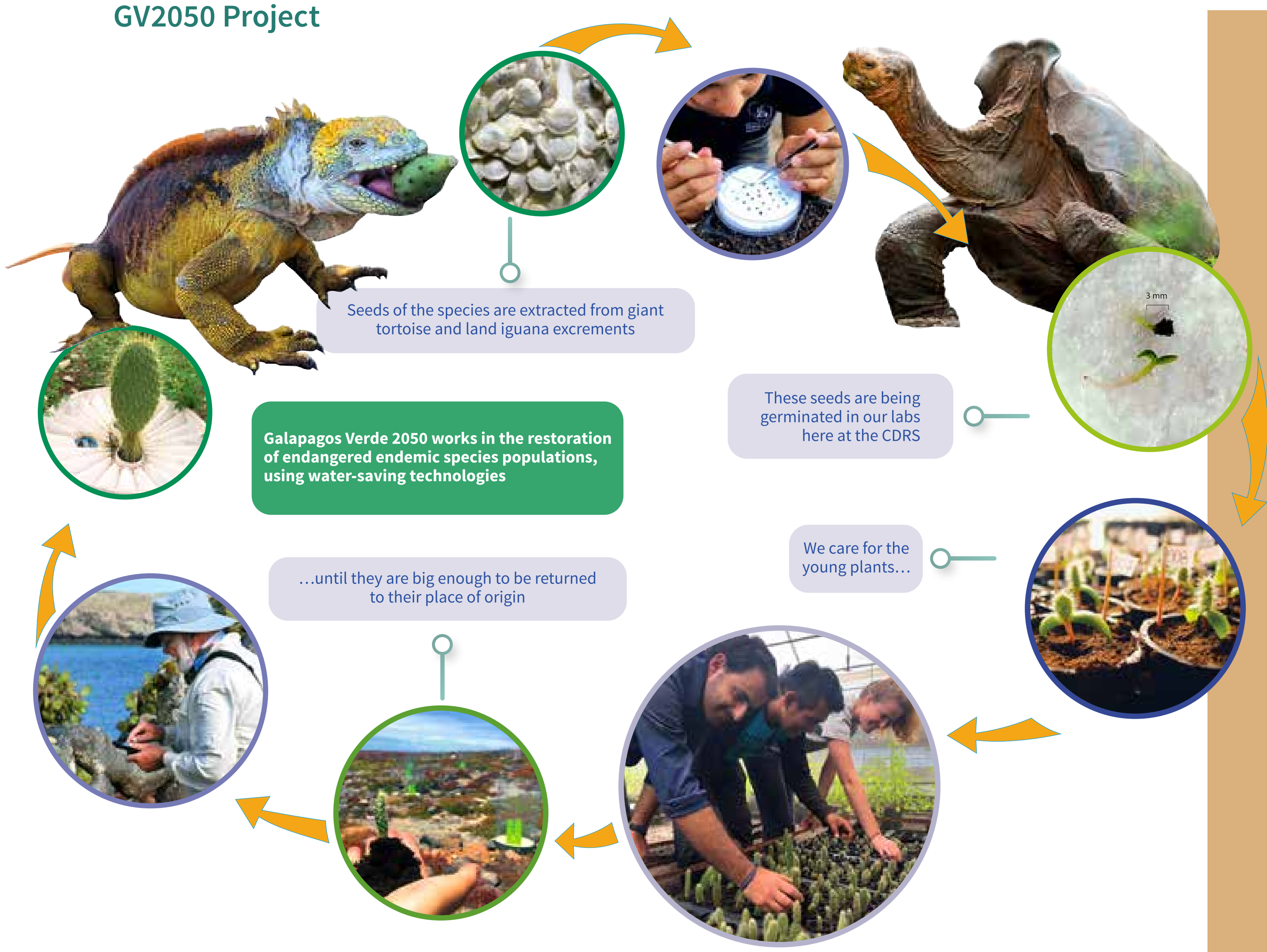


Figure 7. Seed extraction, germination and seedlings´ growth before *in situ* planting at the islands of origin.

In the case of sustainable agriculture, plant species are selected based on farmers' needs according to the local population's food demand. Therefore, we do not carry out *ex situ* germination for crops, as we provide the water-saving technologies to enhance farmers' productivity, using less water and reducing their costs. We also provide advice on which technologies would help them the most in improving their productivity, crop quality and save money.

2. Planting and monitoring

At the study sites, planting follows a previously established experimental design that is unique for each island. This planting experimental design includes the number of species, number of plants, water-saving technology type, control type and number, plant habitat and characteristics (tree, shrub, or creeping plant) and planting distribution according to the ecological role of each species. The geographic location of each of the individuals planted is also recorded and given a unique code. This allows the creation of distribution maps for each of the phases and measurable variables. Information generated is stored in a virtual platform, which allows the publication of open access data from the project.

Subsequent visits are made to the sites roughly every three months. Then, any plant growth and/or physiological change (florescence, fruiting, herbivory etc.) are monitored. Other activities are also carried out, such as the removal of weeds or invasive species, cleaning of the water-saving technologies, and refilling of the technologies with water.

3. Evaluation of results

Resulting data are analyzed and presented in the form of technical reports and scientific publications. This analysis allows evaluation of which technologies are most effective on different sites and with different species. GV2050 has developed its own ANDRIOD app (Figure 8), that allows easy monitoring and recording of physiological changes of plants in the field. These data are then uploaded and stored in a virtual platform (Menendez & Jaramillo, 2015), where data can be exported for comparative studies using the R statistical software (Core Team, 2017).

Figure 8. Use of the Andriod app to monitor a plant using water-savnig technology.

4. Implementation of changes (adaptive management)

It has been necessary to modify some of the originally planned activities of the project based on the data and technical reports created throughout the phases. This allows us to correct and solve the rising changes that are inevitable in such a long-term applied science project. Adapting our activities based on results also allows us to improve our success over time so that we can optimize restoration efforts.

Initial site visits are made in order to design plans that are specific to the requirements and demands of each site. Despite having an experimental design to test the use of water-saving technologies (e.g. 80% of individuals are planted with technologies and 20% without technologies as controls) sometimes collaborating institutions differ in their specific requirements for work carried out in their areas. For example, some of the farmers in rural ecological restoration specifically request certain native plants, as they are able to act as natural barriers.

Water-Saving Technologies

Groasis Waterboxx®

The Groasis Waterboxx® technology is a polypropylene box that works by collecting and retaining water, which is either supplied manually or from rainfall. This box then feeds water to the plant through capillary action. Water is passed through a rope at the base of the box, to the area surrounding the plant's roots. This ensures a constant supply of water to the plant, even during periods of drought. This facilitates accelerated growth, stimulates vertical growth of the main root and increases the plant's survival rate (Hoff, 2013; Jaramillo, 2015; Jaramillo *et al*., 2015b; Tapia *et al*., 2019). Furthermore, the box cools the plant by shading it from the sun, and acts as a physical barrier against herbivores and/or competition from surrounding plants.

The Groasis technology is reusable, and is removed once the plant has reached a sufficient stage of development. This stage is different depending on the plant species and may be indicated by the plant's height. The materials and components of this technology are shown in Table 2.

Table 2. Components and details about Groasis Waterboxx® technology (Hoff, 2014).

Groasis Waterboxx ® Technology	
Producer	Groasis Company
Material	Virgin polypropylene
Total weight	1.4 kg
Components	Box of water reservoir insulation layer (black layer) 2 siphons 1 or 2 strings A lid to collect rain water An external lid
Extra parts	Wind protectors and anchoring system
Capacity	20 liters of water
Modality	Reusable (10-12 times)

Cocoon

The Cocoon technology works similarly to the Groasis Waterboxx®, however, it is composed of 99% biodegradable material (i.e., recycled paper, cardboard, FDA approved-wax and non-toxic-nylon) (Faruqi *et al*., 2018; Land Life Company, 2019). This box, unlike Groasis Waterboxx®, is non-refillable and is placed underground. It supports the seedling during its first year of growth by supplying water and shelter, while stimulating it to produce a healthy and deep root system. The materials and details about the components are shown in Table 3.

Table 3. Components and details about the Cocoon technology.

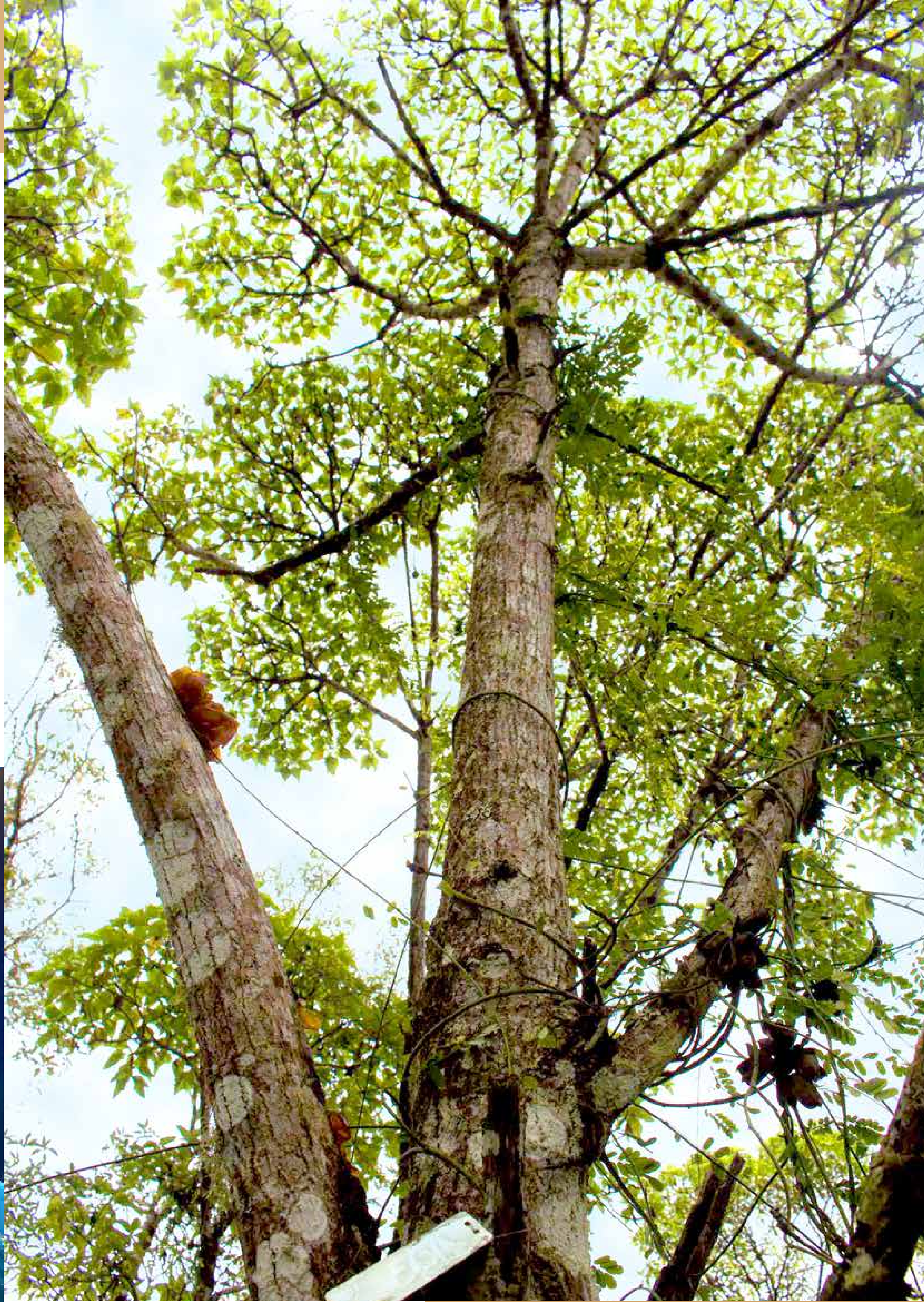
Cocoon	
Producer	Land Life Company
Material	Cellulose Crop or pasture residues Organic wax for waterproofing
Total weight	1.1 kg
Componentes	Box of water reserve Lid of the reservoir Wind protector 2 strings
Capacity	25 liters of water
Modality	Single use and 99% biodegradable

Hydrogel

Hydrogel is a powder of insoluble gel-forming polymers. This composition makes it a superabsorbent material that is able to improve the water-holding abilities of the soil. By retaining and water near the plant roots, it reduces the need for irrigation by up to 70% for five years (Defaa *et al*., 2015; Peyrusson, 2018; Rodríguez-Martínez, 2017). The materials and details of the components are shown in Table 4.

Table 4. Materials and details about the Hydrogel technology.

	Hydrogel
Producer	Cosecha Lluvia and others
Composition	Potassium polyacrylate
General Characteristics	Highly hygroscopic (water absorption capacity) Granular solid White in color Odorless Insoluble
Degradability	3-5 years
pH	Neutral



Pilot Project 2013

The pilot project started in mid-2013 and continued until early 2014. During this phase, we started working on both components: ecological restoration and sustainable agricultural practices. The plants of the pilot project were distributed with the water-saving technologies amongst various vegetation zones, at different altitudes and in different substrates in order to find the most viable restoration actions.

On the three islands of the pilot project (Santa Cruz, Floreana and Baltra), plants were established in seven different types of substrates (Figure 9). During this phase, the Groasis Waterboxx® was used to plant native and endemic species on Baltra (2 sites), Floreana (8 sites) and Santa Cruz (5 sites), and to plant several species for agricultural production on Floreana and Santa Cruz (Jaramillo *et al*., 2014; Jaramillo *et al*., 2013b).

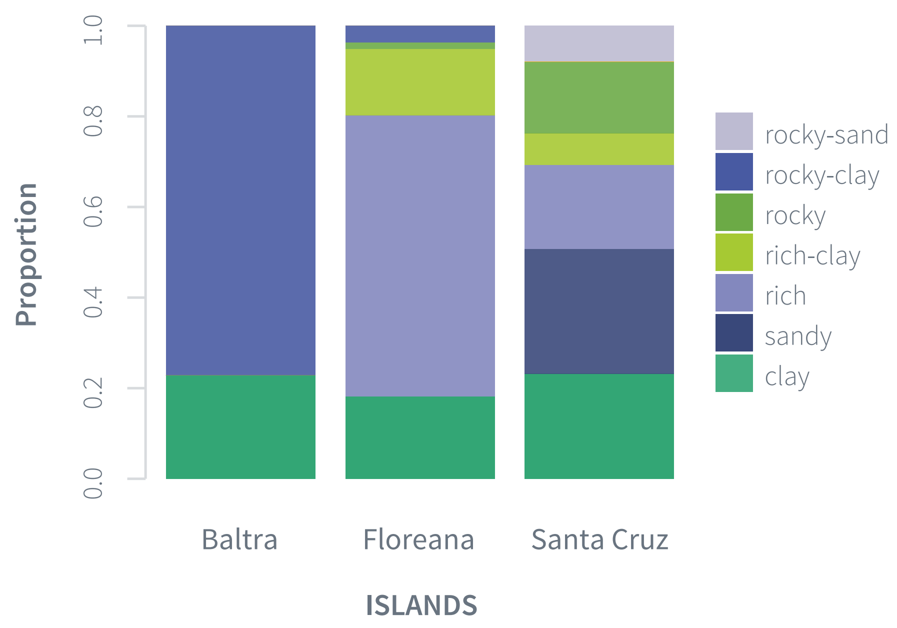


Figure 9. The different substrate types and their proportions on Baltra, Floreana and Santa Cruz islands during the Pilot Project.

Pilot Project - Ecological Restoration

Baltra Island

Baltra Island lies in the arid vegetation zone and has a land surface area of 27 km^2, with a relatively low altitude of 20-30m A.S.L. (Snell *et al*., 1996). The main airport of the archipelago is located on this island, making it the principal point of connection via air between Galapagos and mainland Ecuador (Geist *et al*., 1985; Kenchington, 1989).

In addition to the degradation caused by human activity mentioned previously, the arid conditions typical of an island lying at a low altitude provide another barrier to accelerated restoration (Geist *et al*., 2002; Itow, 1992). During the pilot project, GV2050 started with two study sites close to the airport (Figure 10).

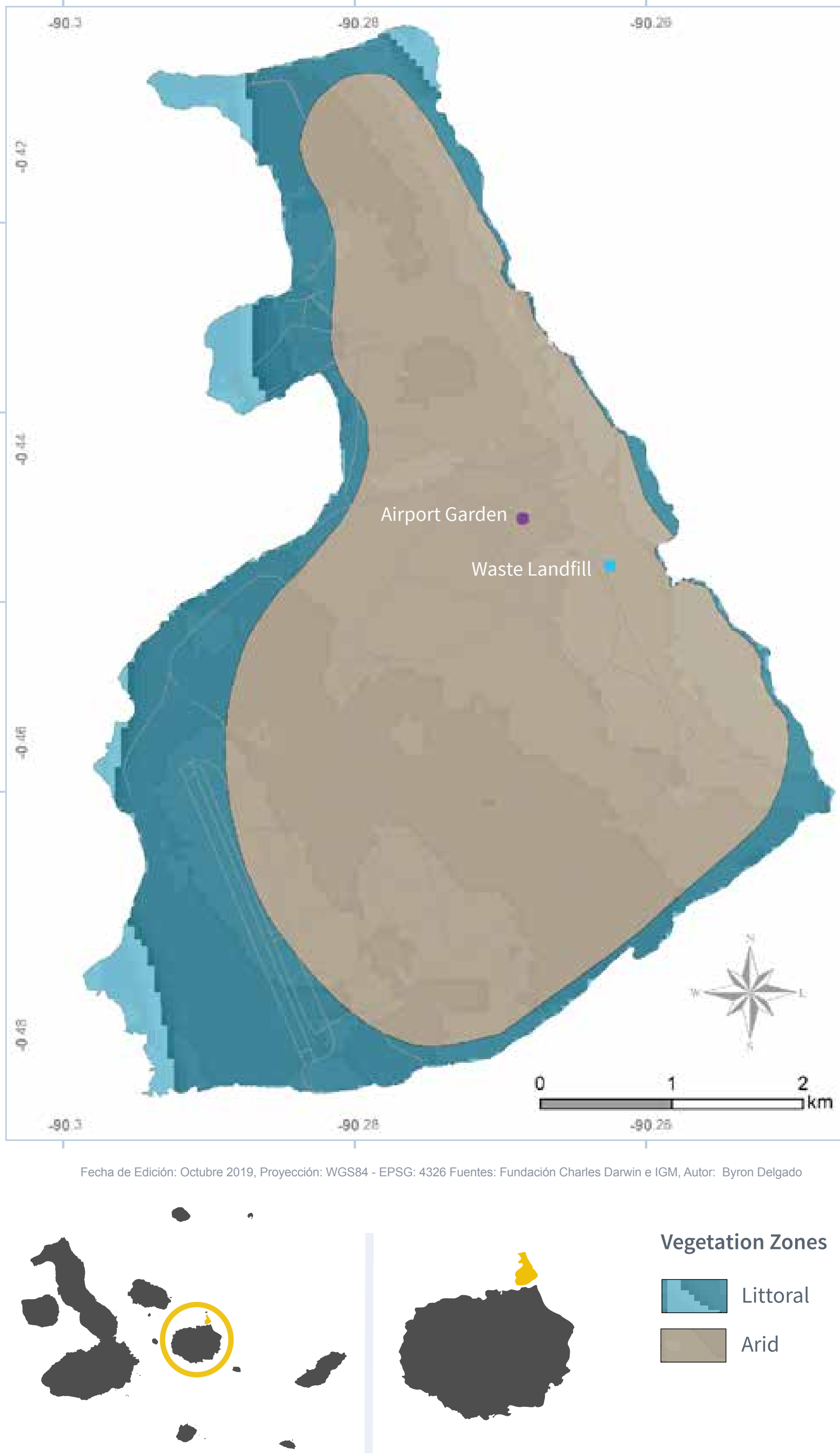


Figure 10. Geographic location of the Baltra study sites during the pilot project.

The preliminary results suggested that *Opuntia echios* var. *echios* seedlings planted with Groasis grow at a faster rate than those planted without any technology (Figure 11). Previous work shows this species typically grows about two cm per year under natural conditions; therefore, Groasis more than doubled the natural growth rate without the technology (Coronel, 2000; Estupiñan & Mauchamp, 1995; Hicks & Mauchamp, 2000).

These results come despite the fact that, unlike the work completed after the pilot project, the technologies were only filled to half their volume capacity of water. This was done in order to get an accurate reflection on the viability of the technologies under arid conditions, as is often the case in Galapagos. This finding accentuates the potential of using Groasis with the project to increase growth rate of planted species and productivity.

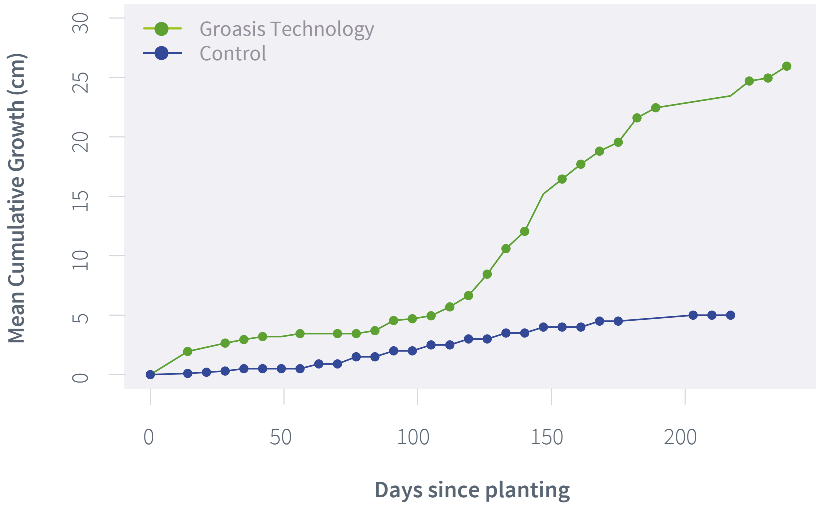


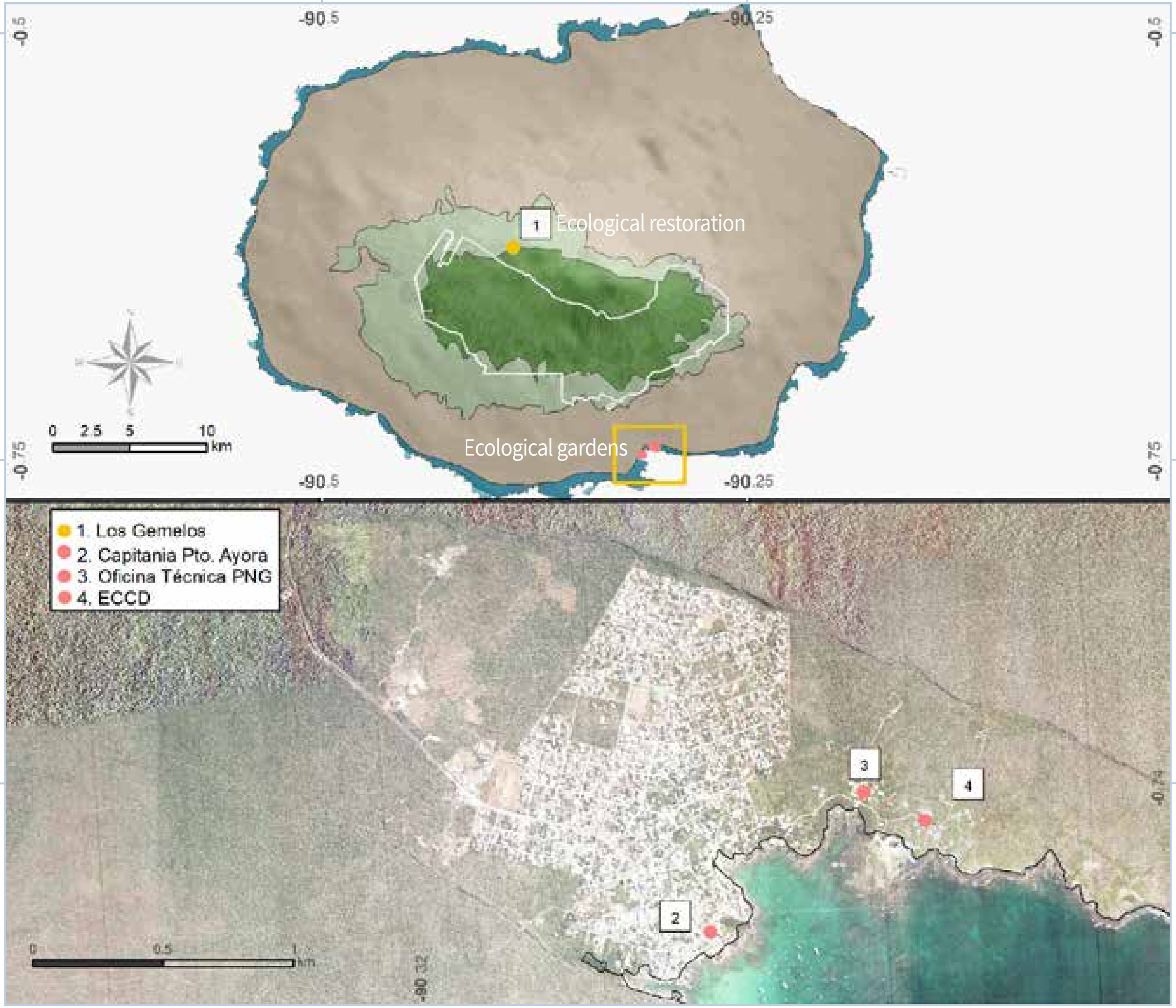
Figure 11. Mean cumulative growth of *Opuntia echios* var. *echios* during the pilot project with Groasis technology and no-technology controls on Baltra Island (Menéndez & Jaramillo, 2015).

Floreana and Santa Cruz Islands

Over recent decades, the various threats on the islands have caused almost an entire loss of some natural communities in the archipelago. An example of this in the humid vegetation zone is the extensive loss of *Scalesia pedunculata* forests, which historically occupied the areas now used for agriculture on the populated islands. Currently, only small remnant patches of these forests exist amongst agricultural land (Mauchamp & Atkinson, 2009).

The preliminary results from planting over 600 plants of 26 species on both islands have revealed critical insights about how Groasis technology should be used for improving restoration success of different species on these islands (Figure 12). The preliminary results were encouraging and set the foundation to expand into Phase 1 of the project, selecting sites in both the urban town and the rural highlands (Figures 13 & 14).

Figure 12. Before and after photos of the restoration of Capitana de Puerto Ayora with Groasis technology on Santa Cruz Island.



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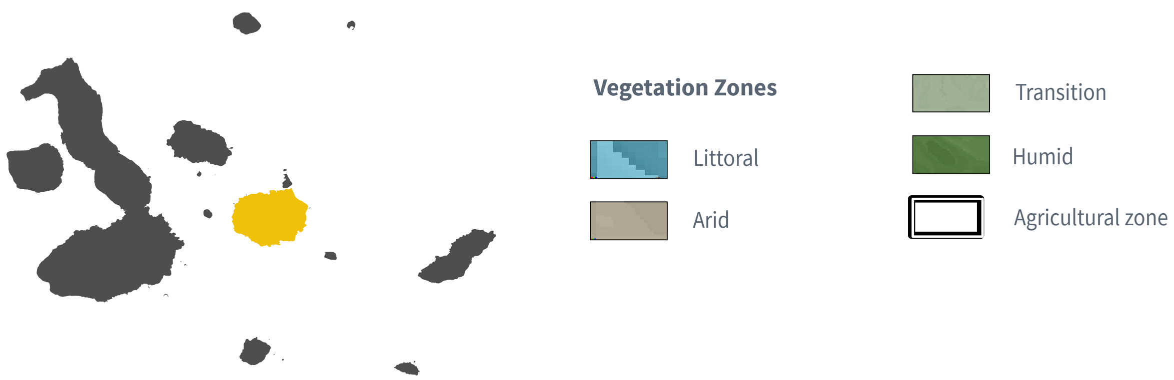


Figure 13. Geographic locations of the pilot project sites on Santa Cruz.

Pilot Project
Sustainable Agricultural Practices

As well as increasing the risk of invasive species introduction, the dependence on imports from the mainland limits farmers' opportunities to increase their earnings and improve their quality of life (Chavez, 1993; MAGAP, 2014; Martínez & Causton, 2007; Nieuwolt, 1991; Toral-Granda *et al.*, 2017). Additionally, the lack of freshwater sources is a pressing matter for continuous crop production, particularly on Floreana (Guyottéphany *et al.*, 2012). For this reason, Floreana was chosen to test the viability of water-saving technologies in agricultural production.

This component of the pilot project was carried out in local farms and family plantations of Floreana, using both short-cycle and perennial plant species, the majority of which were fruit-producing.

The results obtained were encouraging, particularly with tomatoes (Figure 15) and watermelon (Figure 16). These crops are now being used to generate information on the cost-benefits of using the water-saving technologies for agriculture (Jaramillo *et al.*, in prep.). The next step will be to integrate these results within an action plan to aid farmers in generating long-term sustainable production.

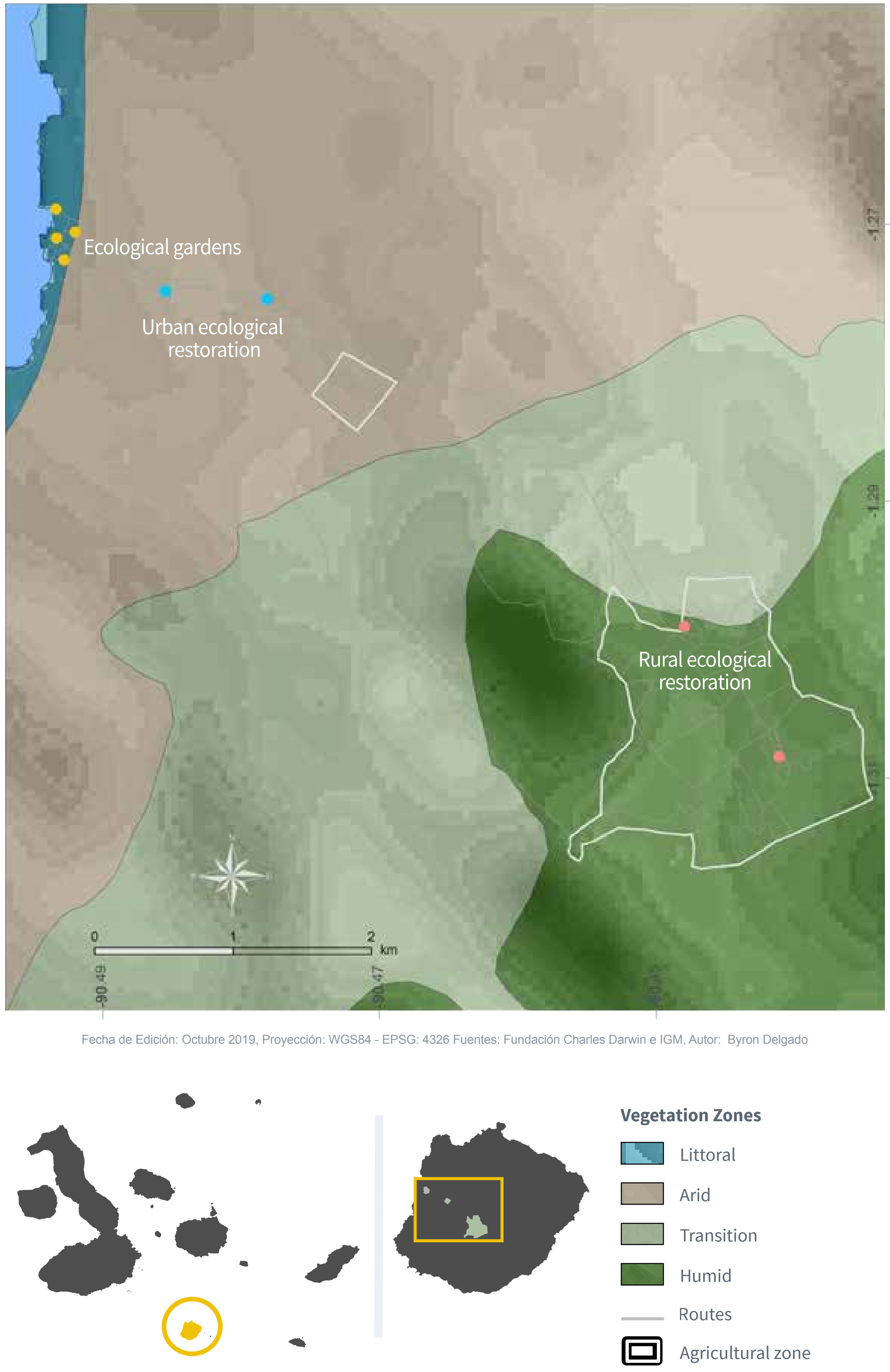


Figure 14. The geographic locations of the study sites in Floreana during the pilot project.

Figure 15. Growth of *Solanum lycopersicum* (tomato) during the pilot project on Floreana.

Figure 16. Growth of *Citrullus lanatus* (Thunb.) Matsum. & Nakai (watermelon) during the pilot project on Floreana.

Ecological Restoration Progress Phases 1 and 2

The work within this component of the project focuses on the ecological restoration of the islands, which gives ecosystems the chance to recover and generate ecosystem services, as well as safeguarding the future of ecologically important species on each island. In phase 1, ecological restoration was initiated on Santa Cruz, Baltra, Plaza Sur and Floreana. Then in phase 2, this work is continued, as well as extended to the islands of Española and Isabela (Figure 17). The ecological restoration component includes urban, rural and natural restoration.

GV2050 project three phases

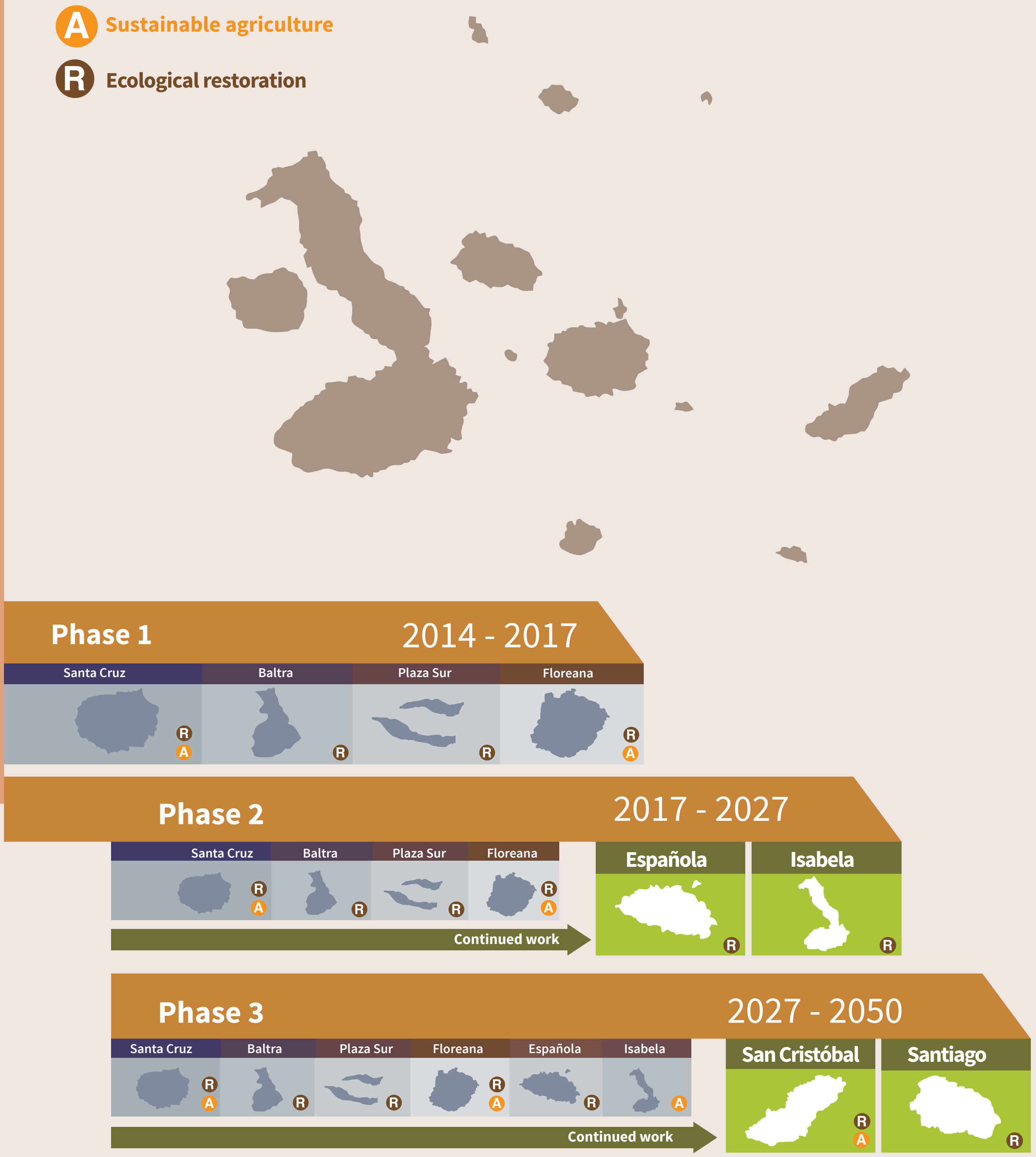


Figure 17. The three phases of the GV2050 project, showing the islands and two components of the project.

BALTRA ISLAND

The three primary study sites, Stone House (Casa de Piedra), Waste Landfill (Antiguo Botadero de Basura) and Wind Farm (Parque Eolico), were selected based on the criterion of high ecological degradation (Figure 18). These sites cover three hectares, and through successive vegetation, restoration actions would create a network of corridors with endemic and native plant species (Jaramillo *et al*. 2017).

In addition to these three sites, the project was able to collaborate with ECOGAL (Ecological Airport of Galapagos). The project established an ecological corridor to deter land iguanas from passing across the airport runway as well as ecological gardens that now harbor more than 200 endemic plants from Baltra. Since then, a visibly reduced number of iguanas have been observed wandering onto the airport runway.

Thus far, more than 4000 plants of 12 different native and endemic species have been planted on Baltra. The results from phase 1 have given insight into the effectiveness of the different technologies in Baltra, and the planting in phase 2 is being altered accordingly for the most effective restoration. For example, counterintuitively, the Cocoon technology has actually decreased the survival of plants on Baltra except in the case of *Acacia macracantha*. The expansion of the project's work on Baltra will now be under the subproject name of 'Baltra Verde 2050'. The work being done is also being used to develop a general method for the restoration of arid ecosystems.

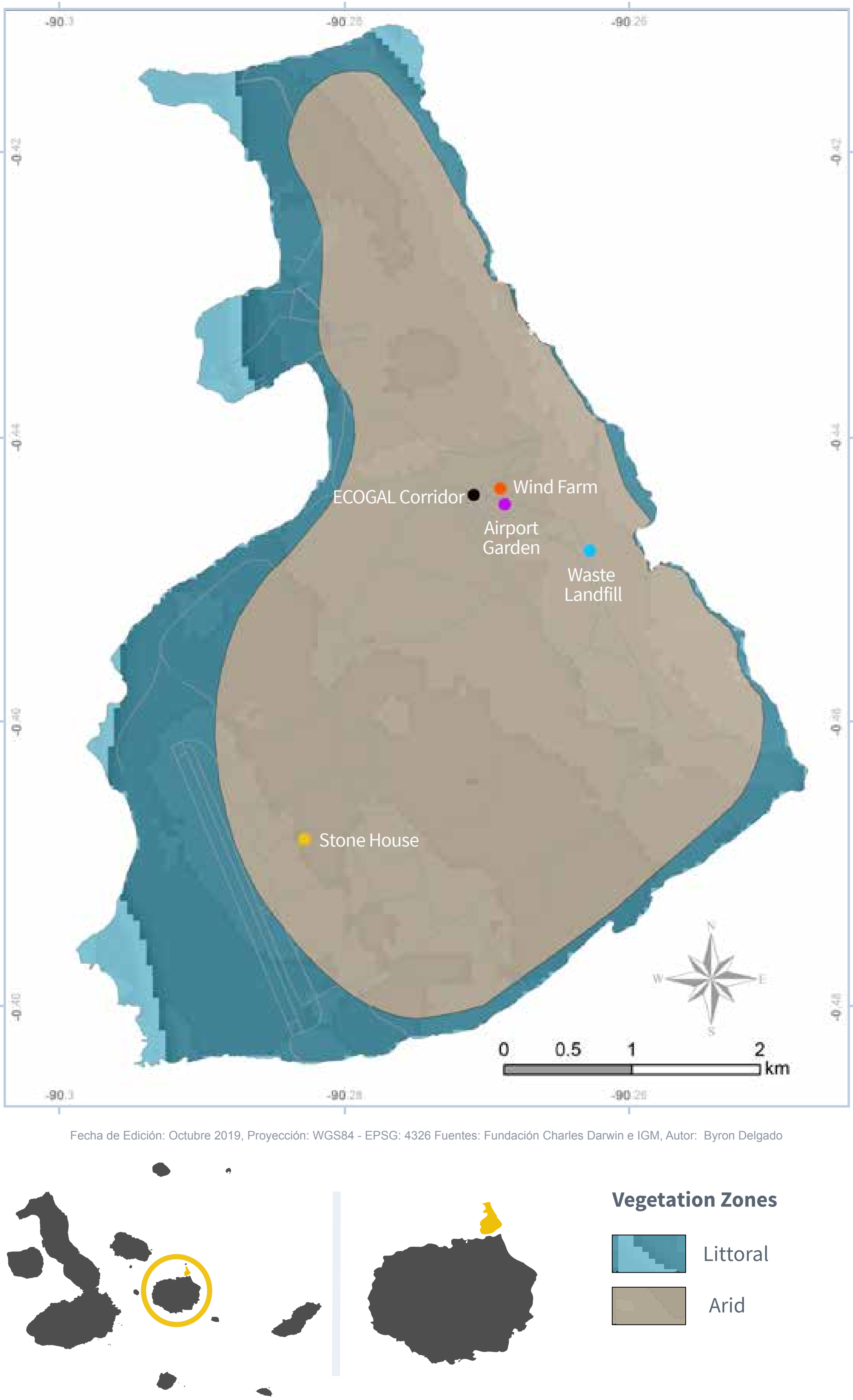


Figure 18. The geographic location of the study sites on Baltra Island in which the GV2050 project works during the first and second phase of the project.

PLAZA SUR ISLAND

During the first phase of the project, work was concentrated on three study sites. These sites were selected based on photographic registries that confirmed the presence of cacti, and reflect the distribution of the population before the occurence of the negative impacts previously discussed (Figure 19).

In 2014, the cactus count was 426 with a regeneration rate of zero (Jaramillo *et al*., 2017; Sulloway & Noonan, 2015). Since the GV2050 project started planting individuals of the threatened *Opuntia echios* on Plaza Sur island (737 individuals were planted between 2015 and 2018, with 452 survivors by the end of 2018) the population has more than doubled (increased by 106%) by the end of 2018 (Figure 20) (Tapia *et al*., 2019). On visits in 2019, natural recruits have been observed growing on the island, and on a visit in April 2019, it was noticed that a Galapagos Hawk had been situated there for over a month. All these observations suggest good news – the ecological integrity may be returning to the island.

After the success of planting *Opuntia megasperma* cladodes on Española, the same methodology is now being carried out in Plaza Sur with *Opuntia echios*. Cladodes are the parts of the adult cactus that are often mistaken as the 'leaves' of the cactus, when actually the spines of the cactus are the leaves, and cladodes are vegetative buds that can sprout to allow asexual reproduction (Hicks & Mauchamp, 1996). The planting of cladodes, as opposed to seedlings, can promise a faster process of restoration due to the propagules being in later stages of development (Coronel, 2002; Hicks & Mauchamp, 2000). However, planting cladodes is a form of vegetative or clonal reproduction and therefore does not increase genetic variation production (Mandujano *et al*., 1998). Therefore, the project continues to use both methods for the restoration of *Opuntia* species on Española and Plaza Sur.

Figure 19. Photographic record of the change in *Opuntia echios* var. *echios* population on Plaza Sur, from the years 1967 (top) and 2014 (bottom) (Sulloway, 2014).

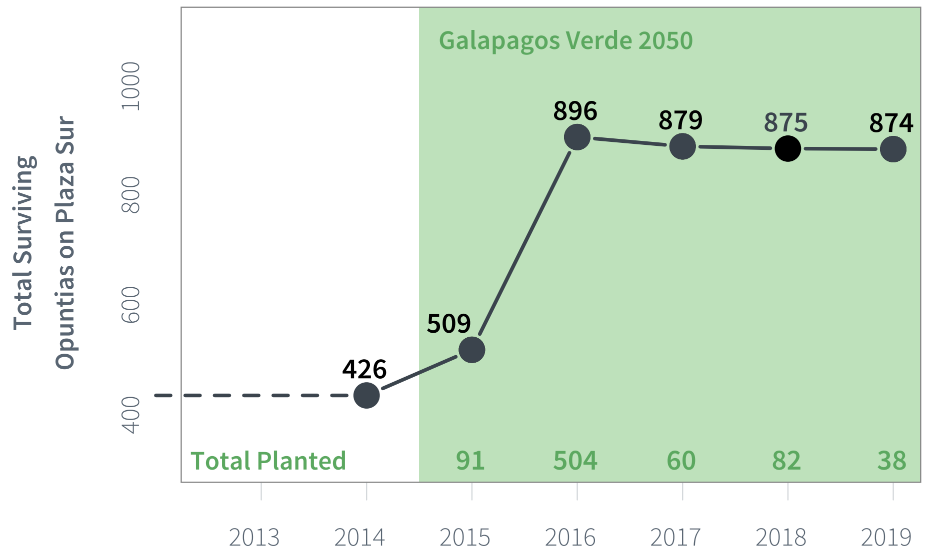


Figure 20. *Opuntia echios* var. *echios* population on Plaza Sur island from 2014 onward. A full survey of the island by the GV2050 team reported only 426 individual cacti. Subsequent years GV2050 has been planting Opuntias (total planted each year are in green). Total surviving plants by the end of each year are labeled in black.

SANTA CRUZ ISLAND

Restoration of *Scalesia affinis*

Individuals of *Scalesia affinis* were planted in the two areas where there are still remnant populations; El Mirador and El Garrapatero, together covering about one hectare of land. In addition to these sites, 31 individuals were planted in the gardens of the Biosecurity Agency for Galapagos (ABG), making up a total of 402 planted individuals as part of the restoration actions for the *S. affinis* population in Santa Cruz. Survival of plants was more than doubled by using Groasis technology (Figure 21), and the 80 surviving planted individuals have more than doubled the existing population of *S. affinis* from 71 in 2014 to 151 in 2019.

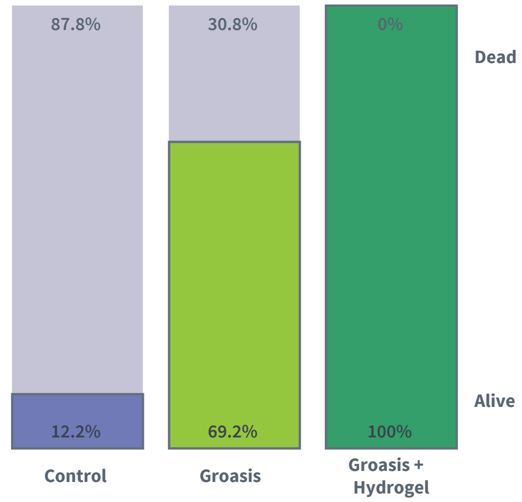


Figure 21. *Scalesia affinis* 6-month survival rate on Santa Cruz Island with different technologies. Percentages represent the proportion of plants alive or dead after six months.

Rural ecological restoration

Santa Cruz is one of two islands where rural ecological restoration began in phase 2. This component involves the planting of native and endemic species and the elimination of invasive species in local farms. Finding a sustainable balance between ecosystem conservation and agricultural production should be a priority on inhabited islands of the archipelago. The work within this component generates a mutual benefit for both the GV2050 project by expanding its purview into cultivated landscapes and for the farms and farmers themselves by providing them with greater conservation value, crop production and tourist attractions. The rural ecological restoration on farms has begun in four study sites on the local farms of Santa Cruz: of Mario Piu, Vicente Castillo and Mick Allen, as well as the ecotourism tortoise ranch El Chato II (Figure 22).

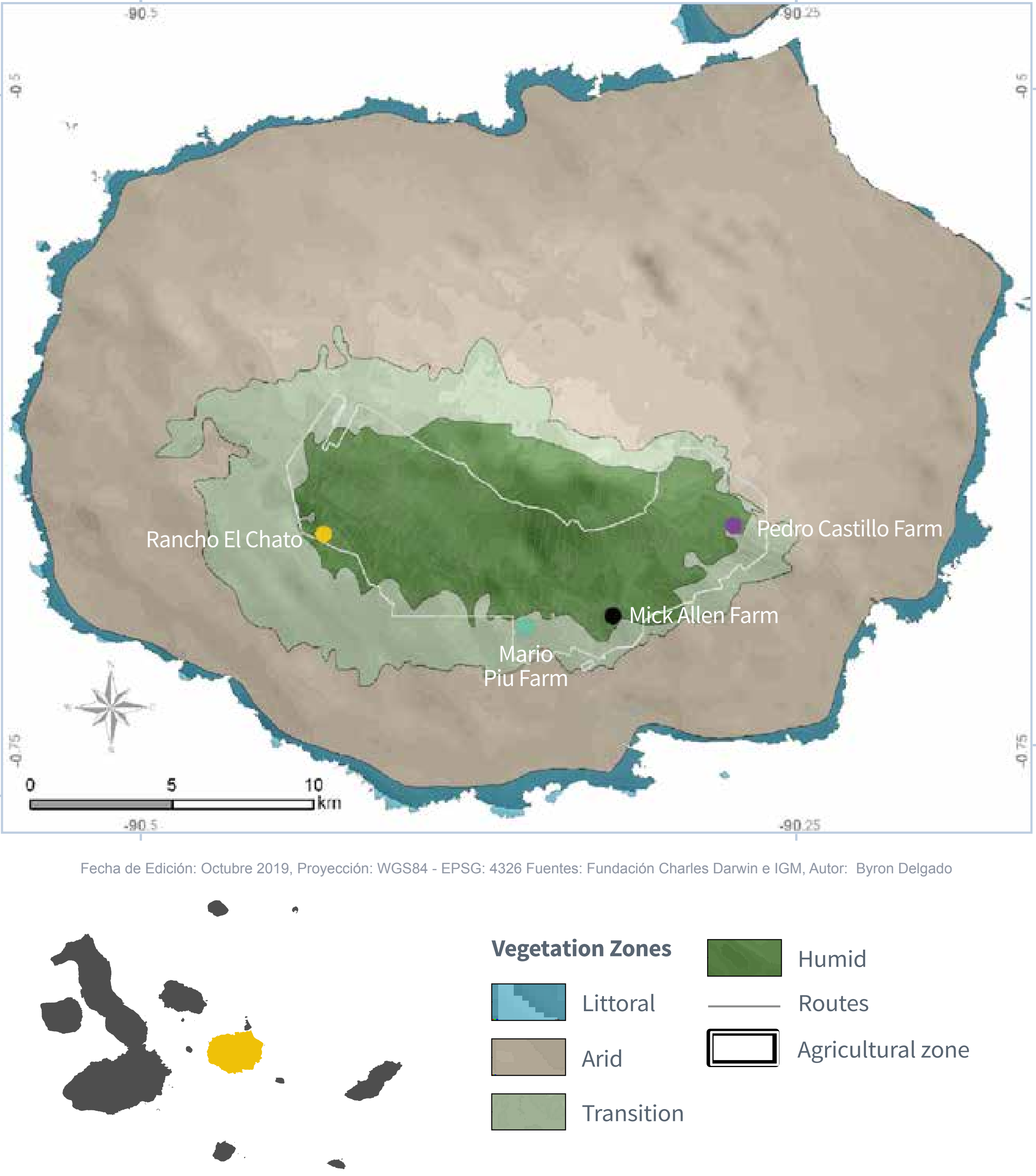


Figure 22. Geographic location of farms on Santa Cruz in which the GV2050 project has implemented rural ecological restoration in phase 2.

Urban ecological restoration

In the urban areas of Santa Cruz, two ecological corridors have been created. The first runs parallel to a bicycle lane in town, and is composed of threatened native trees. The second was created in collaboration with the Ministry of Agriculture (MAG), and runs along the perimeter of a coffee drying area in the north of the island. Santa Cruz is one of the islands where GV2050 collaborates with local institutions to create ecological gardens (Table 5).

Table 5. Percentage of plant surviving with and without water-saving technologies in the study sites on Santa Cruz Island.

COMPONENT	SITE	Percent Surviving	
	Restoration Sites on Santa Cruz	With technologies (%)	Without technologies (%)
ECOLOGICAL RESTORATION	Puerto Ayora Captaincy	96	0
	National Galapagos School	76	25
	Biosecurity Agency Galapagos (ABG) Gardens	33	0
	El Mirador	35	6
	ABG Green Space	77	64
	Charles Darwin Research Station (CDRS)	64	56
	Garrapatero	1	0
	Pikaia Lodge	100	100
	Bicycle lane vía Mirador	100	100
	Galapagos National Park (GNP) Offices	64	75

FLOREANA ISLAND

Urban ecological restoration

From what used to be a substantially altered ecosystem in 2014, the study site of the gravel mine (Mina Granillo Negro) in Floreana has now, thanks to the work of GV2050, been completely restored to a dry forest of native and endemic species in 2019 (Figure 23). By the end of the first phase, more than 600 plants of 15 endemic and native species were planted on the three study sites, of which 62.7% survived with the technologies and only half as many (31.3%) survived without the technologies. These results are extremely encouraging as they show both the extent of positive impacts that GV2050 can yield, as well as demonstrating the value of using water-saving technologies to increase survival of planted individuals. Floreana is another island where the project has created ecological gardens for the local community.

Figure 23. The change in the gravel mine in Floreana since ecological restoration began in 2013.

Rural ecological restoration

Floreana is the second island, after Santa Cruz, where rural ecological restoration is currently being implemented. On the farms of Claudio Cruz and Aníbal Sanmiguel, the project has planted 389 individuals of 11 native and endemic species using different technologies to diversify the current monocultures (Figure 24).

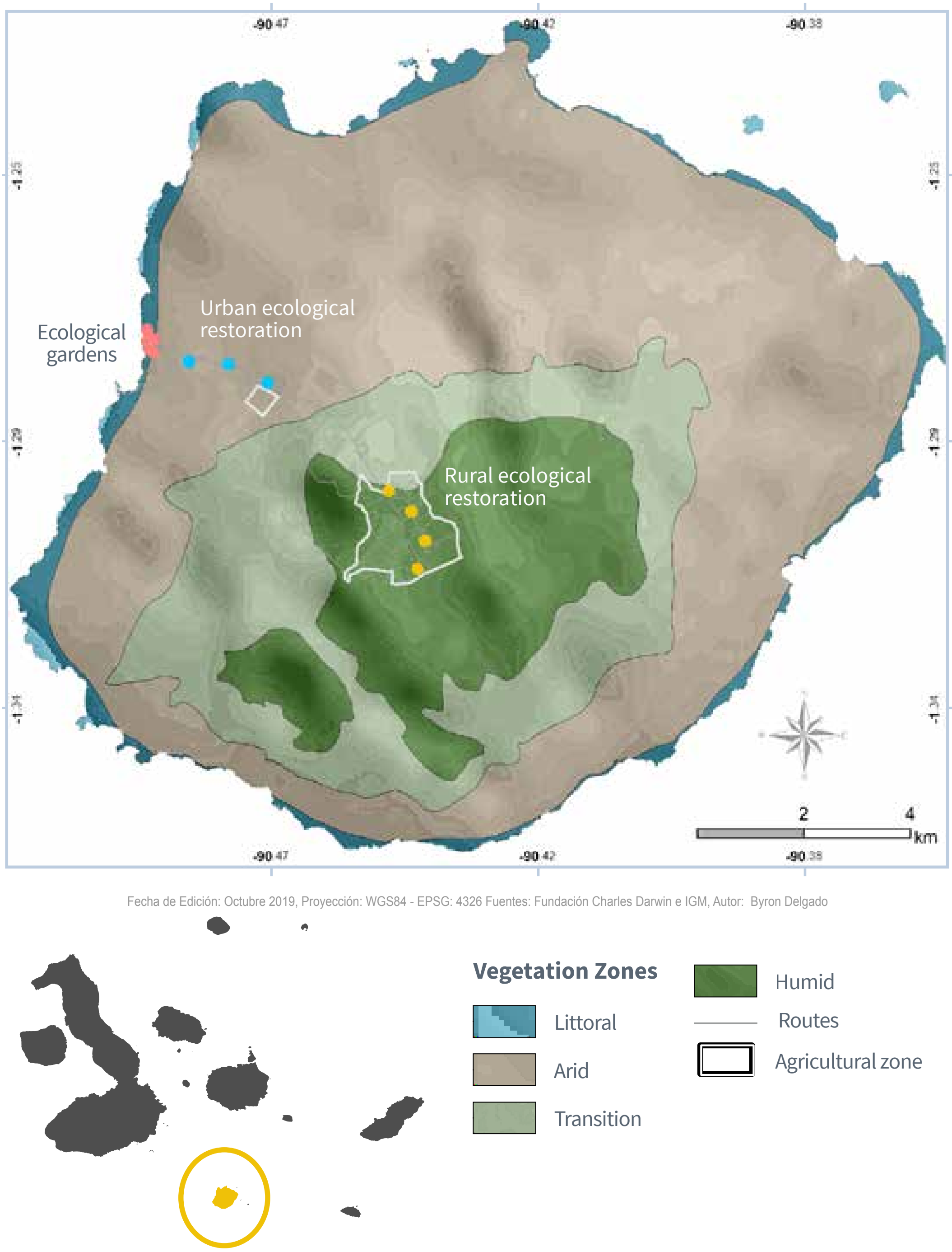


Figure 24. The geographic location of the current study sites on Floreana Island in phase 2.

ESPAÑOLA ISLAND

During the first phase of the project, preliminary germination and viability tests were carried out with the seeds of the endemic *Opuntia megasperma*. The seeds used had been extracted from fruits of adult *Opuntia* individuals and from tortoise excrements collected on the island with the support of the Giant Tortoise Restoration Initiative (GTRI) project (Gibbs *et al*., 2014; Sulloway & Noonan, 2015; Tapia, 2016). However, due to the low success of these seeds from the germination and viability tests, in June 2017 a vegetative propagation experiment, using cladodes of *O. megasperma*, was initiated *in situ* in a site called Las Tunas. 48 cladodes were planted, 40 with water-saving technologies and 8 as controls. In late 2018 successful viability tests and seed germination occurred thanks to the support of the GTRI by providing viable seeds. The difficulty with seedlings, however, is that they need to grow for two years before being transported back to the island. To work around this issue and increase restoration efficiency, another vegetative propagation experiment of *O. megasperma* was initiated. Currently, our study site is Las Tunas, located 2 km away from the coast (Figure 25).

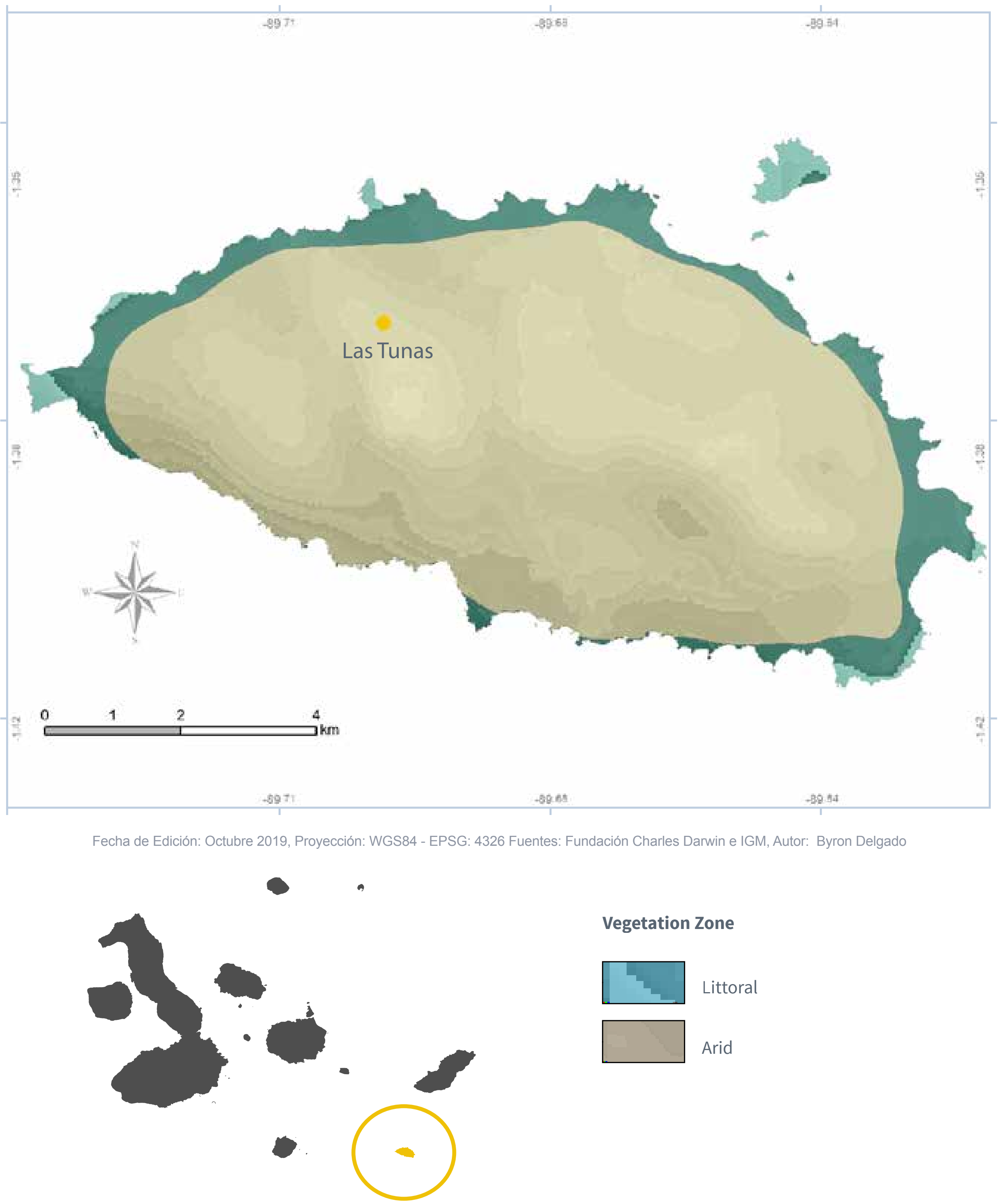


Figure 25. Geographic location of the project´s study site on Española Island.

ISABELA ISLAND

In order to restore the endemic subspecies *Galvezia leucantha* sp. *leucantha*, seeds were collected from the extant four individuals and preliminary viability and germination tests were performed at the CDRS. Out of the 30 seeds, only nine germinated, and of these, only five young plants survived the transplanting process (Figure 26). Rigorous supervision and extensive monitoring aided the successful development of the plants to a stage where they could be taken back to the study site at Tortuga Negra beach (Figure 27). There they were planted with water-saving technology (Groasis and hydrogel) near their mother plants.

This methodology was repeated with seeds in the laboratory at the Charles Darwin Research Station and a further nine plants were planted in 2019. Overall, the threatened population of *Galvezia leucantha* sp. *leucantha* on Isabela Island has been quadrupled and current seedling production will quintuple the population by 2020.

Figure 26. The transplanting and care of the Galvezia individuals in the Charles Darwin Research Station (CDRS).

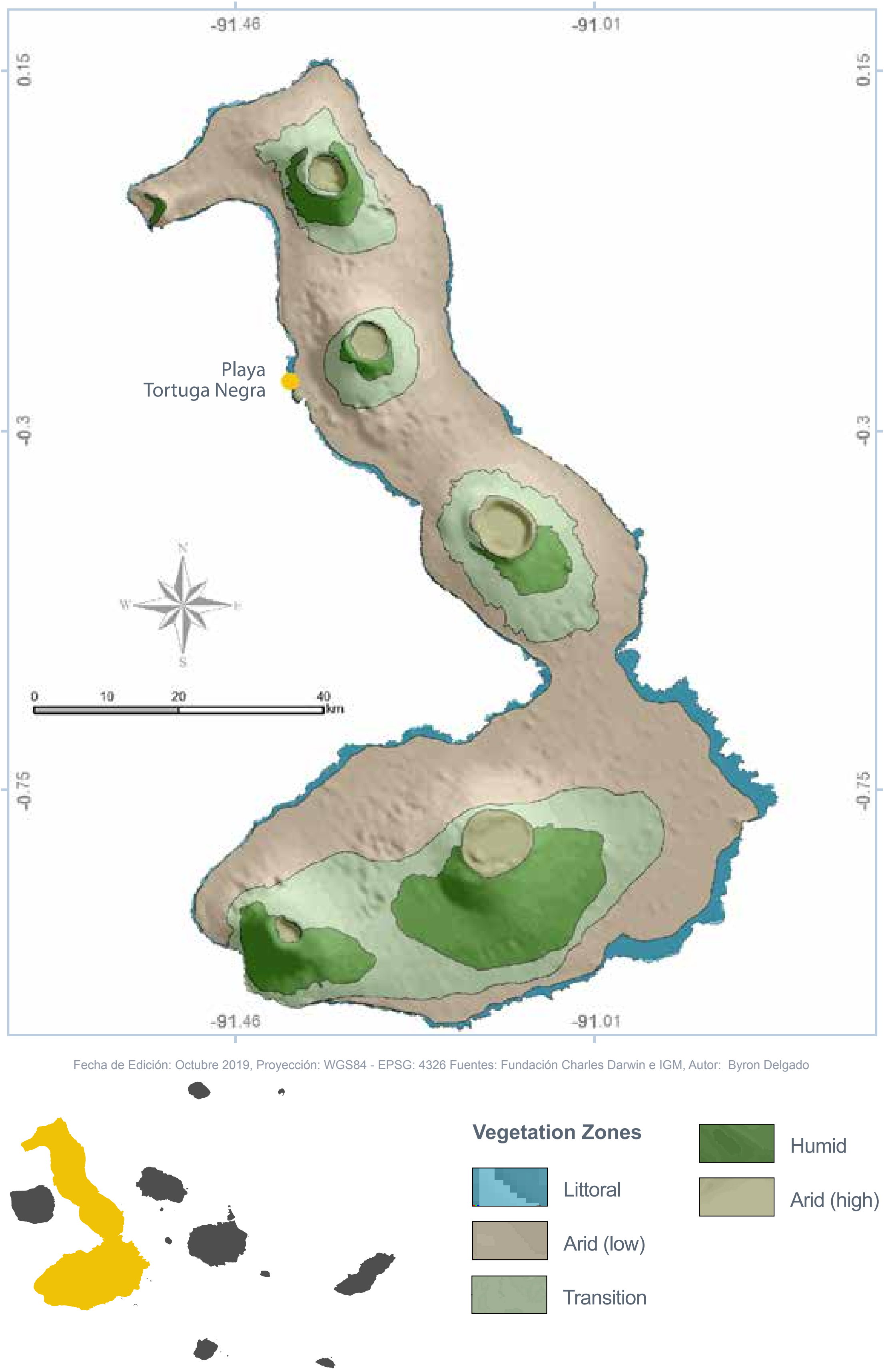


Figure 27. The geographic location of Playa Tortuga Negra on Isabela Island.

Ecological Gardens

On Santa Cruz Island, six ecological gardens have been established in urban areas (Puerto Ayora´s Captaincy, Galapagos National High School, ABG Green Space, Charles Darwin Foundation, Pikaia Lodge and GNP offices). More than 400 plants from 19 different species have been planted so far.

In Floreana four ecological gardens have been established (Amazon School, GADP Floreana, GNP offices, and Mr. Eddy Rosero´s hotel), where more than 100 plants of 10 different species have been planted thus far.

Even though San Cristobal is an island designated for phase 3, the project has already created two ecological gardens in the new Jacinto Gordillo Environmental Education Centre and Humboldt High School. This is because the timeline of the project was flexible so as to accept opportunities to promote environmental education to the local community. The creation of these gardens was done in conjunction with the students of the institutions, thus far planting 53 plants of seven species (Figure 28).

Figure 28. Examples of the creation of ecological gardens in local schools and institutions.

Sustainable Agriculture Progress: Phases 1 and 2

This component has focused on the agricultural areas of Santa Cruz and Floreana islands, with the objective to develop a more sustainable production on local farms by increasing production through the use of water-saving technologies. During the first phase, GV2050 worked on three properties, where more than 250 plants of four commonly cultivated species: pepper (*Capsicum annuum*), watermelon (*Citrullus lanatus*), cucumber (*Cucumis sativus*) and tomato (*Solanum lycopersicum*) were planted.

The project has analyzed results produced from testing tomato productivity with these water-saving technologies, due to its importance in terms of demand in Galapagos. The results so far show promising potential for Groasis and Hydrogel technologies and results are currently being prepared as a manuscript for submission.

On Floreana, GV2050 worked on three study sites owned by farmers Claudio Cruz, Francisco Moreno and Holger Vera. At the end of the first phase, more than 250 plants of 13 commonly cultivated species were planted, including cucumber, cocoa, avocado, papaya and tomato; reaching an average survivorship of 45.1%.

Table 6. Diversity of agricultural species planted in each of the 11 farms on two islands.

Islands	Farm	Number of species
Floreana	Cecilia Salgado	4
	Claudio Cruz	8
	Francisco Moreno	6
	Holger Vera	1
Santa Cruz	Max Freire	3
	Wilson Cabrera	3
	Nixon López (Cascajo)	3
	Nixon López (Occidente)	4
	Rafael Chango	1
	Santa María	2
	Teodoro Gaona	1

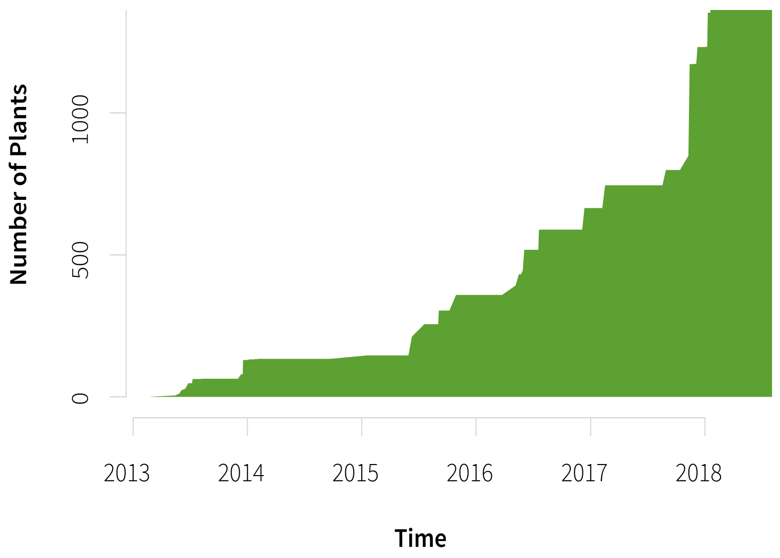


Figure 29. Cumulative number of plantings of agricultural species, so far there have been 1,533 total plantings.

Table 7. Total number of individuals of each of the 14 agricultural species planted.

Species	Common Name	Number Planted
Brassica oleracea Plenck	broccoli	164
Capsicum annuum L.	pepper	262
Carica papaya L.	papaya	53
Citrullus lanatus (Thunb.) Matsun. & Nakai	watermelon	316
Citrus reticulata Blanco	mandarine	50
Citrus x sinensis (L.) Osbeck	orange	12
Cucumis melo L.	melon	68
Cucumis sativus L.	cucumber	122
Inga edulis Mart.	ice-cream bean	8
Musa x paradisiaca L.	plantain	15
Persea americana Mill.	avocado	12
Solanum lycopersicum L.	tomato	415
Syzygium malaccense (L.) Merr. & L.M. Perry	Malay apple	14
Theobroma cacao L.	cacao	22

Insights from farmers: Survey to local farmers

In april 2017, GV2050 interviewed 29 farmers at the weekly free trade market in Puerto Ayora, Santa Cruz, using a survey of 20 questions. The questions covered the characteristics of their farms, as well as giving insights into the different way the farms are managed (Figure 30).

The survey revealed that the majority of the farmers use brackish water, as opposed to fresh water to irrigate their crops. 75.9% of the interviewed farmers responded that they use manual irrigation (buckets, hoses or pipes), while the remainder have some form of drip/sprinkle irrigation installed. In addition, all participants responded that the water availability for agricultural production on the islands is not enough, and expressed a need for mechanisms to store rainwater. Although the agricultural zone of the islands receives rain annually, much of the rain is immediately lost due to the porous volcanic substrate. Around half of the interviewed farmers explained that they also have other means of income and do not fully commit their time to farming due to the insecurity of an inconstant food production. These answers highlight the unsustainability of the current agricultural industry on the Galapagos, largely due to the limited water sources and wasteful uses of this water. This survey confirmed the benefits that water-saving technology may have on countering the barriers of sustainable and cost-effective food production.

Figure 30. Surveys made to several farmers and registration of productivity information on a farm on Santa Cruz Island.

Other Activities during Phases 1 and 2

International Workshop

In order to mark the end of phase 1 of the Galapagos Verde 2050 project, in October 2017 the project hosted its first international workshop at the Charles Darwin Research Station. Representatives from national and international institutions and NGOs came together to discuss the progress of the GV2050´s first phase.

The feedback and contribution of multiple experts from various fields led to a greater evaluation of the work done thus far. This contributes to the adaptive management of the project, as we continue to strive for the most effective and efficient way to carry out this long-term project. The workshop was also an opportunity to encourage the participation of the community and the integration of institutions that look to encourage sustainability and the conservation of the archipelago (Figure 31). If Galapagos Verde 2050 ultimately aims to be a model for ecological restoration and sustainable agriculture elsewhere in the world, it is important that we continue to seek and welcome input from experts on a global scale.

During this workshop, we launched the second edition of the book 'Plant me in your garden'. The book is a guide about the native and endemic plants of the Galapagos that can be planted in gardens. The book is the first trilingual book in Latin America, written in English, Spanish and Kichwa, the language of indigenous Ecuadorian people that make up 32% of the Galapagos population. The book could not have been published if it were not for the generous donations from the COmON Foundation (Figure 32). To conclude Galapagos Verde 2050's first international workshop, a symbolic planting was done with all the attendees of the event in the ecological gardens of the Charles Darwin Research Station (CDRS).

Figure 31. Attendees of the Galapagos Verde 2050 first International Workshop. Talks were given on topics of conservation and control of invasive species.

Figure 32. Launching event of the book "Siémbrame en tu Jardín" with the main donor of the GV2050 project (COmON Foundation) Mr. Wijnand Pon (middle).

Figure 33. Latinoamerica Awards 2018 to four countries: Haiti, Ecuador (Galapagos Verde 2050), Chile and Mexico (from left to right). Galápagos Verde 2050 was also awarded the most inspiring research project for Direct TV.

Latinoamerica Verde Awards 2018

In 2018, the project was announced as a finalist in the fifth edition of the prestigious Latinoamerica Verde Awards. The project was selected from 2.733 projects from 38 countries. Galapagos Verde 2050 was amongst the 31 finalist projects from which it was awarded third place in the "Water" category (Figure 33). In addition to this, it was awarded the 'Protagonist' award "for having been one of the most outstanding stories, for the clarity of its purpose, its impact, its legacy and its ability to inspire a positive change for the region and for the planet". The prize of this award was a documentary about the work of the project filmed and produced by Direct TV and that was released in August 2019 (https://youtu.be/DLLR3T7uJ7A).

Ecuador presente en la final de los Premios Latinoamérica Verde

En esta quinta edición se registraron 2.733 proyectos sustentables

OBJETIVO

UN CAMBIO AL ESTILO DE VIDA

GV2050 and the Community

In order for the GV2050 project to leave a legacy and ensure the archipelago's conservation and restoration beyond 2050, the principles of the project must be instilled in the local population. This is why GV2050 works hard to engage local institutions and the population in its work, as well as sharing the work and results through scientific publications, social media, and open source data, such as the website and GV2050 platform.

Casa Abierta (Open House)

Since 2017, GV2050 has taken part in the annual "Casa Abierta" at the Charles Darwin Research Station. Along with other projects of the CDRS, GV2050 spends the day presenting and interacting with people of the islands about our work, and carries out a series of interactive activities with local school groups, families and tourists (Figure 34).

Figure 34. Demonstration and interactive activities about the Galapagos Verde 2050 project for the community and tourists during the CDRS Open House 2018.

Figure 35. Presentation of GV2050's work to a group of high school students.

Universities and visiting groups

Many workshops, presentations and lectures have been given at the CDRS to visiting tourists, university and scientific groups. Also, we have had the opportunity to present our project nationally and internationally, including places such as San Francisco, Newcastle upon Tyne, London, Madrid, Malaga and others (Figure 35). In addition to this, our collaboration with universities from around the world not only provides us with scientific input from their research experts, but also gives us the opportunity to host volunteers from around the world and special visits.

With the presentations at the CDRS, visiting groups of donors or students often get to experience a demonstration of how water-saving technologies are installled with the plants (Figure 36). These groups get to see and experience planting themselves which also contributes to the ecological gardens at the CDRS.

Figure 36. Symbolic planting of an endangered species (*Scalesia affinis*) with the participation of Mr. Wijnand Pon the Chairman of COmON Foundation.

The Future

Phase 2 continuation

From the information collected in phases 1 and 2, data analyses are yielding valuable insights that are being used to currently write various scientific publications. Tri-monthly monitoring of the study sites mean the restoration efforts can be constantly evaluated, making GV2050 a model of data-informed adaptive management and conservation. Protocols have been adapted based on current results, aiming to return integrity to degraded ecosystems and hence, achieve a truly green Galapagos by 2050.

The third phase will start in August 2027 and will run until December 2050. This is the final and longest phase of this long-term project. To see the positive effects of our work from phases 1&2 and our plans visioned for phase 3, GV2050 requires continuous support in order to complete our objectives, and achieve all that the project is capable of.

Ecological restoration

Ecological restoration will continue on Baltra, Española, Floreana, Isabela, Plaza Sur and Santa Cruz islands. Ecological restoration will be introduced to San Cristobal and the south of Isabela Island, in order for these efforts to be present on all populated areas of the archipelago. These efforts will also begin on Santiago Island, where there is still an invasive species problem and thus, degradation.

On Plaza Sur and Española islands, a full recovery of Opuntia populations to historic levels is anticipated within this phase of the project. "Baltra Verde 2050" will be fully established and form a model for restoring arid ecosystems.

In addition, a complete catalogue of the vascular flora present on Floreana is also being drafted to plan the prioritization of new ecological restoration study sites. This is being done in close collaboration with the GNP (Jaramillo, 2019).

Based on historical and updated information, *Lecocarpus lecocarpoides* will be surveyed for island populations during the second phase of the project. *L. lecocarpoides* is an endangered species of which no presence has been registered in more than ten years on Española Island. The distribution and regeneration of *Erythrina velutina* will also be surveyed—a native tree of which so far only 1 individual has been found (Gibbs *et al*., 2014; Gibbs *et al*., 2008; Jaramillo *et al*., 2018c; Tapia, 2016; Tye & Jaramillo, 2019). After this an action plan for its restoration will be created.

Sustainable agriculture

Regarding sustainable agriculture, the project plans to extend the use of water-saving technologies on farmed land on the four inhabited islands, based on experimental results from phases 1 and 2, helping achieve the goals set in the Bio-agricultural Management Plan.

Finances

Current situation

The pilot project, as well as the first phase (2014-2017) and the second phase thus far has been chiefly financed by the COmON Foundation and some contributions by Helmsley Charitable Trust and BESS Forest Club.

Local socioeconomic context

The Galapagos province has a human population of more than 25,000 (INEC, 2015). The cost of living in the archipelago is considerably higher than elsewhere in the Republic of Ecuador given its isolation from continental Ecuador. Furthermore, this isolation makes the transportation of material and equipment required for research expensive.

The insularity and the volcanic nature of the islands present another distinctive characteristic a general lack of natural resources that can be used by the human populations. This is especially true in the case of sections of land that have not been worked on or developed. Natural water sources are limited and climatic conditions are quite variable from one year to the next.

Funding

An ambitious, long term, applied scientific project, such as GV2050, requires substantial economic funding for successful implementation. Thus, it is critical to safeguard the financial security for the duration of the GV2050 project and guarantee sufficient financial sustainability until the objectives and vision of the project have been met. Any funding acquired is managed by the CDF and contributes to financing all of the required research activities of the project. These will include the acquisition of equipment and materials, intra-island travel, salary payments, support for volunteers and students, as well as any additional research activities.

Cooperation between community and government institutions is also essential to successfully conserve the archipelago and safeguard the wellbeing of the local community. The GV2050 project exemplifies this model: from the beginning, links have been made between several strategic partners. Various resources and services are supplied to the project from institutions such as the GNP, ABG, Floreana GADP and others. Due to the magnitude of the work on islands such as Floreana, the project relies on the support of the GNP. This collaboration between GV2050 and GNP also ensures that the GNP remains informed about the project through conferences and meetings on the island regarding the results obtained from the sites.

For the complete implementation of the GV2050 project, a minimum of $20,000,000 needs to be secured, which will be acquired from various sources of funding (non-governmental and international cooperation agencies), as well as with help from public institutions that support this project.

Although we have reliable and continued support from our donors, we continue to acquire funding through various other methods:

- Seeking additional sources that will act as backup support in case one of the other sources is lost or becomes non-operative.
- Accessing public funding through the contribution of grants.
- Gathering donations from international and non-government organizations. This is an important source of funding.
- Establishing appropriate administrative and financial instruments that will create alternative incentives for those interested in collaborating with the conservation of the ecosystems of Galapagos through the Galapagos Verde 2050 project. This will reach the private sector, which is a key potential financial resource for conservation projects.
- Implementing new programs that secure the long-term sustainability of the project.

All of the work carried out in the first phase (2014-2017) of the project was accomplished with a budget totaling $750,000 USD.

As a retired biologist working in the CDF herbarium, I have watched ongoing GV2050 efforts closely, even joining a field crew restoring populations of giant cacti on Plaza Sur. For 5 years, they have tended the hundreds of cacti they had grown from seeds – hauling water, replanting, and measuring every one. The result is some cacti now large enough they no longer need frequent care.

Plaza Sur is only a small part of GV2050 work to rescue, restore, and conserve this unique biota across the archipelago. Their professional publications also help inform other conservation efforts around the globe. In addition to their intense field labor, each project requires years of planning, patience, and perseverance.

Taken all together, the scope, the quality, and example of GV2050 are a service to conservation. Its success has only been possible because of generous donations by past patrons. I count it a privilege to support them through my volunteer labor at the Foundation. I encourage you to help with this important work however you can.

John Shepherd, PhD

CDF Herbarium Professional Volunteer

What is Galapagos 2050 Verde to you?

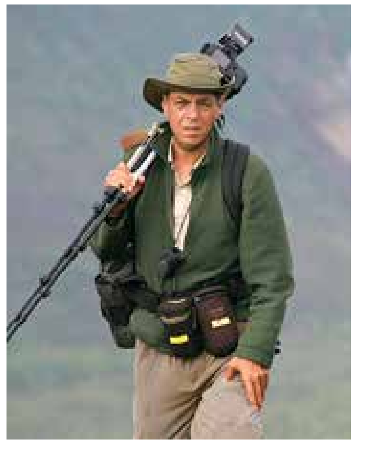
Some opinions from collaborators

Dr. JORGE CARRION
EX-GALAPAGOS NATIONAL PARK DIRECTOR

All research projects have a main goal, which is to contribute towards the conservation of the Galapagos and the local human population's wellbeing. The Galapagos Verde 2050 project, led by the Charles Darwin Foundation and with the Galapagos National Park as a strategic partner, aims to restore zones of special use on several islands within the archipelago. Until now, work has been carried out on seven of them, within both protected and urban areas of the islands, which perfectly balances the equilibrium between man and nature. The implementation and use of novel water-saving technologies to aid the growth of endangered and threatened plant species is one of the aspects that truly makes Galapagos Verde 2050 a model for ecosystem restoration, for which, as the main beneficiaries of the project, we wish them much success.

Dr. MARIA DEL MAR TRIGO
PROFESSOR OF PLANT BIOLOGY AND SCIENTIFIC DIRECTOR OF THE BOTANICAL GARDEN OF THE UNIVERSITY OF MALAGA

Galapagos Verde 2050 is, without any doubt, one of the most important projects of the Charles Darwin Foundation; because it aims to give an integral solution to vegetal biodiversity, loss occurred in the last decades due to anthropogenic pressure and the introduction of invasive species. This project considers not just the reintroduction of species in their natural habitat, but also helps in its initial development by using water-saving technologies in the process. Moreover, it gives solutions to the different threats through the survival of endemic endangered species, just like the accidental introduction of invasive species in the natural ecosystems, or the over-consumption of agricultural products from the continental areas promoting the introduction of pathogens and other threats in the crops. The Galapagos Verde 2050 project engages the community of Galapagos, facilitating sustainable agricultural practices and at the same time promotes the use of endemic species as ornamental plants. From the beginning, Galapagos Verde 2050 has increased the scope of its objectives and study sites and relying on a magnificent working team, which enthusiastically has managed to communicate to the new generations the need of conserving the natural assets of the Galapagos Islands.



Dr. FRANK J. SULLOWAY
ADJUNCT PROFESSOR DEPARTMENT OF PSYCHOLOGY UNIVERSITY OF CALIFORNIA, BERKELEY

The Galapagos Verde 2050 Project is a shining example of the kind of innovative conservation efforts that are needed to stem the ongoing degradation of the Galapagos ecosystems. With the help of water-saving technologies, this program has shown that it is both feasible and practical to reverse vegetation losses in key species of plants that are vital to the survival and welfare of numerous endemic insects, birds, and other animals. We can only hope that the generous funding that has thus far sustained this project will continue to facilitate its implementation in the years to come.

Mr. PIETER HOFF
GROASIS TECHNOLOLGY INVENTOR

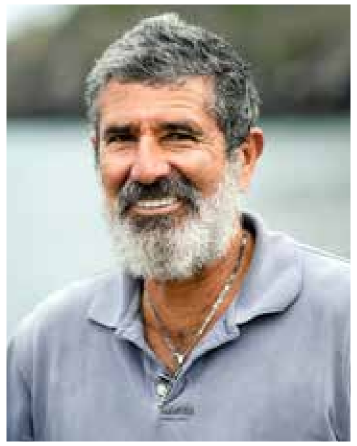
Charles Darwin Foundation set a new challenge, a great step ahead with the project “Galapagos Verde 2050”, CDF teaches us that we need not just to conserve but also to restore our environment. They showed us that we could not just accept that the world is becoming a great desert as a natural landscape, and for this reason the CDF, together with many strategic partners, decided to be an example for the world. We hope that this inspired everyone. It certainly inspired me, and I am proud and thankful to be part of this project. I hope that reading this makes you want to be part of “Galapagos Verde 2050” too.

MSc. DANNY RUEDA
GALAPAGOS NATIONAL PARK DIRECTOR AND EX-ECOSYSTEMS DIRECTOR

The Galapagos National Park Directorate under the integrated management of protected areas has developed native and endemic species reforestation programs in high ecological value ecosystems altered by the presence of invasive species. This reforestation drives the restoration of the ecological integrity in these protected ecosystems. The climatic conditions are not adequate for reforestation processes at least 6 months per year, during the dry season. With the aim of reinforcing these actions, we tried water-saving technology with the GV2050 project in coastal and arid ecosystems. It proved that the seedling development was optimal, guaranteeing growth and coverture of the reforested areas. In the future, we would like to implement the technology in bigger areas and on inhabited islands as a tool in the ecosystem restoration process.

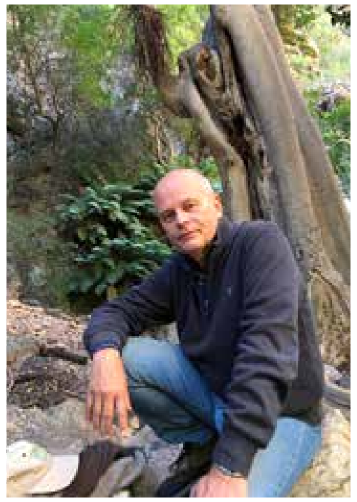
Dr. OLE HAMANN
EMERITUS TEACHER, BOTANICAL GARDEN, UNIVERSITY OF COPENHAGEN

In the last 50 years, the anthropic impact over biodiversity and ecosystems in Galapagos has increased dramatically. Natural resources exploitation, destruction and fragmentation of habitats, foreign species introduction and fires caused the modification of many ecosystems. However, the careful job done by GNP and CDF focused on conservation, was successful in many areas, saving many threatened species and habitat from extinction; nevertheless, there is a growing need for ecological restoration to conserve these unique ecosystems. As a botanist working for many years in these islands, I have come to realize that the Galapagos Verde 2050 project constitutes a major step into the conservation and restoration of ecosystems. Large-scale propagation of native and endemic species will be the basis for degraded ecosystem restoration, ensuring at the same time the future of some of the important plants for Galapagos.



CLAUDIO CRUZ
LOCAL FARMER FROM FLOREANA ISLAND

On Floreana Island we are very interested in the project Galapagos Verde 2050, mainly because of the benefits we've received so far. Among some of the positive results has been the accelerated growth of papayas and bananas using one of the water-saving technologies during the dry season in the pilot project. As well as the current restoration of endemic species on farms that have been altered by invasive species. In the future it will very important and of much help to Galapagos, onwards with this great research project!



Dr. WILLEM FERWERDA
CEO COMMONLAND GROUP

The work Galapagos Verde 2050 is doing is valuable for the islands for the following reasons. Education, the use of new technologies in from of the new generation of tourists, the local community and the governmental entities helps telling the story of the project. Ecological restoration is a very wide and important subject for the archipelago and the CDF, but that must go together with social benefits and inspiration from nature. Cocoon technology and the combination of several factors such as environmental education, invasive species control, together with effective local management of ecosystem protection, ensures a successful project

Mr. SWEN LORENZ
EX-EXECUTIVE DIRECTOR, CHARLES DARWIN FOUNDATION (2012-2015)

The Galapagos Verde 2050 project united COmON Foundation and Fuente de Vida Foundation at the end of 2013, to start a new phase. This allowed the project to take the first steps to become the most ambitious and impressive ecosystem restoration and sustainable agricultural practices project ever carried out in the Galapagos Islands. However, the purpose of the project goes far beyond Galapagos. Just like Darwin used these unique islands to show the world a new way of thinking, CDF has the aim of showing the world a new model for nature restoration and the implementation of a sustainable model of food supply, and therefore solve some of the main problems in the world. In some years, when the same efforts are being carried out in other parts of the world, I will be very pleased to say: "And again, everything started in the Galapagos".

GIANT TORTOISE RESTORATION INITIATIVE LEADERS
GTRI LEADERS AND GV2050 SCIENTIFIC COLLABORATORS

Ecological restoration of the islands represents a great opportunity to recover the terrestrial ecosystem of Galapagos, and to also generate significant ecological, social and economic benefits. For example, the need for ecological restoration on Baltra Island is very high due to the destruction caused by the old military base and its operations. However, at the same time, its restoration potential is also high because outside the old complex there are still pristine plant communities that can act as source for biological material to restore damaged areas on the island. Unlike other restoration, projects in Galapagos that occur on remote islands and witnessed by few people, many tourists and residents visit Baltra, creating an extraordinary diffusion opportunity for engaging visitors in the process of restoration of the island.

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