Advancing the Green Development Initiative: Pilot Study and Management Plan Creation Recommendations

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Abstract

The Green Development Initiative (GDI) is an innovative financial mechanism to conserve biodiversity by creating an international market for its trade. The GDI would accredit management plans for “sale” by land managers to willing buyers. The intent of the plans would be both to conserve biodiversity and improve land manager livelihoods, thus fulfilling the three objectives of the Convention on Biological Diversity. Currently, the GDI Steering Committee is seeking potential candidates for pilot studies; this paper explores the possibility of implementing a GDI pilot study at the site of three allied shade-grown coffee cooperatives in Tacuba, El Salvador. The strong social capital of the cooperatives and their location within the heavily deforested yet biodiversity-rich El Salvador, directly along the path of the Mesoamerican Biological Corridor, makes them ideal for selection as a GDI site. A connectivity analysis of this region was conducted in order to measure its conservation potential and to develop a tool for carrying out similar analyses in the future. This paper concludes by advising the Steering Committee to implement a GDI pilot study with the three Salvadoran cooperatives and provides a number of more general recommendations for implementing the GDI in other sites.
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The Green Development Initiative

It is increasingly clear that humans are now at a crossroads regarding the environment. We can drastically change our approach to land management and resource use in order to conserve what is left of the Earth’s biodiversity, or we can continue with our business-as-usual, anthropocentric attitude toward the environment. For those interested in the prior option, one major question comes to mind: What possible measures can be taken at this juncture that will not be too little, too late? A number of international conservation mechanisms have been proposed in the last few years as potential answers to this question. One proposal in particular, the Green Development Initiative, is compelling for both its striking and unusual design and its dual objectives of human and environmental well-being.

Under development since 2008, the Green Development Initiative, or GDI, is an innovative mechanism to inject millions of dollars of funding into biodiversity conservation through the trading of biodiversity in the free market (Earthmind 2011). The GDI would link biodiversity supply with biodiversity demand through the establishment of a trading market and an accreditation process. Certified protected areas, divided into hectares and accredited by the GDI, would be available for “purchase” by businesses, nonprofit organizations, private consumers, and others. The purchasers would not attain ownership of the actual land, but rather would pay for the land to be managed in a way that is conducive to the conservation of biodiversity; this management would be carried out by the “seller” of the GDI-certified management plan. These sellers could include any person, group, or entity with recognized management rights to the land, such as land owners, local peoples with historical access and use rights, businesses with licenses for use of the land, and so on. Current thinking is that the purchasers would “own” the management of biodiversity on that land for either 10 or 20 years.

The GDI is similar to the Clean Development Mechanism (CDM), which initiated a global carbon-credit trading system to mobilize funding for emissions mitigation (Earthmind 2010). Like the CDM, the GDI would utilize private-sector funding and implement standards and a certification process. However, unlike the CDM, which trades credits for standardized tons of carbon
emissions, the GDI would accredit unique management plans that would “sell” at prices determined by the values and preferences of the buyer.

The GDI arose partially from the realization by the international community that the objectives of the Convention on Biological Diversity (CBD) were not being met, largely due to a lack of funding for biodiversity conservation (Earthmind 2010). In 2008, the 9th Conference of the Parties (COP9) of the CBD called for “studies on approaches to develop markets and payment schemes for ecosystem services at local, national and international levels” and requested that the Parties “improve actions and cooperation for enhancing the engagement of the business community...in the implementation of the three objectives of the Convention.” Specifically, the COP9 requested that the Parties “come forward with new and innovative financing mechanisms in support of the strategy for resource mobilization” (Earthmind 2010). Through a series of international expert workshops, roundtables, seminars, and meetings, the GDI emerged as a potential answer to this appeal. Importantly, the GDI would support all three objectives of the Convention on Biological Diversity (CBD)—conserving biodiversity, ensuring sustainable use of its components, and enabling access to and sharing of the benefits arising from its use (CBD 2011). Because the GDI would not only allow but encourage the certification of areas being actively managed for sustainable use, such as timber- and crop-harvesting lands, land managers would profit from both the increased sustainability of their practices under the GDI and their sale of GDI-certified management plans to willing buyers. This goal of combining biodiversity conservation and productive land use is part of what makes the GDI such an innovative mechanism (Vorhies 2010). The GDI is part of a growing trend in conservation away from sole reliance on protected areas toward “integrated landscape management in which conservation and production units...are managed jointly for long-term sustainability” (Harvey, Komar et al. 2008).

Currently, the GDI is in the process of gaining large-scale international support and researching the implementation of a pilot phase of the program. The GDI’s Steering Committee is made up of biodiversity finance experts from the Dutch Environment Ministry, Earthmind (an
environmental NGO), the International Union for the Conservation of Nature (IUCN), the Organisation for Economic Co-operation and Development (OECD), and the United Nations Environment Program (UNEP). The Committee collaborates with the CBD Secretariat and receives support from the Government of the Netherlands. However, if the GDI is formalized by the CBD, a multi-stakeholder governing structure involving all major participants will be put into place. This will ensure legitimacy and transparency and provide NGOs, the private sector, and governments of both developed and developing countries the opportunity to take part in the GDI’s administration.

Based on the CBD’s objectives, the GDI has established a standard for the management of geographically bounded areas (Earthmind 2011). This standard involves four biodiversity objectives and four biodiversity components. The biodiversity objectives are conservation, sustainability, equity, and development. “Conservation” refers simply to the preservation of habitats and species in their native environments. The “sustainability” objective requires that the use of land and its resources does not decrease its long-term vitality and diversity, nor impede the ability of future generations to use the resources. “Equity” ensures that the benefits gained from the utilization of the environment are fairly shared by the people living within the area. Lastly, the “development” objective makes certain that the GDI advances the health and happiness of the people and communities involved. This is particularly necessary within developing countries, where the populace is unlikely to focus on environmental needs when their own basic necessities are not being met.

The GDI’s four biodiversity components, meaning the various elements of biodiversity to be conserved, are ecological complexes, ecosystems, species, and biological resources. An “ecological complex” is the geographically bounded area that is regulated by the GDI-certified management plan and can be thought of as a landscape or seascape. “Ecosystem” refers to the complex web of plants, animals, microbes, and the inorganic environment that functions as a unit. The term “species” has several different definitions which the GDI Steering Committee is still considering, but generally refers to a group of similar life forms that can breed and produce
viable offspring. Finally, the GDI defines “biological resources” as genetic resources that are being or have the potential to be utilized by humans.

These four objectives and four components have been combined into a “management matrix” (see Figure 1).

![Figure 1: Management matrix provided on GDI website (http://gdi.earthmind.net/standard/).]

For each GDI-certified management plan, the 16 cells of this matrix must be filled out in a satisfactory way. However, it is likely that for each particular area managed under the GDI, certain cells within the matrix will be more important than others.

The GDI’s Steering Committee is currently reviewing proposals of potential sites for the pilot phase of the project. This paper recommends that a pilot study be undertaken within the municipality of Tacuba in western El Salvador, on the land of three allied coffee cooperatives. In El Salvador, only 2% of the original, native forest remains, and of the 14% total current forest cover there, shade-grown coffee plantations comprise 60% (Messer, Kotchen et al. 2000). These farms are therefore vital to the conservation of biodiversity in the country, since they provide habitat for native, forest-dwelling species and ecological corridors between protected areas. Additionally, because of economic pressures to deforest, “there is an urgent need to directly integrate support and improvement of [coffee] farmer livelihoods as part of...conservation schemes” in El Salvador (Méndez and Lovell 2007). Because they are ideally situated to conserve biodiversity through their management practices and will not be able to do so without development assistance, the previously mentioned cooperatives in Tacuba would
be ideal for a GDI pilot study. Additionally, the presence of “charismatic” endangered species within the region, such as the margay (*Leopardus wiedii*), will provide ample international marketing opportunities for the GDI upon the successful completion of the pilot study. A connectivity analysis of the region was conducted using GIS (Geographic Information Systems) software and supports the predicted conservation potential of the cooperatives.
Coffee and Biodiversity

Coffee cultivation is extremely important to the economies of northern Latin American countries (Perfecto, Rice et al. 1996; Gobbi 2000; Perfecto, Vandermeer et al. 2005). Coffee farms cover about 3.6 million hectares in this region, and coffee is the most important economic export (Perfecto, Vandermeer et al. 2005). In El Salvador, there are some 20,000 coffee farms, comprising an estimated 196,000 hectares or 9% of the country’s land and employing about 15.5% of the rural population (Gobbi 2000). Historically, coffee farms in El Salvador and the rest of Central America have contributed to the preservation of tree cover (Perfecto, Rice et al. 1996; Messer, Kotchen et al. 2000; Blackman, Ávalos-Sartorio et al. 2007; Méndez and Lovell 2007). The traditional manner of coffee growing, “shade coffee,” involves planting the coffee beneath tree cover. Tree cover regulates the microclimate (temperature, humidity, and irradiation) of the coffee plantation. Additionally, it provides habitat that conserves biodiversity, sequesters carbon, prevents soil erosion, and filters groundwater. Thus, shade coffee has been one of the few human-dominated landscapes that “provides many of the same ecological services associated with natural forests” (Blackman, Ávalos-Sartorio et al. 2007). These services include biodiversity preservation, as “loss of species richness in highly shaded coffee farms is minimal compared with the enormous losses experienced with other forms of agricultural modification” (Philpott and Dietsch 2003).

Unfortunately, the coffee crisis of recent years has forced many Latin American farmers to shift away from traditional coffee-growing practices. Due to a glut in supply, international coffee prices have dropped to their lowest point in half a century—about $0.42 per pound, which is not enough to compensate most farmers for their production costs (Philpott and Dietsch 2003). Those farmers that have not sold their land to developers, loggers, or conventional farmers—or simply abandoned their farms to migrate to urban areas—have adopted modern methods of coffee farming. These methods involve clearing away the tree cover and growing the coffee plants in direct sunlight (Messer, Kotchen et al. 2000) (see Figure 2). This technique was developed as a means to prevent plant fungal diseases such as coffee leaf rust and increase yields (Perfecto, Rice et al. 1996). Because the removal of tree canopies decreases the organic
matter available to enrich the soil and eliminates protection from pests, modernization or “technification” also requires the use of fertilizers, pesticides, and herbicides (Messer, Kotchen et al. 2000). Technification does result in greater coffee crop yields, but it also strips away all of the important ecological services provided by shade coffee farms. Unfortunately, almost 40% of all coffee farms in Latin America are now “technified.” This striking loss of tree cover is especially problematic in El Salvador, the most densely populated and intensely deforested nation in the Americas (Blackman, Ávalos-Sartorio et al. 2007). In this country, 60% of the six million acres of coffee-growing land has been cleared of shade trees since 1972 (Eartheasy 2011).

Figure 2: Coffee-growing techniques (Moguel and Toledo 1999).
It is vital, from both an environmental and a human development perspective, to reverse this trend of technification of El Salvador’s coffee farms. As previously mentioned, shade tree cover provides a number of environmental benefits. This is due in large part to the structural similarity of shaded coffee plantations and natural forest cover (Méndez and Bacon 2006). According to Gobbi, these services include: “(1) providing refugia and habitats for biodiversity; (2) maintaining and enhancing the nutrient and organic content of soils; (3) sequestering carbon; (4) pollinating crops and other plants; (5) controlling pest outbreaks; and (6) acting as sources of clean air and water” (Gobbi 2000). The first point—that of shade trees conserving biodiversity—is of extreme importance in Central America. This region is a biodiversity “hotspot,” and it has been shown that shaded coffee farms can support large numbers of native forest species (Perfecto, Rice et al. 1996). For example, Perfecto et al. found that “the species richness of birds in coffee plantations with a structurally and floristically diverse canopy compares well with other natural forest habitats with which many species are shared.” (1996). Additionally, “individuals of several migratory [bird] species in shade coffee plantations survived the winter at a rate comparable with those in natural forest habitats.”

Shaded coffee farms also support a huge diversity of other animal species. Gallina et al. found that shaded coffee plantations “can be inhabited by a diversity of medium-sized mammals” (Gallina, Mandujano et al. 1996). These plantations are one of the only anthropogenically productive systems that are “capable of sustaining a highly diverse mammalian community, in spite of the transformation of the original vegetation,” because they maintain complex arboreal strata. These strata provide food, protection, and shelter for mammals. In particular, farmers’ use of fruit trees to provide shade is extremely beneficial to mammals.

It has also been found that the greater the complexity of the vegetation in these coffee plantations, the greater the diversity of mammalian species they can support (Perfecto, Rice et al. 1996). For some threatened and tree-dependent mammal species, like the margay, restoring vegetative complexity in coffee farms in Central America may be the only way to prevent extinction or extirpation. Heightened structural and vegetative complexity also
benefits an array of other species such as reptiles, amphibians, and arthropods and increases the likelihood of their survival (Perfecto, Rice et al. 1996; Messer, Kotchen et al. 2000). Higher tree density has also been found to increase species richness on shaded coffee plantations (Méndez, Shapiro et al. 2009).

Because of the widespread disappearance of Central America’s forests, the international conservation community has devised an initiative known as the Mesoamerican Biological Corridor (MBC) (Giovannucci, Brandriss et al. 2000; Kaiser 2001) (see Figure 3). This would be comprised of a “network of interconnected protected habitats stretching from southern Mexico to Northern Columbia” (Giovannucci, Brandriss et al. 2000).

Figure 3: Mesoamerican Biological Corridor (York 2011).
Conservationists believe that creating connections between existing protected areas is the last opportunity to preserve rapidly declining populations of species. To accomplish this goal, protected areas must be expanded, and agricultural land will need to be managed in a way that supports biodiversity. This means it is now even more vital to restore traditional coffee-growing techniques in El Salvador.

Shaded coffee plantations and their concomitant high levels of biodiversity are beneficial to farmers, as well. Farmers can derive economic benefits from selling the products of shade trees such as fruit, timber, and flowers, and they can utilize fruit and medicinal herbs to improve the health of their families (Perfecto, Rice et al. 1996). Méndez examined the livelihood benefits of shade coffee within the Tacuba cooperatives specifically being proposed as a pilot site for the GDI and found that farmers profited from each of these tree uses (Méndez 2008). Gobbi lists the additional benefits to farmers stemming from higher levels of plantation biodiversity as follows: “(1) improved health conditions for farmers and coffee workers through reduced and/or controlled use of agrochemicals; (2) improved living conditions for local workers through an environmental education campaign to provide information on how to live in a cleaner and healthier environment; (3) increased opportunities for recreation and ecotourism; and (4) increased opportunities for expressing and developing the ethical, aesthetic, and cultural values of many farmers and citizens who appreciate ‘the beauty of nature’” (Gobbi 2000).

Shaded coffee farms are normally organic, and because they are not exposed to fertilizers and pesticides, they produce a healthier end product for consumers. Because coffee beans grow more slowly in the shade than in the sun, their natural sugar content increases, thus enhancing the coffee’s flavor (Eartheasy 2011). Additional benefits of shade-grown coffee are therefore its high-quality taste and lack of chemical residues.

Despite all of these advantages of shade-grown coffee, the coffee crisis has led many farmers in El Salvador (as well as the rest of Latin America) to convert to higher-yield sun coffee systems,
change to other types of crops, or abandon their farms altogether (Perfecto, Vandermeer et al. 2005). These farmers must somehow be financially incentivized to revert to shade-grown coffee, or this trend will continue (Gobbi 2000). Researchers have explored a number of possibilities for such an incentive, among them creating a shade coffee certification (Perfecto, Vandermeer et al. 2005), distributing payments for ecosystem services (PES), enabling participatory action research (PAR) initiatives, and facilitating agroecotourism (Méndez, Bacon et al. 2010).

The shade coffee certification idea has merit, especially given the success of Fair Trade and Organic certification labels; however, the premium for shade-grown coffee may not be high enough to compensate for the lower yields of shaded coffee farms (Perfecto, Vandermeer et al. 2005). Additionally, attempts by Rainforest Alliance to work with small farmers to implement such a certification have not yet been successful due to suspicion on the part of the farmers (Méndez, Bacon et al. 2010). Because PES has “so far been implemented...through top-down mechanisms requiring a high level of capacity from participants,” it has experienced limited participation and success. The PAR processes that have attempted to encourage agroecotourism have lacked enough funding, support, and participation to be widely successful.

According to Méndez, all of this evidence “argues for a hybrid model, which is able to integrate community-based projects with the resources from top-down approaches” (Méndez, Bacon et al. 2010). The Green Development Initiative, with its site-specific management plans and flexible levels of funding, would be an ideal “hybrid” model to implement in El Salvador. The three previously mentioned coffee cooperatives in Tacuba will therefore provide an excellent site for application of the GDI.
**Tacuba Coffee Cooperatives**

Tacuba, a municipality in western El Salvador, has a diverse topography and large number of coffee plantations. It acts as a buffer to the adjacent Parque Nacional El Imposible (PNEI), which is the largest protected forest area in the country (Méndez and Bacon 2006; Méndez 2008). Tacuba is also within the planned area of the Mesoamerican Biological Corridor. Within Tacuba, three coffee cooperatives have allied to form the Association of Organic Coffee Producers of Western El Salvador (ACOES) (see Figure 4). The founding members were motivated to develop ACOES because they wished to expand their capacity to improve their livelihoods while maintaining the integrity of the environment (Méndez 2011). Legalized in 2007 and made up of 25 members who represent about 200 individuals (the total number of members of the original three cooperatives), ACOES functions as a “second-level cooperative” or organizing body that works to market the coffee and create connections with potential partners, among other objectives (Shapiro 2011). ACOES is governed by officials elected by its member cooperatives. ASINDEC, a nonprofit research foundation in El Salvador run by academics and environmental professionals, helped to form ACOES and continues to support its efforts. Currently, ACOES is taking part in a Participatory Action Research (PAR) process run by Dr. Ernesto Méndez, Professor of Agroecology at the University of Vermont (UVM 2011). The purpose of the PAR is to “engage parallel processes of research and local development or social change, through more horizontal relationships between local actors and researchers” (Méndez 2008).
These three coffee cooperatives have unique management and organizational structures, but all are committed to maintaining their traditional shade-grown coffee systems. However, because the farmers’ profits from shade coffee sales alone are not high enough to sustain their families, many of them selectively harvest trees for timber and firewood. Any efforts to reduce this practice and increase the biodiversity-supporting capabilities of the coffee plantations must be coupled with economic or development assistance for the farmers (Méndez 2008). Fortunately, as long as they make enough income to support their families, the farmers are eager to adapt their practices to the benefit of the environment; a study by Méndez of farmer perceptions found that they consider themselves important providers of ecosystem services in the region and wish to conserve native trees (Méndez 2008).
The already existing willingness of the cooperatives’ farmers to improve their environment and provide ecosystem services to Tacuba makes them ideal proprietors of a GDI-certified management plan. Importantly, the involvement of Dr. Mendez and his PAR project ensures that the farmers will have enough support to draft and carry out such a plan. The cooperatives’ location within the projected area for the Mesoamerican Biological Corridor, as well as within the heavily deforested and biodiversity-rich El Salvador, means that implementation of the GDI there has the potential to make an incredible contribution toward biodiversity conservation.

It will be important in any GDI pilot study to have a concrete way to measure the success of the certified management plan in increasing or supporting regional biodiversity. Within Tacuba, there are a number of threatened species that would benefit from additional tree cover. However, one in particular would benefit specifically from increased tree density on shade coffee plantations and would serve as a charismatic marketing tool for the GDI—the margay, or *Leopardus wiedii*. 
Measuring Success with the Margay

The margay is a member of the cat family that closely resembles the ocelot (de Oliveira 1998) (see Figure 5).

Its range extends from Mexico through Central America to Uruguay. Unlike ocelots, margays are almost completely arboreal and have evolved specific traits to allow them to thrive among tree canopies (Oliveira Calleia, Rohe et al. 2009). These traits include large, flexible paws and hind feet that can rotate 180 degrees. This last feature allows margays to run down tree trunks head first—the only member of the cat family with this ability. The margay’s numbers are declining rapidly throughout most of its range because of habitat reduction largely due to conversion of forested areas to agriculture (IUCN 2011). According to the IUCN, this decline will continue at a rate approaching 30% in the next 18 years. Historically hunted for its fur, the margay is now protected from hunting and trading within most of the countries in its range; however, it has not been legally protected in El Salvador.
For several reasons, the margay would be a perfect “test species” for biodiversity conservation efforts in the Tacuba cooperatives. First, the Tacuba cooperatives fall directly within the margays’ traditional range. Second, margays are willing to live in disturbed forest or agroforestry systems as long as sufficient tree cover is provided. Therefore, if the cooperatives increase their coffee plantation tree density to a level mimicking that of a natural forest, margay individuals are likely to take up residence there. Because these felids have a maximum size of about eight pounds and occur at densities less than five individuals per 100 square kilometers, they are small and rare enough that any as-yet-unknown effects they may have on coffee yields would be miniscule. Since margays are nocturnal, they are unlikely to cross paths with the farmers very often, protecting them from the danger of being hunted. Additionally, margays are generalists in their diet, eating reptiles, birds, small arboreal marsupials, and rodents (Wang 2002). This quality makes margays flexible in their habitat requirements. According to Wang, felids are “top predators and play an important ecological role in the forest community, influencing not only the abundance of their prey-species populations, but also the dynamics of the plant community and consequently, the plants’ diversity” (Wang 2002). Thus, the presence of margays in shaded coffee plantations may help to increase the species richness of the farms.

Because margays generally live in areas where ocelot numbers are low, they fare better in non-legally protected areas (where ocelot densities are high) (IUCN 2011). The shaded coffee cooperatives are not protected and therefore likely have low ocelot densities. Furthermore, ecologists have found evidence that felids can successfully utilize corridors between protected areas (Kaiser 2001); since the cooperatives are within the proposed Mesoamerican Biological Corridor, margays may be able to make future use of them as a corridor between natural forest habitats.

The goal of boosting tree density within the cooperatives enough to sustain populations of margays will provide a measurable way to increase biodiversity. There is a strong direct relationship between tree stem density and overall species richness, so increasing tree density
on the farms would likely increase biodiversity levels (Méndez, Shapiro et al. 2009). It would be important, though, to specify in the GDI management plans that replanting or enrichment of the shade cover be done with diverse, native trees. Currently, the mean tree density of the three cooperatives is about 54.3 stems per plot of 1,000 square meters (Méndez 2008). Tree density in the adjacent protected Parque Nacional El Impomible is about 138.3 stems per plot of the same size (see Figure 6). A possible GDI-certified management plan for the cooperatives could include a goal of matching, as closely as possible, the tree density levels of the coffee plantations to those of the PNEI.
Figure 6: Map of current tree density in cooperatives versus Parque Nacional El Imposible.
Connectivity Analysis

The GDI Steering Committee may wish to conduct a quantitative analysis of the conservation potential of increasing the tree density on the cooperatives. There are a number of GIS-based analyses that would determine whether increasing cooperative tree density would improve biodiversity levels (Urban 2011). First, it is possible to analyze the current biodiversity levels of the cooperatives, then compare them with biodiversity levels in other areas of El Salvador. Unfortunately, there is currently not enough GIS data on El Salvador’s species richness levels for this approach to be feasible. Another method is to examine habitat patches and determine which are most ideal for a particular species. However, the patches of protected areas and forests in El Salvador are too small to enable such an analysis. Therefore, the method that makes the most sense in this case is to examine the area of the cooperatives within a spatial context—that is, determining their connectivity potential with other forested areas of El Salvador. Such potential could include creating in-country corridors between Parque Nacional El Imposible and other protected areas or advancing the Mesoamerican Biological Corridor. Such a connectivity analysis was therefore conducted as part of this study.

The first step of the connectivity analysis was to acquire data on El Salvador’s ecosystems and land cover and prepare this data for analysis within GIS. A map of El Salvador’s ecosystems was produced (see Figure 7).
Figure 7: Map showing the ecosystems of El Salvador.
The next step of the analysis was to create a map of the country’s protected areas (see Figure 8).

![Map of protected areas of El Salvador](image)

**Figure 8:** Map showing the protected areas of El Salvador.
Connectivity analyses require a test species in order to set the parameters of the analysis (Swenson 2010), and in this case, the margay was selected as the test species. Based on the margay’s habitat preferences, costs were assigned to the landscape. “Costs” refer to the level of difficulty a species will encounter when traversing a landscape; animals generally disperse in such a way as to incur the lowest possible cost. Since the margay lives in forested areas, forests were assigned the lowest cost, followed by vegetated areas, then open areas, then urban regions, then water. These costs ranged in value from 1—forests—to 50—water. Although information from the literature on margays was referenced when assigning these costs, there is no way to know and assign exact cost values within GIS (Urban 2011). Therefore, a certain amount of educated guesswork by the user is required for this portion of the analysis. An important step at this point was classing the area of the cooperatives as forest rather than agriculture, in order to analyze its connectivity potential should its tree density be raised to mimic that of the neighboring forest.

After running the tools to assign costs to the habitat types, a cost surface map of El Salvador was produced (see Figure 9).
Figure 9: Map showing the cost surface of El Salvador based on the margay’s habitat preferences.
The cost surface map closely resembles the ecosystem map. Forested areas are in dark green, indicating lowest cost, followed by vegetated and agricultural areas, since margays are willing to cross these ecosystems when need be (Kaiser 2001). Urban and aquatic areas are displayed in red to indicate highest cost, since margays will not cross these regions.

The next step was to create a cost distance map. “Cost distance” refers to accrued cost as the species moves across the landscape. The animal’s goal is to find the “cheapest” route—the path of least cost—from one area of habitat to another (Swenson 2010). For the margay, which lives in and travels between forested areas, the cost distance from each forest is significant. The cost distance a margay would incur as it moved away from the forest of Parque Nacional El Imposible is shown below (see Figure 10).
Figure 10: Map showing cost distance from Parque Nacional El Imposible.
Cost distance values are difficult to analyze because it is not possible to convert them to real-world values (Urban 2011). Still, it is clear from this map that the darker green portions, where cost distance values range from 0 to 616,942, represent areas that are relatively easy for the margay to reach. Similarly, the darker red areas, with values ranging from 1,645,181 to 2,056,476, would be much more difficult for the margay to reach.

Parque Nacional El Imposible represents the beginning of the MBC’s path within El Salvador (Consortium 1993) (see Figure 11).

![Figure 11: Map showing the path of the Mesoamerican Biological Corridor.](image)

This path ends with Montecristo, a large and important protected forest at the northern edge of the country (Shapiro 2011). Presumably, a margay traveling along the path of the MBC would need to get from Parque Nacional El Imposible to Montecristo; therefore, the next step
of the analysis was to calculate the corridor—the least-cost corridor—that the margay would take from El Imposible to Montecristo.

To calculate this corridor, the cost distance map of a margay traveling from Montecristo needed to be created first (see Figure 12).
Figure 12: Map showing cost distance from Montecristo.
As with the first cost distance map, green areas show low accrued cost values, and red areas show high values.

Now that cost distance maps from both the “source patch”—PNEI—and the “end patch”—Montecristo—had been created, it was possible to run the tools to create a corridor within GIS. These tools analyze both sets of cost distances and determine the path of minimum cost incurred for the species traveling from the source to the end patch. The initial, “raw” corridor produced by GIS assumes that the corridor is allowed to cover all available land (Swenson 2010) (see Figure 13).
Figure 13: Map of initial corridor produced between El Imposible and Montecristo.
In order to cut the corridor down to a size that is both usable by the species and meaningful for the researchers, the corridor’s width needed to be reduced based on species information. There are a number of ways to do this within GIS. The method that makes the most sense for this region and with the margay as the test species is to limit the width of the corridor to approximately twice the size of an adult male margay’s home range (CorridorDesign 2011). This allows for margays to live within the corridor, in forested areas, while still leaving room for other margays to cross the corridor. Since margays are extremely territorial, it is important that the corridor be wide enough to prevent bottlenecks when one margay will not cross through the territory of another (Nowak 1964). Fortunately, this only applies to male margays; several female margays can live within the territory of one male. Since adult male margays’ home ranges are estimated to be about 10 square kilometers, the width of the corridor was limited to 20 kilometers. After removing the portions of the corridor that exceeded 20 kilometers in width, an appropriate corridor was produced (see Figure 14).
Corridor between El Imposible and Montecristo

Figure 14: Map showing corridor between El Imposible and Montecristo.
It is clear from this map that the cooperatives, once their tree density is increased to equal that of native forest, will function as a portion of this corridor of least cost for margays traveling between PNEI and Montecristo.

In order to make this connectivity analysis more widely useful, a tool was created that will enable the GDI Steering Committee to calculate corridors between any protected areas within El Salvador, using any species’ habitat preferences (see Appendix).
Pilot Study with Tacuba Cooperatives

As stated above, the Tacuba coffee cooperatives would be an excellent location for a GDI pilot study. There is a pressing need to preserve biodiversity in El Salvador, and because coffee farmers manage such a large proportion of the “forested” land in that country, doing so will require their cooperation and involvement. The poor economic situation of most of the rural farmers in El Salvador means that they will require financial assistance in order to cultivate coffee in a way that is favorable for the environment but less profitable for them. The Tacuba cooperative farmers have expressed an interest in pursuing this course of biodiversity-friendly coffee cultivation coupled with economic backing, but no suitable opportunity for doing so has presented itself as of yet (Méndez, Bacon et al. 2010).

One of the most compelling arguments for engaging these specific cooperatives in a GDI pilot study is the significant amount of social capital that already exists in these sites. Social capital, as defined by Bebbington, refers to “organizations, institutions and networks...of various types, and at a range of levels” (Bebbington 1997). The Tacuba cooperatives formed ACOES in order to increase the organizing abilities of the coffee farmers themselves, and the members of the organization have much experience networking with outside partners such as Dr. Méndez and his research team. Social capital such as this is extremely helpful, if not vital, to the objective of implementing sustainable resource management in areas like rural Central America; organizing and networking power provides opportunities to enter new markets and make connections with external actors and institutions (Bebbington 1997). Furthermore, Bebbington found that when farmers have a working relationship with a university professor, as well as an external source of support—as the Tacuba cooperatives do—their likelihood of successfully improving both their economic situation and the environment increases considerably.

The social capital of the cooperatives will make embarking upon a pilot study with them fairly uncomplicated for the GDI Steering Committee. In turn, the GDI will enable the cooperative farmers to improve their livelihoods in ways they could not do on their own (Bebbington 1997; Earthmind 2011). The GDI will connect the cooperatives with market demand for their
environmental services by both setting up the macro-economic program through which biodiversity can be bought and sold and certifying the farmers’ management plan.

Logistically, it should be simple to both implement and measure the degree of success of a GDI pilot study with the Tacuba cooperatives. Because the farmers are already involved with the ACOES PAR and the organic certification processes, they are accustomed to monitoring the environmental conditions of their plantations. Therefore, they have the “knowledge, skills, and willingness to be involved in actively monitoring the margay populations,” which as explained above would serve as an ideal indicator of biodiversity levels (Shapiro 2011). Furthermore, the current plan to require GDI-certified management plans to last a duration of 10 to 20 years should not be a problem for the farmers, since shade-grown coffee plantations have a life span of 30 or more years (much longer than the life span of technified coffee farms) (Perfecto, Rice et al. 1996).

One of the first steps in devising a management plan for certification by the GDI is to fill out the previously explained GDI management matrix in a satisfactory manner. Figure 15, below, illustrates a possible method for doing so with the Tacuba cooperatives pilot project.
The next steps in the development of a management plan for the Tacuba cooperatives will depend upon the specific modalities decided upon by the GDI Steering Committee. However, it is clear that any acceptable management plan must include certain information. First, comprehensive data regarding current floral and faunal biodiversity levels within the three cooperatives, as well as tree stem densities, must be included. This should make specific reference to current margay numbers in the area. Second, current coffee crop yields and annual profits of the farmers should be delineated clearly. Importantly, the farmers and Dr. Méndez should determine what the projected crop yield loss would be with varying levels of shade cover increase. This will allow the GDI Steering Committee to ascertain the baseline of how much funding the management plan “buyer” would need to provide in order to make the
project worthwhile to the farmers, bearing in mind that the funding should more than make up for the loss in profits so that the farmers’ situation can be advanced.
Recommendations to GDI Steering Committee

It is the overarching recommendation of this paper that the GDI Steering Committee consider the Tacuba coffee cooperatives as a pilot study candidate. In the course of this study of El Salvador and the cooperatives, a number of lessons have emerged that can also be extrapolated as secondary recommendations to the Committee. First and foremost, it is clear that management plan regulations must be site specific. In the case of the Tacuba cooperatives, the farmers have already had experience with external actors attempting to improve their livelihoods, with varying levels of success. The Committee must therefore make sure that it allows these farmers both flexibility and a feeling of equal partnership in the formation of their management plan. However, land managers in other locations will have had vastly different experiences and may require differing levels of assistance from the Committee, though they must also be treated as equal partners in the process. Such assistance may include the building of organizational skills, social networks, and the technical skills needed to develop and implement a satisfactory management plan. The unique circumstances of each GDI site must be taken into account when developing certified management plans.

Second, local partners at each GDI site are a necessity. Organizations such as ACOES in Tacuba are already trusted by locals and will be extremely helpful to the Committee when it comes to communicating with land managers and acquiring GIS and other data (Shapiro 2011). Lastly, the traditional practices of land managers should be respected and maintained wherever possible. This is particularly true when the objective is biodiversity-friendly agriculture, which is generally best achieved by mimicking the structure and diversity of native vegetation—thus requiring heavily site-specific knowledge possessed only by local farmers (Harvey, Komar et al. 2008). As explained by Harvey et al. and demonstrated by the Tacuba cooperatives, “Small farmers are more likely to know their land intimately, embrace complexity and multifunctionality, retain multiple traditional varieties, [and] focus on inputs of knowledge and labor rather than purchased agrochemicals and mechanization” (Harvey, Komar et al. 2008). It is therefore vital for the GDI Steering Committee to begin with a goal of keeping local land
managers on their land, managing in their traditional ways—and then add the environmental and economic value of a GDI management plan.

The GDI appears to be the perfect way to satisfy Harvey’s call for a “new approach [that] recognizes farmers as stakeholders in conserving biodiversity and actively solicits farmers as partners to create resilient landscapes that foster wildlife and preserve rural livelihoods and local knowledge” (Harvey, Komar et al. 2008). It is just such an innovative and multi-stakeholder approach that will be the solution to preserving the Earth’s dwindling biodiversity and improving the livelihoods of struggling land managers the world over.
Literary Citations


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Appendix: Corridor Tool for El Salvador

The tool created in the course of this analysis produces, among other outputs, corridors between any protected areas in El Salvador. The tool will enable the GDI Steering Committee to evaluate the connectivity potential of any protected site as far as in-situ conservation efforts go or to assist the Mesoamerican Biological Corridor. The major benefit of this tool over existing connectivity tools is that it is specifically calibrated for El Salvador. It includes the country’s ecosystems and protected areas and produces a number of useful outputs. The user can choose how much he or she wants to control the parameters of the model. The defaults are set to favor forested habitat and utilize the more common statistical methods within the analysis, but the user can change these settings very easily (see Figure 16).
The tool allows the user to reclass the ecosystems of El Salvador based on the preferences of his or her species of choice. The tool’s outputs include Euclidean distance rasters and statistics (see Figure 17), cost distance rasters and statistics (see Figures 17 and 18), one source and two end patches (as shapefiles) (see Figures 17, 18, and 19), and two corridors—between the start patch and each of the two end patches (see Figures 18 and 19).
Figure 17: Corridor Tool, part 1.
Figure 18: Corridor Tool, part 2.
Figure 19: Corridor Tool, part 3.
This tool can also be used by the GDI Steering Committee to confirm the results of the connectivity analysis referenced in this study, or to conduct a similar analysis with a different test species.