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Ecological Restoration and Sustainable Agricultural Landscapes

July 30, 2013
Bogotá, Colombia

Proceedings of the Symposium
held during the III Iberoamerican
and Caribbean Conference
on Ecological Restoration

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Acronyms

AFS	Agroforestry Systems
APASPE	Association of Agro-silvopastoral Producers of the Municipality of Pedasí
APP	Areas in Permanent Preservation
CATIE	Tropical Agricultural Research and Higher Education Center
CIPAV	Center for Research in Sustainable Agricultural Production Systems
ELTI	Environmental Leadership and Training Initiative
ES	Environmental Services
ISAEM	Integrated Silvopastoral Approaches for Ecosystem Management
ISPS	Intensive Silvopastoral System
LASTROP	Laboratory for Tropical Silviculture
LP	Leadership Program
LR	Legal Reserve
LERF	Ecological Laboratory for Forest Restoration
MSCR	Mainstreaming Sustainable Cattle Ranching
PES	Payment for Environmental Services
SPS	Silvopastoral Systems
STRI	Smithsonian Tropical Research Institute

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Introduction

Ecological Restoration and Sustainable Agricultural Landscapes

Zoraida Calle

Center for Research on Sustainable Agricultural Production Systems, CIPAV

In recent years, the dilemma of how to meet the growing demand for agricultural products while at the same time conserve biodiversity and prevent a global climate crisis has been framed in terms of two competing approaches. On the one hand, there are those who propose a *land sharing* strategy, where production and conservation objectives are integrated within complex multifunctional landscapes[1,2,3]. On the other hand, there are the proponents of the *land sparing* strategy, through which agricultural production is maximized in high-yield systems while other lands are reserved exclusively for the protection of natural habitats[4,5]. Discussions about these approaches often are presented as black-and-white scenarios with little consideration for the many shades of gray that influence land use planning under real conditions and that depend upon a variety of biophysical, economic, social and political factors, all of which are interrelated.

While certain agricultural practices make significant contributions to climate change and the global biodiversity crisis and often are at the root of these and other major environmental problems, it is also true that there are alternative forms of agriculture that may help to resolve these problems. Several recent scientific studies suggest, for example, that certain agricultural landscapes and practices provide basic environmental services and contribute significantly to conserving biodiversity without sacrificing productivity and profitability. Thus, it is possible that there is an alternative to the dilemma of land sharing vs.

1 Perfecto, I., & Vandermeer, J. (2008). Biodiversity conservation in tropical agroecosystems. *Annals of the New York Academy of Sciences,* 1134(1), 173-200

2 Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., ... & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation,* 151(1), 53-59.

3 Fischer, J., Brosi, B., Daily, G. C., Ehrlich, P. R., Goldman, R., Goldstein, J., ... & Tallis, H. (2008). Should agricultural policies encourage land sparing or wildlife-friendly farming? *Frontiers in Ecology and the Environment,* 6(7), 380-385.

4 Green, R. E., Cornell, S. J., Scharlemann, J. P., & Balmford, A. (2005). Farming and the fate of wild nature. *Science,* 307(5709), 550-555.

5 Phalan, B., Onial, M., Balmford, A., & Green, R. E. (2011). Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science,* 333(6047), 1289-1291.

land sharing, which involves combining sustainable intensification, ecological restoration and conservation strategies.

In regions where large numbers of people depend upon degraded landscapes for their livelihoods, the integration of ecological restoration with sustainable production will be instrumental in the future. It, is therefore, a priority to develop and test strategies that integrate conservation and restoration practices in productive landscapes in order to simultaneously achieve goals, such as to conserve biodiversity and natural resources, ensure the provision of goods and services, mitigate and adapt to climate change and increase agricultural production, food security and human welfare.

Currently, several large-scale restoration initiatives are addressing these issues from different perspectives. This symposium was designed to provide a space to share the progress of initiatives currently under way in Latin America that are tackling the dual goals of conservation and restoration in productive landscapes. Examples include restoration of riparian corridors in fragmented landscapes of the Atlantic forest of Brazil, yerba mate production in agroforestry systems in Argentina and intensive silvopastoral systems in Colombia and Mexico. The speakers briefly presented their projects, discussed their environmental and social impact and offered their critical reflections and lessons learned. The symposium concluded with a dynamic question and answer session between the audience and the speakers.

Talk 1

The Future of Biodiversity in Tropical Agricultural Landscapes: Ecological Restoration and the Importance of the Matrix

Felipe Melo

Federal University
of Pernambuco, UPF

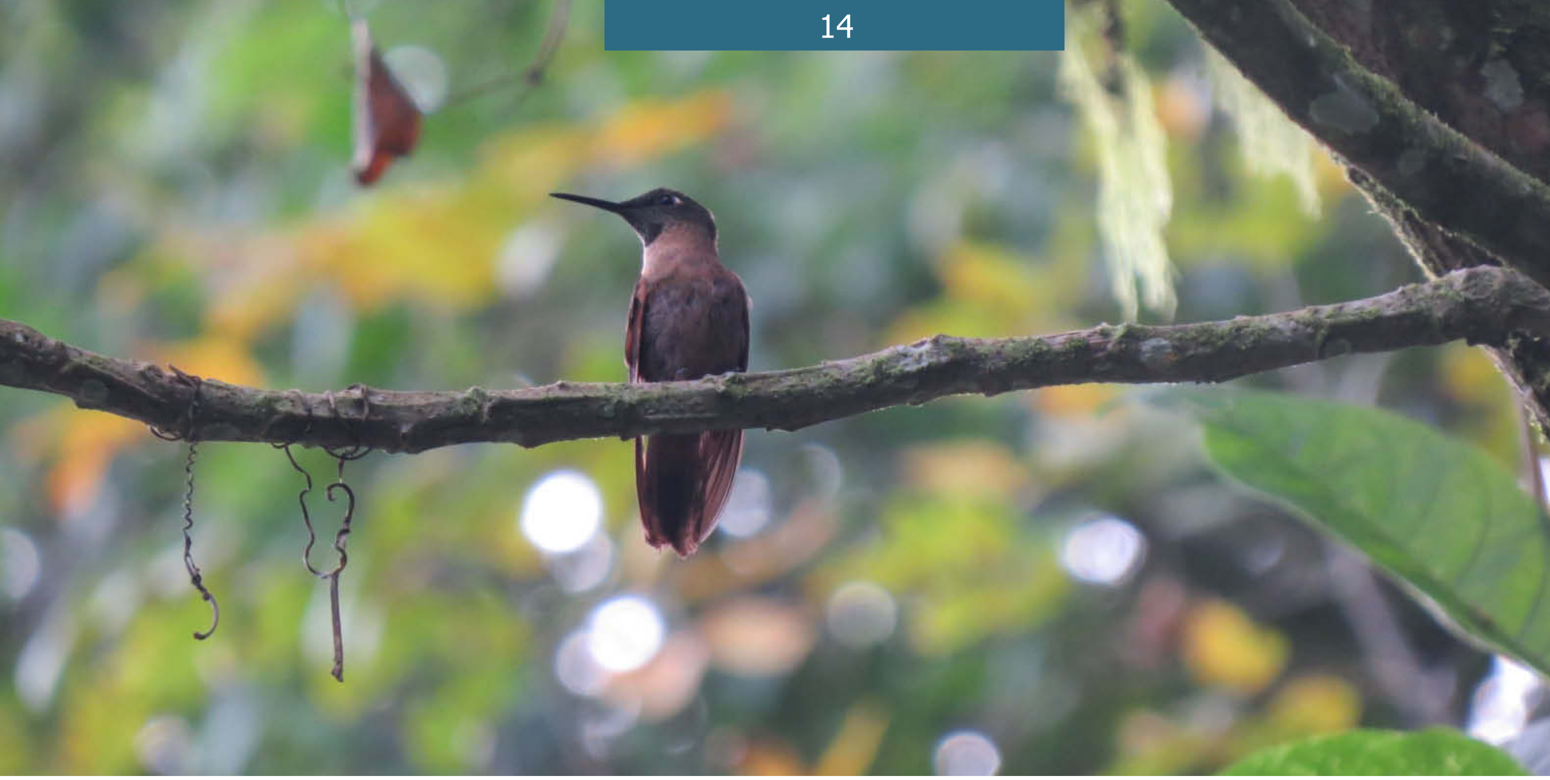
Although I am not a specialist in ecological restoration, I am interested in restoration because it allows me to test ecological theories that, as a biologist and ecologist, I have developed about the management of altered ecosystems. Therefore, the aim of this presentation is to share what we currently know about the functioning of forests in disturbed landscapes and to examine the implications for restoration.

First, I think it necessary to re-contextualize ecology as a science. For many years, much of the academic efforts devoted to understanding the future of tropical forests have focused on the study of intact portions of forests, which retain much of their biodiversity. However, predicting the future of biodiversity in altered landscapes requires a broader, more realistic approach. That is why I consider that one of the most interesting concepts that recently emerged in the field of ecology is that of 'emerging ecosystem' or novel ecosystem. According to this concept, in order to effectively manage the remaining fragments it is necessary to consider them in the context of the landscape matrix in which they are embedded. Following this logic, my studies on the future of diversity in the Atlantic Forest in northeastern Brazil have focused on these remaining fragments, examining them not in isolation but as part of the dominant sugarcane matrix that surrounds them.

To understand the future of these emerging habitats in agricultural landscapes, there are many questions that still need to be answered. For example, it is important to determine if forest fragments in these highly transformed landscapes can actually retain their biodiversity in the long term. Another key question that is especially relevant for restoration efforts is how resilient and resistant these landscapes really are. In this regard, it is important to recognize that some landscapes have already crossed the threshold of degradation and that restoration might not be an economically viable approach. Looking forward, it is worth reflecting on how many of these tropical landscapes will be able to survive as productive agricultural lands with tropical forest fragments.

In the scientific literature, there are many stories about how secondary and restored forests are important for maintaining tropical biodiversity. However, it is worth remembering that the contribution of these forests, both the remnant and the regenerating fragments, cannot be generalized because it depends entirely on the context. For example, in places like northeastern Brazil it is likely that many of the remaining forest fragments in agricultural landscapes are no longer able to provide environmental services. According to the FAO, the area in secondary forests will continue to increase as countries move ahead in the forest transition model and farmlands continue to be released. However, we do not know to what extent these new habitats will be able to provide the goods and services of the original forests. These questions are relevant because we know that the clearing of new productive land to meet the demands of a growing population leads to the destruction of primary and secondary forests[1], and we must know how to manage and restore these lands.

1 Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences,* 107(38), 16732-16737.



It is possible to make inferences about the future of fragmented forest based on studies of well-established landscapes, which allow us to identify the responses to the most recurrent disturbances within that context. For example, we know that in the sugarcane landscapes of the Atlantic Forest of Brazil, seed dispersal in forest fragments is a limiting factor. The seed rain inside the forest differs from that on the forest edge, where many large seeds that are dispersed by frugivores are not adequately represented. Given that most fragments are small and with a significant amount of area in edges, recruitment is biased towards species dispersed locally by birds and bats and regeneration is dominated by generalist plants with low habitat specificity. From the perspective of restoration, this situation creates a huge challenge because even if the existing forest fragments retain some of their diversity, the resilience of these forests can no longer be counted on as a starting point for the restoration process.

Beyond the purely biological aspects, restoration must also consider the socio-ecological context since other types of disturbance are occurring at less obvious scales. For example, in regions of Brazil where much of the low-income population relies on firewood as a source or energy, firewood production in forests is already insufficient and its harvest is unsustainable. In other regions, such as the agricultural areas of southern Bahia, although many small patches of forest still remain, hunting pressure by the surrounding populations has severely reduced the presence of wildlife and is compromising the natural processes of forest succession. When it comes to large-scale restoration, it is essential to consider this type of ancestral and chronic factors that impact the complexity and resilience of the landscape, and ultimately affect its ability to recover.

Thinking precisely about this type of human-dominated landscape, we have developed a conceptual model to manage agricultural lands[2]. Using the original ecosystem as a starting point, it is possible to reach alternate degradation states with different levels of structural and biological complexity. For example, many natural landscapes have been transformed into what we call *conservation landscapes*, which are resilient landscapes that still have good amounts of forest cover and provide a range of services. If intervention and use continue, these areas will be transformed into *functional landscapes*, which have less of the original forest cover but can still provide services. With good management and effective regulation, it is possible to return these landscapes to their previous stage. However, if the pressure persists, functional landscapes can be turned straight into *degraded landscapes* with scarce forest cover, high fragmentation and little connectivity.

Eventually, degraded landscapes cross a threshold beyond which they no longer provide services. In reality, when this happens two thresholds are crossed simultaneously. The first is a biophysical threshold, because these landscapes will require restoration actions in order to be functional again. The second is a political threshold, given that the decision to restore a landscape that has already crossed that line may require diverting resources that could otherwise be invested in maintaining landscapes that are still functional. Thus, in order to optimize the management of agricultural landscapes and maximize restoration success, it is important to know the baseline condition of the original ecosystem and to understand, from the biological perspective, how much functionality these landscapes still conserve and what part of that functionality can be recovered through restoration.

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2 Melo, F. P., Arroyo-Rodríguez, V., Fahrig, L., Martínez-Ramos, M., & Tabarelli, M. (2013). On the hope for biodiversity-friendly tropical landscapes. *Trends in Ecology & Evolution,* 28(8), 462-468.

In summary, restoration in agricultural landscapes is a complex issue that requires consideration of the following factors: (1) the amount of biological functionality that is conserved in the landscape and how much natural processes can contribute to their recovery; (2) the presence of all species, including those that are able to persist as well as those that are not; (3) the socioeconomic context; and (4) ways to focus restoration efforts on returning degraded landscapes to their functional state.

TALK 2

The Role of Agroforestry Systems in Ecological Restoration at a Landscape Scale

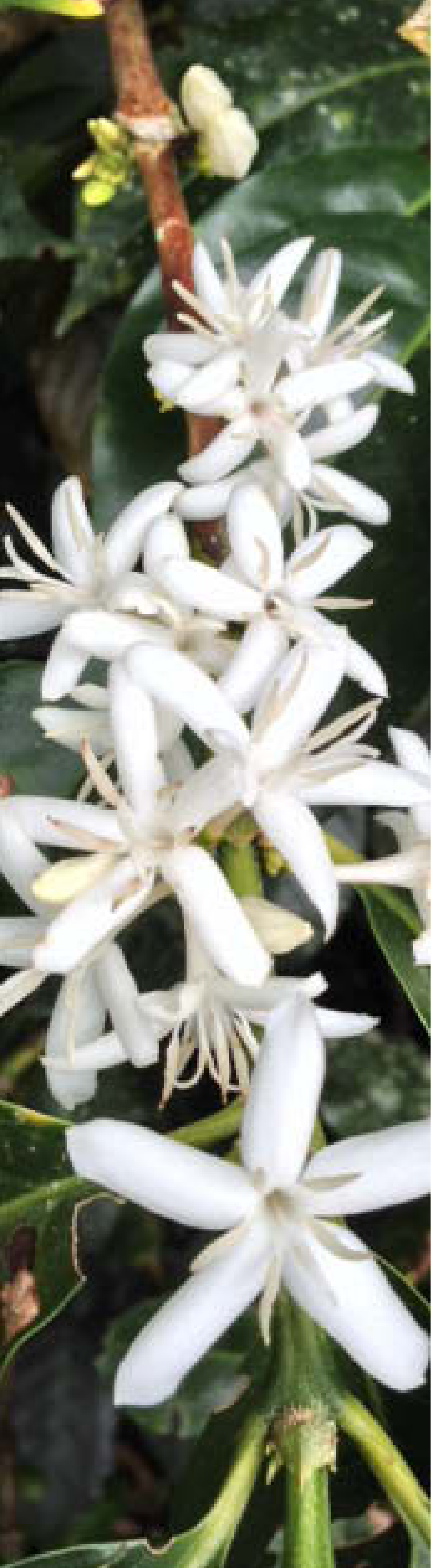
Florencia Montagnini

Yale University

In order to implement restoration in productive landscapes, it is necessary to combine strategies that integrate conservation and production in the same landscape. In this context, agroforestry systems (AFS) are a key tool because they allow landholders to simultaneously achieve diverse objectives, including protecting forest remnants, increasing vegetation cover to enhance connectivity between fragments, protecting biodiversity, generating wildlife habitat, recovering and conserving soils and increasing biomass production and carbon storage. In addition, AFS also incorporate many of the elements that are necessary for restoration, such as improving microclimates or increasing species diversity. This presentation illustrates the contributions of AFS through examples of well-established systems with perennial species, such as yerba mate and coffee, as well as other supporting systems that contribute to the restoration of productive landscapes.

AFS integrate agricultural and silviculture techniques to allow a more sustainable use of the land. There is a great variety of AFS, such as silvopastoral systems (SPS), home gardens, agro-successional systems and multi-strata systems, which are usually accompanied by complementary systems, such as live fences, windbreaks and riparian corridors. The production and conservation functions of these systems vary, but in general they largely depend upon how they are designed and managed. Worldwide, the total area in AFS is estimated to be approximately one billion hectares, of which between 200 and 350 million are in Latin America. At the regional scale, SPS are the most dominant, followed by shade grown annual and perennial crops, such as coffee, cocoa, and *yerba mate*, which are the central theme in this presentation.

A first example of AFS is coffee grown under the shade of timber trees. In Central America, coffee is traditionally grown in the shade of woody species of the genus *Inga* and *Erythrina.* However, there are a wide variety of native trees with excellent shading properties that also provide timber of good commercial value. For over 10 years, the



Tropical Agricultural Research and Higher Education Center (CATIE) in Costa Rica has been studying the effects of different forms of coffee cultivation on productivity and sustainability. For example, a recent study compared the effects of shade (with three different timber species), full sun and different management regimes on plant diversity, productivity and the recovery of soils degraded over a period of eight years[1]. In terms of productivity, systems with shade and moderate management, both chemical and organic, were the best option because they allow for a balance between coffee productivity and plant diversity. The high diversity of plants and animals associated with these shade systems contributes to the reduced use of chemicals. In the case of the system grown under the shade of *Terminalia*, it produces a layer of leaf litter that protects the soils. In the long term, systems with intermediate management can maintain more stable levels of production than those systems under intensive chemical management, which is an important finding for smallholder producers.

A second example of AFS, perhaps my favorite, is the cultivation of yerba mate from the leaves of the tree *Ilex paraguayensis* in the region of Misiones, Argentina. The production of yerba mate as a monoculture in full sun creates serious erosion and soil compaction problems. However, *Ilex* grows naturally in the understory of the Atlantic Forest in the southeast of Brazil, Paraguay and northern Argentina, which makes it ideal for AFS. Cultivation in agroforestry systems is a very attractive option for small-scale producers because organic yerba mate can command a price of up to five times higher in the growing markets of Europe, Asia and North America, depending on the type of certification[2]. For example, the company Guayakí provides *Ilex* seedlings to smallholders and then buys their organic yerba mate for up to three

1 Rossi E., Montagnini F., & de Melo, E. (2011). Effects of management practices on coffee productivity and herbaceous species diversity in agroforestry systems in Costa Rica Pp. 115-132 In: Montagnini, F., Francesconi, W. and Rossi, E. (eds.). *Agroforestry as a tool for landscape restoration.* Nova Science Publishers, New York. 201pp.

2 Montagnini, F., Eibl, B. I., & Barth, S. R. (2011). Organic yerba mate: an environmentally, socially and financially suitable agroforestry system. *Bois et Forêts des Tropiques,* (308), 59-74.

times the price of the conventional product. A number of family businesses and cooperatives that export certified organic yerba mate are integrating agroforestry production with other activities, such as agrotourism, silvopastoral systems, native tree nurseries and crops of tea and timber trees.

Beyond being an attractive option for producers, AFS can be used as a strategy to restore lands that have been degraded by conventional agriculture. For example, we have observed that producers working with AFS assign great importance to the protection of the remaining forests because they value their contribution as a source of biological control and natural regeneration. Also, several studies show that the quality of both the soils and the harvested leaves are better in agroforestry systems than in monocultures[3]. Although it would be desirable, an economic valuation of these environmental services has not yet been done. What we have done is to quantify carbon sequestration in these systems using allometric equations for yerba mate and many of

3 Day S., Montagnini, F., & Eibl, B. (2011). Efectos de árboles nativos en sistemas agroforestales en los suelos y la yerba mate en Misiones, Argentina. Pp. 99-112 In: Montagnini, F., Francesconi, W. and Rossi, E. (eds.). *Agroforestry as a tool for landscape restoration.* Nova Science Publishers, New York. 201pp.

its associated tree species. In addition, we are moving forward with the identification of other promising species to improve the design of AFS with yerba mate.

A third example comes from a study of living fences in the province of Esparza, Costa Rica[4]. The study compared the presence of birds in living fences located at different distances from forest patches and revealed that the number of birds decreases as the distance from the forest increases. According to the multivariate analysis, the diameter of the trees, their canopy and the number of tree species in the living fences greatly influence the diversity of birds. It, therefore, is clear that not all living fences are the same. Some recommendations to encourage wildlife, both in living fences and other AFS, are:

- Include at least 10 species of trees;
- Use native trees, including epiphytes and lianas;
- Conserve at least 40% of shade cover throughout the year;
- Maintain tree cover at a height of 12-15 m, with different strata;
- Create the highest possible diversity within the AFS.

The final example is the use of AFS to promote connectivity in the Path of the Tapir biological corridor, which connects La Amistad and Corcovado parks in Costa Rica and is part of the Mesoamerican Corridor[5]. Because it is part of a protected area, the strategy in this landscape was based on managing the existing natural regeneration and incorporating pure and mixed plantations. In addition, systems that integrate the use of native species of value for people and wildlife were promoted, such as living fences, home gardens and multilayer AFS, all of which have a positive impact on bird diversity. Logically,

4 Francesconi, W., Montagnini, F., & Ibrahim, M. (2011). Living fences as linear extensions of forest remnants: a strategy for restoration of connectivity in agricultural landscapes. Pp. 115-126 In: F. Montagnini and C. Finney (Eds.). *Restoring degraded landscapes with native species in Latin America.* Nova Science Publishers, New York.

5 Redondo-Brenes, A. & Montagnini, F. (2010). Contribution of homegardens, silvopastoral systems, and other human-dominated land-use types to the avian diversity of a biological corridor in Costa Rica. pp.185-224 In: Lawrence R. Kellimore (Editor). *Handbook on agroforestry: management practices and environmental impact.* Nova Science Publishers, New York.

integrating the local population through environmental education and training programs is essential to achieving these goals.

In conclusion, AFS have much to contribute to the success of restoration projects. When well managed, they can have interesting financial returns and ensure long-term sustainability. They also serve as an incentive for landholders to maintain the remaining forest patches since they provide valuable environmental services. Although their productivity may be somewhat lower than in systems with chemical management, their production tends to be more stable and extended over time, making them more sustainable. Finally, AFS also contribute to landscape-scale restoration indirectly because they can prevent land conversion to other uses.

Talk 3

Environmental and Agricultural Adjustment Program for Rural Properties

Ricardo Ribeiro Rodrigues

University of São Paulo, USP

According to the Brazilian Forest Code that was issued in 1965 and updated in 2012, all rural property owners must retain 20% of their lands with forest cover as Legal Reserves (LR), and maintain vegetation cover in riparian strips and areas not suitable for agriculture as Areas in Permanent Preservation (APP). However, until recently there was very low compliance with the code, primarily due to the widespread use of fire as a tool to prepare farmland that precluded any planning efforts on rural properties. It is for this reason that today most properties are still in a state of non-compliance. Our group works on a program known as the *Environmental and Agricultural Adjustment for Rural Properties* in the state of São Paulo, which aims to implement the changes needed to comply with the regulations of the Forest Code in these properties.

The Program for the Adjustment of Rural Properties consists of two phases, the first of which is the Environmental Adjustment. The first step towards compliance in a rural property is to conduct an environmental assessment, which starts with the creation of a map based on aerial photographs. The farm's hydrological network is delineated on the map and the extent of the APP required by law is outlined. The next step is a field verification to collect information on the presence of regeneration potential and forest fragments that will serve as seed sources —or the absence thereof— in order to analyze the ecological resilience potential of the property. This characterization is the basis for planning the most appropriate strategies in light of the context of the landscape that surrounds the property[1,2].

The second step involves the development of planning strategies to restore APP and LR areas within the property. It is important to note that different sites within the same property may require different

1 Joly, C. A., Rodrigues, R. R., Metzger, J. P., Haddad, C. F., Verdade, L. M., Oliveira, M. C., and Bolzani, V. S. (2010). Biodiversity conservation research, training, and policy in São Paulo. *Science,* 328(5984), 1358-1359.

2 Rodrigues, R. R., Lima, R. A., Gandolfi, S., and Nave, A. G. (2009). On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest. *Biological Conservation,* 142(6), 1242-1251.

restoration methods depending on the context. The range of possible restoration strategies is wide, including simple interventions —such as isolating to exclude the disturbance factors and allowing natural regeneration from stumps and seeds without further intervention— or managing the natural regeneration to accelerate succession. It should be noted that despite the effectiveness of natural regeneration as a tool for restoration, this method is not used as much as it should. When these interventions are not enough, more intensive actions are required, such as planting seeds or seedlings.

The Ecological Laboratory for Forest Restoration (LERF) and the Laboratory for Tropical Forestry (LASTROP) collaborated on the development of a theoretical model that explains forest succession in three stages: structuring, consolidation and maturation. To expedite the structuring phase during the restoration process, LERF devel-

oped a methodology that involves simultaneously planting alternate lines of two types of trees. The *coverage lines* consist of between 10 and 15 species of fast-growing trees that develop good canopy cover and achieve rapid canopy closure. These are alternated with *diversity lines*, in which 60 to 80 species of trees belonging to various functional groups are planted, including pioneers with a sparse canopy and other types of trees with slower growth rates and less coverage. To reduce costs, more recently we developed an alternative method that consists of first planting a mix of coverage species with green manures through direct seeding, followed two or three yers later by an enrichment with a diversity of seedlings in order to introduce a greater variety of genetic, floristic and functional life forms.

The second phase of the Program for the Adjustment of Rural Properties is the Agricultural Adjustment. The first step of this phase is to implement technologies to improve productivity on those lands suitable for agriculture. The second step that is more relevant for restoration is to develop land use proposals with less environmental impact aimed at areas with low agricultural potential. The question guiding this work is: *Is it possible to combine native timber production systems with restoration?*

LERF has been working with its partners to develop restoration models that incorporate the economic exploitation of the species[3,4]. This option may be particularly attractive to replace activities that —like cattle ranching on steep hillsides— are widely practiced but have a low economic return. These models include mixtures of fast, intermediate and slow growing native species that can be harvested in cycles of 10, 20 and 30 years respectively to generate a more continuous cash flow. Another model involves planting eucalyptus in the

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3 Brancalion, P., Viani, R. A., Strassburg, B. B., & Rodrigues, R. R. (2012). Cómo financiar la restauración de los bosques tropicales. *Unasylva: Revista Internacional de Silvicultura e Industrias Forestales,* (239), 41-50.

4 Rodrigues, R. R., Lima, R. A., Gandolfi, S., and Nave, A. G. (2009). On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest. *Biological Conservation,* 142(6), 1242-1251.

initial mixture and then six years later harvesting them for pulp and replacing them with native high quality timber trees. The best silviculture techniques are used for planting in order to ensure that the timber produced complies with market standards. For regions such as the Amazon, where the LR have been exploited as logging concessions, the proposal focuses more on enrichment planting with up to 156 fruit and timber trees per hectare. To date, we have established 2,200 hectares of restoration experiments with economic potential.

In the highly fragmented Atlantic Forest landscape of Brazil, where there are no remaining patches of a significant size, the ensemble of fragments plays a key role in the conservation of biodiversity. At the landscape level, the strategy is to use restoration as a complement for conservation, with the following three priorities: (1) maintain the remaining fragments; (2) restore the degraded fragments to conserve their biodiversity; and (3) restore the riparian corridors and other degraded areas with low agricultural potential. The stage of environmental adjustment of the properties includes the characterization of all species present in the fragments, with the goal of identifying and marking the best seed trees for future seed harvest. In turn, this process is articulated to a network of nurseries in order to ensure the production of native trees that reflects the full floristic and genetic diversity present in the fragments.

This process of large-scale environmental adjustment originated from the state's decision to criminalize non-compliance of the Forest Code. Faced with the possibility of being charged with environmental violations, many landowners saw the need to take steps to normalize the situation on their farms. Once they understood that the restoration of riparian corridors and legal reserve areas was a feasible alternative with which to comply with the law, many of them incorporated these restoration activities into their agricultural land use plans. Nowadays, landowners are among those who most often seek LERF's services for the design of adjustment plans over 8 to 10 years, allowing for a gradual transition. The costs are partly offset through certification

programs for the products of these compliant farms, like sugarcane. Since its inception in 1998 until 2013, the Environmental Adjustment Program has intervened in 3,850,000 hectares of rural properties, protected 92,000 hectares of protected forest fragments, restored 8,500 hectares of riparian forest and hopes to continue reaching over 2,000 hectares per year. Today, the program no longer needs to be promoted since it is perceived as being an established legal requirement.

Finally, I want to note that although the new Brazilian Forest Code marked a setback for the country in terms of the environment, in the case of this particular process it meant an important improvement because it established the Rural Environmental Registry (CAR, in Portuguese) and a Plan for Environmental Regularization (PRA, in Portuguese) as being mandatory requirements. Both of these requirements promote the restoration of degraded areas in APP and LR in rural properties within a maximum 20-year time period.

TALK 4

Intensive Silvopastoral Systems: Integration of Sustainable Cattle Ranching, Silviculture and Restoration at the Landscape Scale

Zoraida Calle
Julián Chará
Co-authors:
Enrique Murgueitio
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In Latin America, livestock has been considered for decades as one of the primary factors that cause environmental degradation by negatively impacting soils, biodiversity, hydrological cycles and the climate. With production averages as low as 20 kg of meat and 90 L of milk per hectare per year, livestock production also is a very inefficient use of the land. However, it is unrealistic to expect that livestock production will disappear from the region in the near future, not only because demand for its products continues to rise, but also because this activity is deeply rooted in the region's Spanish and Portuguese cultural ancestry.

The transformation of the livestock sector should, therefore, be an environmental priority for Latin America. If well managed and practiced sustainably, cattle ranching can be a tool with which to rehabilitate degraded lands. When integrated with forest remnants and connectivity corridors, cattle ranching systems can even be a restoration tool at the landscape scale. However, in order to achieve these positive impacts, the livestock sector needs to contribute to food production for a growing population, limit environmental impacts, adapt to climate change and ensure animal and human welfare.

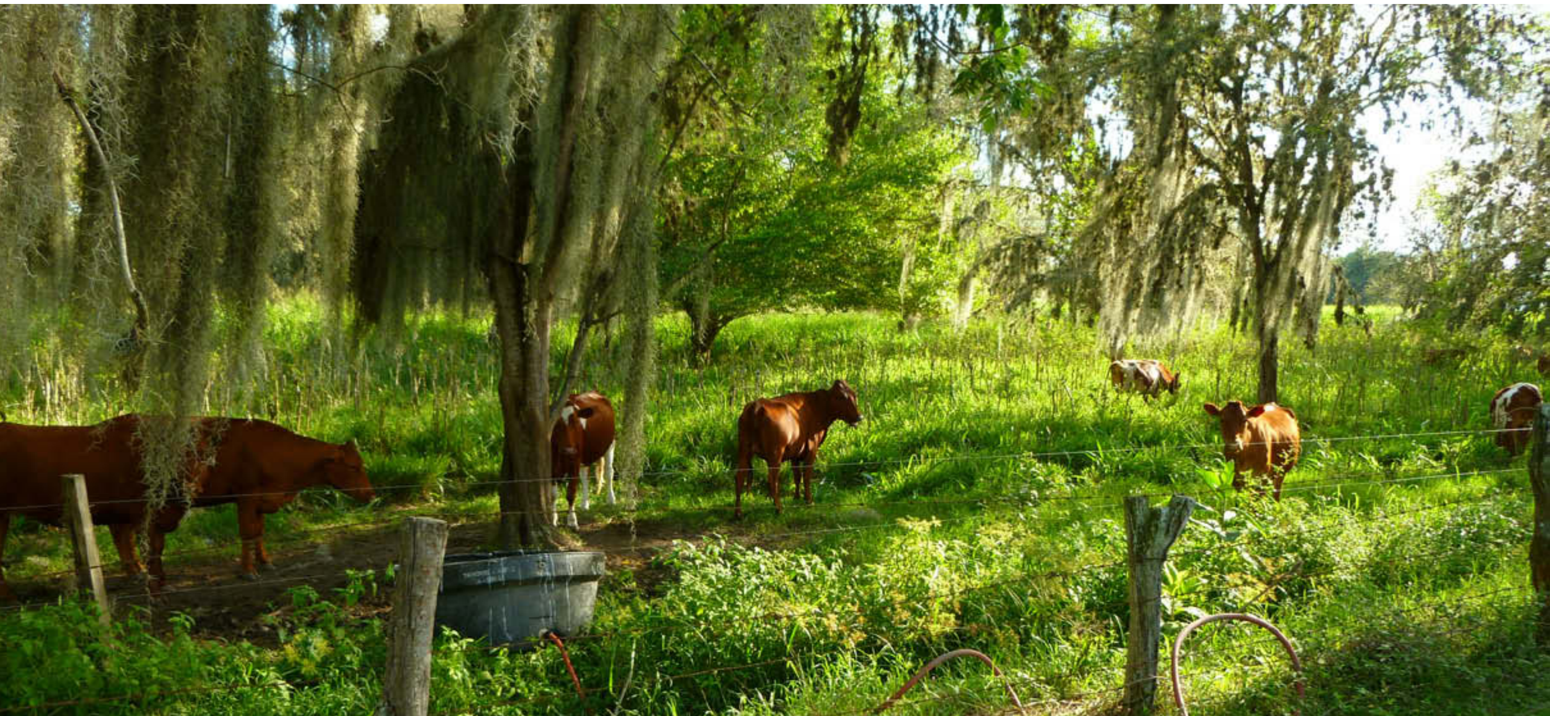
The most important change that must occur in tropical cattle ranching is with the cattle ranchers themselves and how they envision their production system. At a biophysical level, this transformation must comprise the following four key aspects:

1. Increase biomass and plant productivity;
2. Halt soil degradation and promote its recovery;
3. Protect water sources and use them rationally;
4. Improve animal productivity on a *per hectare* basis.

By implementing these changes at the landscape scale, it is possible to rehabilitate cattle ranching lands so that landholders can simultaneously achieve these three goals: (1) increase the productivity and profitability of the system; (2) enhance the provision of environmental goods and services; and (3) set aside fragile and marginal lands for restoration.

One strategy with which to advance the transformation of cattle ranching is the use of a form of agroforestry known as silvopastoral systems (SPS). There are different types of SPS, such as trees scattered in pastures, living fences, mixed fodder banks and intensive SPS (ISPS), the latter of which is the focus of this presentation. ISPS combine high productivity pastures, fodder shrubs planted at densities of 10,000 or more shrubs per hectare and lines of timber trees in spatial arrangements compatible with livestock production. Natural intensification in these systems aims to maximize the efficiency of biological processes, such as photosynthesis, nitrogen fixation or phosphorus solubilization, in order to increase the production of biomass and soil organic matter. These processes provide productive benefits as well as environmental services.

The success of ISPS depends on adequate species selection, especially the fodder shrub that is used to sustain and invigorate the system. To date, advances have been made with two key species: leucaena *Leucaena leucocephala* and Mexican sunflower *Tithonia diversifolia.* Leucaena has qualities that make it particularly well suited for these systems: it fixes nitrogen efficiently making it available to other plants;



it grows well in association with pastures; and it is palatable for the cattle, re-sprouts vigorously and is a high quality source of food for livestock. Compared to conventional systems, ISPS require more rigorous management with simple but mandatory protocols and controls. The most important thing is to maintain intensive —but very brief— grazing periods with long resting periods to reduce the impact of the livestock and allow the system to recover.

One of the major bottlenecks for the adoption of these systems is their establishment cost. Thus, it is important to facilitate access to credit and to plan for a gradual and phased implementation process that incorporates the integration of agricultural systems in order to generate a cash flow during the transition period.

A good example of the potential of these systems is the Lucerna farm in Valle del Cauca, Colombia, which replaced its pasture monoculture with ISPS more than 20 years ago. This change allowed the farm to completely eliminate the use of chemical fertilizers, increase per hectare stocking rate and improve milk production from 9,000 to 15,000 L per hectare per year. This example illustrates the paradigm shift of tropical cattle ranching, which recognizes that maximum biomass production is not achieved in treeless grass monocultures, but in agroforestry systems that combine grasses, trees and shrubs.

Another example is the Integrated Silvopastoral Approaches to Ecosystem Management project (ISAEM), which was implemented in Colombia, Costa Rica and Nicaragua between 2002 and 2007. In Colombia, 110 cattle ranchers participated in this project that aimed to test the effect of payment for environmental services (PES) on the adoption of SPS and to evaluate the potential of these systems as providers of environmental services. A study with ants in this project showed that over time species richness in SPS can resemble levels found in secondary and bamboo forests, because it increases predictably with canopy cover[1].

1 Rivera, L. F., Armbrecht, I., & Calle, Z. (2013). Silvopastoral systems and ant diversity conservation in a cattle-dominated landscape of the Colombian Andes. *Agriculture, Ecosystems & Environment,* 181, 188-194.

An evaluation conducted four years after the completion of this project showed that SPS adoption in the region continued over time and that there is a trend towards decreasing areas in treeless pasture, and increasing systems with trees, live fences and riparian corridors.

Another case that illustrates ecological rehabilitation with ISPS can be found in Colombia's Cesar river valley, where lands that were severely degraded by decades of cotton monoculture practices were later converted to extensive ranching systems. These systems have very low productivity due to soil compaction and to the impact of strong trade winds that cause an extended drought period, during which all edible biomass disappears and soils erode rapidly. The implementation of ISPS resulted in a substantial increase in livestock productivity due to, among other factors, a difference of up to 12°C less in systems with trees and shrubs compared to those without trees, which drastically reduces the thermal stress for the cattle.

This approach is a win-win situation because the productive benefits that attract farmers to ISPS originate from the environmental services they provide, which also makes them compatible with biodiversity. Many of the advantages of these systems are related to the natural biological control of pests, such as ticks and horn flies, whose presence in ISPS is significantly lower than in improved pastures with no trees. Something similar occurs with the dung beetles present in systems with trees, which provide a range of ecological services, including rapid recycling of nutrients in the manure, soil aeration and regulation of cattle parasites. The benefits of ISPS extend to the efficient use of land and other productive parameters. For example, producing one ton of beef per year requires 15 hectares in the conventional extensive system, three hectares in an intensive system with improved pastures and no trees, and only one hectare in an intensive silvopastoral system.

Another example of the efficiency of SPS is the El Chaco farm, located in the dry forest of the state of Tolima, also in Colombia. Soils there are clayey and tend to degrade easily and cattle productivity is low. Thanks to the implementation of a variety of SPS, such as live fences, fodder banks and ISPS, this farm increased its capacity for both milk and meat production and today produces over a ton of beef per hectare per year on average, compared to the regional average of 74 kg. From the perspective of ecological rehabilitation, El Chaco combines its SPS with timber production and riparian corridors, thus increasing landscape connectivity and contributing to the creation of a more supportive matrix for biodiversity.

The El Hatico nature reserve in Valle del Cauca, Colombia, underwent a profound transformation by transitioning from conventional livestock production systems with low tree cover and a high use of fertilizers and irrigation in the 70s to the production of organic milk in ISPS with more than 70 tree species. Today, El Hatico's ISPS comprise several strata, including grasses, fodder shrubs, medium and large timber trees and palms. Milk and meat production are not only much higher than they were four decades ago, but they also remain stable even during the dry months of El Niño, thereby demonstrating the resilience of the systems. Soil studies in El Hatico also show that the levels of organic matter underneath the trees in SPS can be higher than in the soils of the remaining forest.

From the perspective of landscape restoration, one of the great advantages of SPS is that they allow for increases in livestock productivity without increasing the area under production. This scenario is the case of the Environmentally Sustainable Milk project, developed with Nestlé in Caquetá, Colombia, which sought to increase productivity while protecting the natural capital of the farms. Using soft loans and paying bonuses for milk quality, the project successfully promoted the use of more productive and nature-friendly farming systems and increased per hectare productivity.

The Mainstreaming Sustainable Cattle Ranching (MSCR) project, currently under implementation in Colombia, uses SPS as part of a national strategy to reduce the total area in livestock production in order to release areas for other uses, including restoration. Applying the lessons learned from the ISAEM project in terms of PES, the MSCR project seeks to establish around 60,000 hectares of SPS and contribute to the conservation of important forest areas by incorporating endangered plant species or those of conservation interest into SPS and connectivity corridors. It also aims to increase connectivity in five major ranching landscapes through the strict protection of conservation corridors, surrounded by productive strips of a silvopastoral matrix that is more amenable to the movement of fauna and flora than the conventional matrix. Another key component of this project has been capacity building, in this case on the topic of landscape-scale restoration, which was provided to project staff in two field courses offered jointly by ELTI and CIPAV, with instructors from LERF, STRI and Yale University.

It is important to highlight that this process is taking place not only in Colombia but also in Argentina, Brazil and Mexico. In the latter country, the adoption of ISPS is taking place at a significant spatial scale in ecosystems where the most common production systems are based on the total elimination of the forest. This transformation has been possible thanks to the work of producers like Porfirio Alvarez from Los Guarinches ranch, who in only six years was able to quadruple the stocking rate and cut production costs per liter of milk in half. Today this farm produces silvopastoral Cotija cheese, and in 2013 won the award for best traditional Mexican cheese. Another example is the La Concha *ejido* (communal lands used for agriculture) in Michoacán, where an innovative farmer incorporated ISPS in her lemon orchards and now produces organic 'shade' lemons at a lower cost and sells them at a better price. These examples illustrate the potential to produce differentiated ISPS products for specialized markets as a complement to livestock production.

In summary, what is being proposed is that the diffusion of ISPS in degraded ranching landscapes can contribute to increases in productivity and profitability in these areas, while at the same time contribute to restoring soils, protecting water resources and increasing biodiversity and environmental services, thereby allowing cattle ranching to become part of the solution to —rather than the cause of— environmental problems[2,3,4].

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2 Calle, Z., Murgueitio, E., & Chará, J. (2012). Integrating forestry, sustainable cattle-ranching and landscape restoration. *Unasylva* (FAO).

3 Calle, Z., Murgueitio, E., Chará, J., Molina, C. H., Zuluaga, A. F., & Calle, A. (2013). A strategy for scaling-up Intensive Silvopastoral Systems in Colombia. J*ournal of Sustainable Forestry,* 32(7), 677-693.

4 Murgueitio, E., Calle, Z., Uribe, F., Calle, A., & Solorio, B. (2011). Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. *Forest Ecology and Management,* 261(10), 1654-1663.

Talk 5

Strengthening Capacities for Ecological Restoration in Latin America

Eva Garen

Environmental Leadership and Training Initiative, ELTI

In recent years, a global recognition regarding the importance of restoring forests and ecosystem services has emerged, which is reflected in an increase of scientific and applied studies published on the subject. These themes, however, are not frequently addressed in capacity building initiatives, which tend to focus training opportunities on themes related to protected areas management, and more recently, on carbon measurements. A gap, therefore, remains in terms of opportunities for capacity building on ecological restoration, particularly regarding restoration in the context of productive landscapes.

The Environmental Leadership and Training Initiative (ELTI) was developed to help fill this and other gaps in training and capacity building. ELTI is a program of the School of Forestry and Environmental Studies at Yale University that works collaboratively with the Smithsonian Tropical Research Institute in Panama and the National University of Singapore. Its mission is to provide decision makers with the knowledge, tools, skills, motivation and contacts to advance the protection, management and restoration of tropical forests in Latin America and tropical Asia. ELTI focuses on issues related to conservation and restoration in productive landscapes, working closely with local partners to provide subsidized training opportunities for decision makers at all levels. ELTI also provides follow-up support to participants through its Leadership Program (LP).

ELTI takes two primary approaches to capacity building. The first approach is to design courses in multiple locations in response to the specific needs of the country, region or community, followed by Leadership Program support for the implementation of alumni-led initiatives. The second approach is to develop permanent field training sites at which a range of field courses are developed and offered that can be modified to meet the needs and interests of different groups of participants.

ELTI has used the first approach in places like the Azuero Peninsula, a dry tropical forest ecosystem and one of Panama's major cattle producing regions, where decades of conventional ranching practices have contributed to extensive environmental degradation. In response to the interest expressed by producers in this region to improve livestock productivity and recover environmental services, especially during the dry season, ELTI offered a first field course in 2009 on native species reforestation and agroforestry and silvopastoral systems. Given the participants' interest in the topic of silvopastoral systems (SPS), ELTI designed a follow up field practicum on silvopastoral systems, during which the farmers learned about other SPS experiences previously established in another region of Panama, with technical support from CIPAV.

As a result of these initial trainings, several local producers were interested in applying what they had learned during the ELTI course and practicum to improve ranching practices on their farms. To accomplish this goal, the farmers received support from ELTI's Leadership Program to create a farmers association (the Association of Agro-silvopastoral Producers of the Municipality of Pedasí, referred to by the Spanish acronym APASPE) and to identify an interested

donor to support the establishment of demonstration silvopastoral and restoration projects. ELTI worked jointly with organizations like CIPAV and the Peace Corps to assist APASPE members to develop and implement the pilot projects and to provide them with training and follow-up technical assistance. Four years after the first course in Azuero, the impact is clear: APASPE is now an established organization, the APASPE members are viewed as environmental leaders in their region and APASPE has been invited to apply for funding for a second and larger silvopastoral and restoration project.

Another example of how ELTI responds to local training needs is the training programs developed for the Mainstreaming Sustainable Cattle Ranching (MSCR) project in Colombia. This project addresses the integration of SPS with connectivity corridors, remnant forests and protected areas as a tool for rehabilitation in productive landscapes. Within the framework of this project, ELTI worked with local partner CIPAV to identify that the specific training need in this context was to complement the existing knowledge in Colombia on SPS with the theoretical and practical principles of large-scale restoration, something that has yet to be done in the country. ELTI and CIPAV worked together to design and implement two field courses with MCSR in 2011 —*Connectivity Corridor Restoration in Cattle-Ranching Landscapes* and *Strategies for the Sustainability of Connectivity Corridors.* The Ecological Laboratory for Forest Restoration (LERF) was in charge of the restoration component of these courses, with contributions from both Yale F&ES and STRI.

Additionally, the LP has supported several alumni of these courses by funding internships on the production of plant material for restoration projects, small projects to research promising native species for restoration and a range of opportunities for alumni to showcase their work during international conferences.

From the experiences with the first approach, ELTI has learned several positive lessons: the value of fostering collaborations between organizations that are working at a regional level and whose work is

complementary; the effectiveness of training people who are already involved in real projects and can apply the knowledge learned during an ELTI event in practice; the relevance of designing training events around specific needs that can be replicable in several places; and the importance of having a system with which to provide participants with follow-up support.

ELTI's second approach to training that is based on the development of permanent training sites is currently being implemented in Panama. Two sites were chosen for this approach: the first is located in the dry forest in the Azuero Peninsula and the second, known as the Agua Salud Research Project[1], is located in the wet tropical forest ecosystem within the Panama Canal Watershed. For each site, ELTI designed courses on the ecology and environmental services of tropical forests, the degradation of these ecosystems and various restoration alternatives, keeping in mind both the biophysical and social context. The courses draw upon existing, long-term scientific research at each of the sites by Yale F&ES and STRI, emphasizing the importance of science to inform decision-making. Each site also has a permanent infrastructure of trails, guided field trips, case studies, field exercises and study materials.

Moving forward, ELTI hopes to continue developing training events with both approaches, depending on the needs of the countries where we work. The goal is to develop permanent training sites in other countries, such as Colombia and the Philippines, in other ecosystems, such as Andean forests, and on other topics, such as restoration in productive landscapes. As a complement to our field courses, and in order to continue expanding our audience to other countries where we are not yet working, ELTI also is developing its online training program that already offers an introductory course on tropical forest ecology and restoration strategies in human-dominated landscapes and is developing more advanced courses on the topic of restoration.

1 The Agua Salud Research Project is a collaborative initiative of the Smithsonian Tropical Research Institute (STRI), the Panama Canal Authority (ACP, in Spanish), Panama's National Environmental Authority (ANAM, in Spanish) and other partners.

Discussion Session

Moderadores

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This symposium was convened to address an issue that is currently being debated: how to meet the growing demand for agricultural products without sacrificing biodiversity, especially within the context of climate change. In the scientific world, this dilemma has been framed in terms of two opposing strategies. On the one hand, proponents of the *land sparing* strategy believe that maximizing productivity in agro-industrial systems will free up other less productive lands for conserving natural habitats. Some recent studies suggest, for example, that when production and conservation areas are separated, food production and biodiversity protection can be done more effectively. On the other hand, proponents of the *land sharing* perspective believe in the integration of both goals within multifunctional landscapes using sustainable practices that are more compatible with biodiversity. This perspective is supported by scientific studies that show that certain agricultural landscapes can retain significant levels of biodiversity without sacrificing productivity and profitability.

The goal of the symposium was to present a series of talks to stimulate reflection on this topic. Felipe Melo spoke about the future of biodiversity conservation in the forest fragments embedded within the agricultural matrix of Northeastern Brazil. Florencia Montagnini used several examples from Latin America to illustrate the contribution of AFS to forest conservation, land restoration and rural livelihoods. Ricardo Rodrigues explained the strategy of environmental adjustment

of rural properties that is being used in the Atlantic Forest of Brazil to attain a balance between production and conservation at a relevant scale. Zoraida Calle and Julián Chara explained the role of agroforestry systems as a tool for the productive recovery of degraded landscapes. Finally, Eva Garen shared the experiences of her organization in designing capacity building events for the restoration of productive landscapes in Latin America.

To introduce the discussion session, the following question was raised: Is there an alternative to the dilemma of land sharing vs. land sparing? Clearly, the conservation of biodiversity in agricultural landscapes requires a strategy that combines ecological restoration, conservation and sustainable use of resources. Thus, maybe we should be thinking more about the integration of these three components into a single strategy, such as sustainable intensification or agroforestry of restoration.

First, the public raised the issue of illicit crops and asked if there are alternatives to minimize their environmental impact. Panelists agreed that the problem of illicit crops is political and legal rather than technical or scientific in nature. As a matter of supply and demand, it would only be feasible to fix the situation by way of legalization, which is not a possibility at this moment. From a purely technical perspective, it would be perfectly feasible to develop restoration strategies that incorporate illegal crops, a solution that was proposed years ago in Bolivia with coca in agroforestry systems, but ultimately was not politically viable.

Another issue discussed was the generation of environmental services (ES) in productive agricultural landscapes. In this context, the traditional goal of recovering a historical 'reference ecosystem' is unrealistic. Instead, the goal is to rehabilitate the land with respect to its baseline present state, which in many cases is severely degraded by years of misuse. Therefore, the implementation of sustainable production systems primarily seeks to recover a sustainable level of productivity, but without claiming that they will provide the same services as the original ecosystem. In any case, it is clear that sustainable systems themselves can contribute to achieving goals like conserving biodiversity, regulating water cycles, recovering soils, and —above all— helping to prevent deforestation of new lands. In addition, it is important to remember that productive rehabilitation contributes to the human dimension of restoration, a frequently overlooked topic that plays a key role in terms of sustaining livelihoods and strengthening human values.

Panelists also noted that the provision of ES occurs at different scales —local, regional, and global— and that there is a threshold of degradation beyond which these services are lost and are very difficult to recover. For example, agricultural landscapes in southeastern Brazil have been degraded substantially due to 100-200 years of use so that they no longer provide local ES and the forest fragments are doomed to collapse. In such extreme cases, although it is not feasible to recreate the original ecosystem, restoration actions can help to recover ES, such as carbon sequestration. Comparative studies between remnant and restored forest fragments of different ages show that - over time - some parameters in both types of areas can become similar. However, a better understanding of which and how much ES these fragments provide is still needed. For that reason it is important to adequately manage productive landscapes so that they maintain their functionality over time.

A good example of productive systems that favor the maintenance of landscape functionality are SPS, a highly relevant topic in Latin America given the prevalence of cattle ranching in the region. In this regard, panelists highlighted four key aspects of sustainable cattle ranching systems. The first is that the immediate goal of ISPS is to increase productivity in the most suitable lands, which makes it easier for the producer to accept and adopt the systems permanently. The second is the importance of proper and rigorous management, given that successful ISPS require short grazing and long recovery periods. The third is the instrumental role of trees and shrubs in these systems, as they are the key to increasing nutrient cycling and biodiversity and to reducing or eliminating dependence on chemical inputs, which is a prerequisite for SPS to be truly sustainable. The fourth element is the promotion of animal welfare since these systems reduce livestock stress by providing shade, lower temperatures, clean water and abundant and high quality fodder.

Finally, the usefulness of reducing this debate to two extremes like land sharing and land sparing was questioned, more so if one considers that under certain contexts each approach may be valid. The panelists noted that the root of the problem is even more complex due to its economic and political components. A clear example is development within the Brazilian Amazon, a region that still does not have a sustainable economic development model despite having a population of 30 million people. With the false argument that there are no technologies that allow for the coexistence of production and conservation, agribusiness expansion has proceeded at the expense of the forests. Meanwhile, the FAO suggests that Brazil should allocate

an additional 15 million hectares of land for agricultural production in order to meet growing demands. However, 210 of the 270 million hectares currently under agricultural use in Brazil are degraded pastures with low productivity (only 0.8 animals per hectare). By implementing technologies such as the SPS advocated by CIPAV and some Brazilian institutions, production could be concentrated and productivity improved to 1.5 animals per hectare, thus releasing 60 million hectares for agriculture and restoration without deforesting an additional hectare. Thus, the problem is also political because there is a lack of integration between agricultural and environmental policies, which should be working together.

As illustrated by this and many other examples presented during the symposium, existing technologies such as SPS and AFS can harmonize production and conservation objectives. Many recent studies show that agro-ecological farming systems can not only achieve good levels of productivity, but they also are more effective in the long term because they help to intensify production in a smaller area, provide a steady stream of ES and release land for restoration. However, it should be highlighted that the fact that technologies to simultaneously produce and conserve on the same land exist does not necessarily mean that they will be applied at a relevant scale in the short term. As Dr. Melo cautioned, intensification of conventional agriculture is still the dominant global trend and as long as this is the case the strategy of reserving lands for conservation will remain relevant. If we want restoration efforts to succeed, we must consider these two facts.

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Glossary

Forest fragmentation

Type of habitat degradation that occurs when forests are eliminated such that only small and isolated patches, known as fragments or remnants, remain.

Sustainable intensification

An agricultural strategy that leads to producing more in the same unit of land, while reducing the environmental impact and increasing the flow of ecosystem services and the contribution to the natural capital.

Landscape matrix

The dominant element in the landscape in which the other components, such as fragments and corridors, are embedded. The type of matrix is essential for determining the functionality of the landscape.

Forest transition model

The theory that describes the change of land use from a period of net loss or deforestation to a time of net forest gain.

Ecological restoration

The intentional process of starting or accelerating the recovery of a forest ecosystem after it has been degraded, damaged, transformed or totally destroyed by a disturbance.

Ecosystem or environmental services

Benefits to humanity that originate from the resources and processes provided by a given ecosystem, in this case forest ecosystems.

Silvopastoral system

Productive system that integrates grazing cattle with the presence of trees or tree plantations.

Agroforestry system

System that integrates trees, livestock, and pasture or fodder in the same production unit and seeks to improve productivity in a sustainable manner.

Resilience

The ability of an ecosystem to recover its capacity for reorganization and functioning following a disturbance.

Environmental Leadership & Training Initiative

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