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The Potential for Agroecosystems to Restore Ecological Corridors and Sustain Farmer Livelihoods: Evidence from Brazil

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The Atlantic Forest is a highly diverse biome, extending from the northeast to the south of Brazil. The diversity of elevation and climate of this biome allows for extraordinary biodiversity with high levels of endemism (Tabarelli et al. 2005). The original territory of the Atlantic Forest contains 65% of the Brazilian population, providing fundamental ecosystem goods and services, such as climate regulation, water supply, erosion control, and pollination (Ditt et al. 2008). An estimated 100 million people in Brazil depend on the water provided by Atlantic Forest rivers and streams. Despite its importance, the Atlantic Forest is one of the most threatened and fragmented biomes worldwide (Myers 1988, Tabarelli et al. 2005). Slightly over 11% of the original forest remains, mostly remnants (83%) smaller than 50 ha and within 100 m from forest edges, revealing high levels of fragmentation.

Reconnecting forest fragments became a national policy at the end of the 1990s through the Pilot Program for the Tropical Forest Protection (PP-G7), financed by the World Bank. This program has resulted in both the establishment of protected areas and some small functional corridors between them in high priority areas, particularly in the Amazon region. In addition to the PP-G7 program, Brazil's main Forest Act of 1965 mandates permanent preservation areas (PPA or in Brazil, APP) along rivers and streams in an effort to provide natural ecological corridors for fauna and flora outside protected areas. According to the Forest Act, hilltops, springs, and areas with slopes greater than 45 degrees must be set aside for conservation purposes. The Forest Act also requires farmers to maintain Legal Reserves (LR or in Brazil, RL) on their farms, characterized by sustainable use of natural resources, conservation and restoration of ecological processes, conservation of biodiversity, and the protection of native flora and fauna (Ditt et al. 2008). The minimum area of LR required in the Atlantic Forest is 20% of the total area of each farm.

Theoretically, the Forest Act and programs like the PP-G7 should guarantee connectivity and forest conservation within the Brazilian territory. Nevertheless, because the enforcement of the Forest Act is weak, the PP-G7 program has brought results only at a small scale, and they are predominantly restricted to the Amazon region. Approximately 16% of the required LR and 42% of PPAs show severe deforestation, representing 87 million ha to be restored in private areas (Sparovek et al. 2011).

Santa Catarina State offers an interesting case study. It holds the highest relative forest coverage (23%) among the Brazilian states, although most of them are secondary forests (Tabarelli et al. 2005), but it also experiences the most rapid deforestation (Meister & Salviati 2009). According to the Brazilian Institute of Geography and Statistics, small family farms encompass 87% of all properties and 44% of the land in the State, a much greater proportion than in other States.

Figure 1. Farmers' implementation of agroecological practices can decrease deforestation and fragmentation, increase connectivity and improve their livelihoods while complying with the Brazilian Forestry Act. *Top*: Slash and burn practices. *Middle*: Intervention, forest regeneration, and succession after slash and burn. *Bottom*: Establishment of silvopastoral rotational grazing systems. Photo Credit: Dr. Abdon Schmitt Filho.

Many smallholders in Santa Catarina have removed most of the forest cover in their farms in violation of the Forest Act. In many, if not most cases, the small size of family farms along with their characteristic high slopes and conspicuous number of streams means that compliance with the law would make it almost impossible to sustain themselves with traditional agricultural practices. While compliance with the Forest Act would likely protect and restore critical ecosystem functions (Metzger 2010), it would also force smallholders off the land and into poverty. One cause of deforestation has been declining incomes in rural areas relative to urban areas, leading farmers to clear more forests to increase short term income as the PPAs and LR represent much of their land (Frank 1995).

In the 2000s, new regulations established special conditions for smallholders. These regulations allowed for farmers to plant fruit, ornamental, and commercial trees, along with native trees in the LR. In addition, smallholders are currently allowed to exploit non-timber forest products from PPAs and also to consider PPAs zones as part of the area required for the LR. Such flexibility allows land use systems that can potentially reconcile economic viability of farms with the legal environmental requirements. Anticipating such opportunities, the Voisin Grazing Group at the Universidade Federal de Santa Catarina established over 600 agroecological projects in farms located in sensitive Atlantic Forest areas. These projects aim at increasing farmers' income while reducing forest destruction and restoring forest connectivity in the PPAs by fostering silvopastoral and agroforestry systems within the Atlantic Forest Biome in Santa Catarina. We interviewed 61 farmers who implemented such agroecological practices (Figure 1). In general, the survey addressed water, soils, forest, presence of biodiversity, farm productivity, and environmental awareness issues.

The survey revealed that more than 90% of the farmers have streams or rivers in their farms. Although 60% of these farmers acknowledge the legal requirement of preserving the PPAs, approximately 80% do not agree with preserving riparian buffers as required by the Forest Act. When asked about native trees, most farmers perceived them as an obstacle for production. However, livestock and forage production in silvopastoral rotational grazing systems (where pastures were shaded up to 30%) resulted in similar or higher production than traditional grazing systems, according to their perceptions. Additionally, smallholders were able to double food production and income without significantly increasing acreage ($p < 0.01$), and without affecting protected PPAs. Nevertheless, 68% of the interviewed farmers reported that compliance with environmental laws would decrease their income by at least 50% because the smallest farms were located inside or bordering PPA areas.

With traditional agricultural technologies, Brazil is forced to choose between conflicting ecological and economic thresholds. Over 60% of bird species from the southeastern Atlantic Forest are extinct, critically endangered, or vulnerable (Ribon et al. 2003), while in the northeast over a third of tree species are currently threatened with extinction. Failure to restore the Atlantic Forest will likely lead to a wave of extinctions in the future (Brooks & Balmford 1996), potentially reducing biodiversity by more than 50% if we extrapolate from studies of island biogeography (MacArthur & Wilson 2001). Compliance with the Forest Act would increase the connectivity of existing forest fragments by restoring riparian corridors and other critical habitat (Metzger 2010). However, it would also drive farmers into poverty. A similar dynamic is currently playing out on a global level, where agriculture is the leading threat to global ecosystems (Millennium Ecosystem Assessment 2005; Rockström et al. 2009), but 1 billion people are currently malnourished, and the failure of food production to keep pace with growing populations threatens famine or worse (FAO 2011).

The costs to society of inadequate food production and of massive biodiversity loss are both unacceptably high. Society's challenge is to find land uses that serve as vital corridors between remnant habitats without sacrificing food production. Our research in Santa Catarina suggests that agroecological practices, such as agroforestry and silvopastoral systems, are promising solutions to one of society's most serious challenges.

Acknowledgements

The authors acknowledge the Gund Institute for Ecological Economics at the University of Vermont for its financial contribution to this publication

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The Coal Canyon Story

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At the juncture of 4 of Southern California's most rapidly growing counties lies a transverse hillside system known as the Puente-Chino Hills. Local lore holds that treasure still lies buried in these hills, but the real treasure lies above ground along the streams and in the oak and walnut woodlands.

These hills are an extension of the Santa Ana Mountains, separated from them by the Santa Ana River and the Whittier and Chino earthquake faults in the Elsinore Fault Zone. The hills are bounded by the 605 freeway on the west in Whittier, the 60 freeway to the north in southeastern Los Angeles County, the 71 freeway on the east in the city of Chino Hills in San Bernardino County, and the 91 freeway on the south in Riverside and Orange Counties. The hills are virtually an island in a sea of urbanization.

Oil was discovered here in 1880, leading to an array of oil companies purchasing large parcels of land hoping to exploit the resource. Many of the oil fields are now depleted, but a century's worth of extraction kept housing developments at bay (Keating 2006).

Despite the real estate boom and the now 18 million inhabitants, the hills remained relatively undeveloped, thereby providing an opportunity for area residents to organize to protect them. Efforts began in the mid 1970s to establish Chino Hills State Park (CHSP) on the eastern side of the hills. Today CHSP protects over 5,706 ha of oak and