

Melting Pots of Biodiversity: Tropical Smallholder Farm Landscapes as Guarantors of Sustainability

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In the rush toward securing food supplies and saving nature, agroecosystems such as smallholder farming landscapes in the tropics appear at times to be a missed opportunity.¹ Efforts tend to focus instead on two distinct pathways in separate portions of the landscape: efficient agriculture in larger scale farmlands, and wild nature for conservation. The mixed tropical landscapes managed by smallholder farmers tend to be seen as neither very productive, nor good for nature. For conservationists in particular, a key obstacle is that these agroecosystems host many introduced or invasive species, instead of just native or endangered species. In this article, we argue that the arrival of alien plants in these ever-changing “melting-pot” landscapes can contribute to people’s adaptation to social and environmental changes, to a diversification of livelihoods and habitats, to avoided deforestation, to biodiversity conservation, and finally to sustainability. Based on a three-part analytical framework applied to several case studies, we argue that more resources should be dedicated toward understanding, protecting, and enhancing tropical smallholder farming systems, and that introduced plants should not be an obstacle to this.

Smallholder Farming Systems and Introduced Plants

Smallholding farm landscapes in the tropics contrast strongly with industrial monocropped agribusiness, fenced-off protected areas, and state-owned forests. These diverse landscapes—think of the terraced rice fields and farm forests of southeast Asia, the multi-storied gardens of Caribbean or Pacific islanders, or African rain-fed maize, cassava, or millet farms—are celebrated for their contributions to food security, for their preservation of a diverse array of crop varieties, for their role in local culture, or for their aesthetic appeal.²

Scientists have recently begun to investigate the potential contributions of such tropical agroecosystems to biodiversity conservation.³ Such landscapes occupy large areas in the tropical world, probably in excess of 6 million square kilometers.⁴ Perhaps a billion people living in the tropics practice small-scale agriculture, often in family or household units, on land to which they have relatively durable access rights.

Critics, however, argue that intensive, modern agriculture is more productive and efficient, that such smallholder farming systems are based on romanticized ideas that trap people in village lifestyles, and that they are not sustainable in the face of rapid economic, social, and demographic changes to the world.⁵ For many environmental actors, a key stumbling block to seeing such landscapes as valuable is that they are not pristine places full of native species; instead, these landscape replace pristine habitat with a hybrid anthropogenic nature that includes many introduced species. The typical smallholder farming landscape of the tropics includes a variety of favorite widely dispersed introductions (like banana, mango, cassava, and eucalyptus) with regional cultivars and native species. Alien plants are often the chief source of food, fiber, and construction wood for subsistence and cash income. Yet these plants—like the agroforestry trees *Prosopis*, *Leucaena*, and *Acacia*—sometimes become problematic weeds, or escape into nearby natural or secondary vegetation, and negatively affect agriculture, aesthetics, or native biodiversity.⁶

Approach

By what criteria should one compare and evaluate smallholder farm landscapes characterized by a mix of native and alien plants? How can their advantages or disadvantages be ascertained in contrast to landscapes sharply divided into productive industrial agriculture and protected natural areas? Clearly, different theoretical and ideological positions would produce different evaluations, or give different priorities to different aspects. Here we propose a holistic framework that allows for a balanced presentation of evidence across three main categories.

Anchored in our research experience in such landscapes, we found conceptual inspiration for these categories from several important recent schools of thought. First, the widely utilized framework of “sustainability” focuses attention on meeting the needs of present and future generations of humans while reducing poverty and protecting the environment. It is often conceptualized as resting on three pillars—economic, social, and environmental.⁷ We took this as a broad starting point for our categories. Second, “ecosystem services” is a conceptual tool to assess the value of nature to humans. This idea directs attention not just to obvious benefits like food and fiber, but also indirect benefits like nutrient cycling, water purification, and climate regulation.⁸ Finally, interventions in environmental management in the name of sustainability or ecosystem services have social motivations and consequences that may not be seen as positive or equitable by all, affecting social sustainability. The research perspective of “political ecology” focuses attention on the social dynamics of environmental changes, asking who wins, who loses, and why.⁹

Drawing on these schools of thought, we propose a simple framework to evaluate the value of tropical smallholder farming landscapes mixing native and alien plants:

1. *Productivity*. Are tropical smallholder farming landscapes sustainable and resilient sources of products useful to subsistence and economic activities, locally and beyond? With respect to alien plants in particular, do they damage the productivity of other desired species?
2. *Community*. Do these landscapes contribute to (and not disrupt) the vibrancy, social justice, and resilience of culturally rich rural communities?
3. *Environment*. Are these landscapes resilient contributors of regulating and supporting services for the functioning of local and global biophysical systems, contributing to

(or at least not damaging) biodiversity conservation, water resources, and soil fertility?

Next, we apply this framework to alien plants in tropical smallholder systems in general; we then illustrate with more detailed descriptions of case studies in southeast Asia, Cameroon, and Madagascar.

Productivity

Our framework first asks whether smallholder landscapes incorporating alien species are sustainable and resilient sources of products useful to subsistence and economic activities, locally and beyond. Introduced plants indeed contribute the lion's share of agricultural products in most parts of the world, and not just in terms of New World wheat or African maize on vast farms. The pigeon pea and cassava in the family farms of Zambezia in Mozambique; the sweet potatoes, taro, yams, and bananas of Hawaiian gardens; the avocado, plantains, and pineapples of upper Amazonian forest-fallow fields—these were all introduced from elsewhere. Indeed, some places, particularly late-settled islands like Madagascar or Polynesia, have almost no indigenous food crops.¹⁰

Introduced plants also supply diverse foods (like fruits, seeds, leafy greens), medicines, poisons, dyes, fodder, bee pollen, thatch, cordage, plaiting, adornment, hunting sites, construction timber, and fuel wood. Home gardens and farm fields have smatterings of useful plants spread purposefully and accidentally, which farmers know to come to for one use or another. Around the Indian Ocean, for example, one finds *Abrus precatorius*, used as beads and for its toxins; *Syzygium cumini*, the jambul, adored for its fruits, medicinal use, and religious significance; and *Centella asiatica*, sought for medicinal uses and as a leafy green. In some cases, however, alien plants in smallholder farm systems can also hurt productivity. Alien plants, particularly accidental introductions, are well represented among cropfield weeds. Purposeful introductions can also become problematic. For example, *Chromolaena odorata*, a shrub used to colonize degraded lands, has invaded many areas, demanding extra labor for weeding and reducing pasture resources. Likewise, a number of leguminous trees and shrubs introduced to provide fuelwood and to rehabilitate and fertilize soils, have later threatened other interests due to their rapid spread.¹¹ Smallholder farming systems based on diverse crops and landscape mosaics are arguably better placed than industrial monocultures to weather such challenges. As Andrew McWilliam found in the case of Timor, smallholder farmers were “adept at accommodating the exotic weedy visitor and adjusting their farming systems to the constraints and opportunities that it offered.” <AQ>are both of the McWilliam quotes from the same page number?</AQ>Over the longer term, these weeds lost their momentum and found “a much reduced place in Timorese ecology.”¹²

Community

Do tropical smallholder farming landscapes mixing native and alien plants contribute to (and not disrupt) the vibrancy, culture, social justice, and resilience of rural communities? Aside from the obvious—that the productivity of introduced plants provides subsistence and cash income that keeps a community alive and well—we can note that certain introduced plants have become important cultural icons, joining native plants in mythology, in rituals, in symbolism, and in making up the smells, tastes, and sights of a place. What, after all, would an African village be without the shade of the mango tree, Madagascar without rice, or Polynesia without taro?

In turn, however, the planting and promotion of alien plants can sometimes cause unjust social disruption. For example, the extra weeding requirements posed by

Chromolaena odorata in Ghana necessitated complex household labor negotiations that hampered farmer and government efforts to increase agricultural production.¹³ Programs promoting the wide-scale planting of plants like *Jatropha* in Mozambique, eucalypts in Amazonia, or tropical acacias in Vietnam can damage social fabric of rural communities as the economic benefits only accrue to elites.¹⁴ In these cases, it is not the alien species that is “at fault,” of course; it is the nature of land access, labor arrangements, and institutional maneuverings.

Rural smallholder farming communities are active creators and stewards of landscapes. They try out new plants; they exchange seeds and cultivars with friends and family.¹⁵ They react to new plant arrivals, seeking to make best of opportunities, develop practical knowledge about the plants, surmount obstacles, and guide the landscape into an acceptable future. They are neither passive victims of invasive aliens, nor indiscriminate spreaders of weeds, and as such may regard as unjust certain well-meaning but disempowering interventions such as blanket invasive alien eradication programs.¹⁶

Environment

Do smallholder landscapes mixing native and alien species contribute regulating and supporting services for the functioning of local and global biophysical systems? Are these contributions resilient to changing ecological and social contexts? What is the impact of alien plants in these landscapes on biodiversity, water resources, and soil fertility?

Smallholder farming landscapes in the tropics are now recognized for maintaining and improving soils and biodiversity—particularly when compared to large-scale agribusiness. Farmers have long sought out alien plants to help restore or improve soil fertility—this inspired the diffusion of clover across Europe in the past, and today’s agronomic research into leguminous plants.¹⁷ Smallholder landscapes with alien plants support biodiversity conservation in a number of ways, both direct and indirect. Alien vegetation can directly maintain native bird and mammal populations, provide soils that native plants can colonize, create microclimates, nesting sites, and food sources, and even create new functional dependencies. Furthermore, at the landscape scale, the presence of woodlots, hedges, and stands of alien trees contributes to heterogeneity and creates conditions for further recruitment of forest flora, thus helping maintain biodiversity outside “primary” forests.¹⁸ However, it should be noted that this only works if the landscape matrix includes patches of “natural” habitat, as opposed to wholesale conversion to farms. Finally, an indirect contribution of alien plants is that they provide supplies that reduce pressure on native forests.

One concern that has been raised is the potential for the homogenization of tropical landscapes.¹⁹ Farmers around the world often draw from a similar array of plants; the introduced floras of most tropical countries are quite similar. Yet one could also assert that different places host divergent new ecosystems, mixing common aliens, culturally specific farming practices, and native vegetation. The impact of some level of homogenization on sustainability is a judgment call—we suggest that the alternatives to the homogenization found in smallholder farming landscapes (like monospecific forest plantations or large-scale agribusiness) are worse. <AQ>Is there any evidence to support this assertion?</AQ> A further concern is that smallholder landscapes can become introduction pathways for problematic pest plants. Agroforestry practitioners have already come under fire for turning a blind eye to the invasion potential of the trees they promote. In Kenya, for example, villagers took proponents of mesquite to court for disrupting livelihoods and damaging the environment.²⁰ Clearly each plant introduction is different, and depends highly on the local land management and environmental context.

Introduced plants cycle nutrients, water, and carbon dioxide just like native plants, yet sometimes in different amounts and speeds. They join food chains, shape the structure and

seasonality of habitats for other plants, insects, and animals, and influence soil biology and chemistry. It is without a doubt that alien species—particularly when numerous—change the nature of regulating and supporting services like water storage, fire regimes, pollution filtration, local climate moderation, carbon sequestration, and disease and pest regulation; indeed, in many cases they are planted for those reasons.²¹ Yet it is next to impossible to assert at a general level whether these changes are good or bad, for the answer depends on the particular case (the species, the context, the scale), on interactions between different ecosystem services, and—most crucially—on diverse human judgments.

Case Studies

Local and regional contexts play a crucial role in shaping the character and impacts of specific smallholder landscapes. Hence, we highlight three case studies to illustrate their particularities.

Highland Madagascar

Rising from 1000 to 2600 m, Madagascar's central highlands include humid, rainforested slopes to the east and large grasslands in the seasonally dry west. Figure 1, Figure 2 Farmers cultivate irrigated rice in valley bottoms and sculpted terraces, as well as various rain-fed crops. During the colonial era, they added new crops and trees like eucalypts, wattles, and pines that have become the dominant visual element of many highland landscapes.²² These are now the everyday landscapes that feed the nation, animate its culture, and document its past. Unfortunately, they are largely ignored and denigrated by a preponderance of environmental attention on the island to native species and biodiversity hotspots.

Productivity. All cultivated food plants on the island (bar one type of yam) are introduced. Alien forestry trees provide a wide variety of goods for both subsistence and economic activities, including woodfuel, construction wood, herbal medicine, soil fertility, essential oils, and fodder. Overall, at least 70% of the introduced flora is known as useful.²³ Even in forest fallows, farmers find alien species useful: In one study, about 60% of fallow colonizing species were considered useful, and one-third of these were introduced species.²⁴ Some, however, are more problematic—indeed, roughly one-third of agricultural weeds are introduced plants.²⁵ Several introduced plants have become invasive, with some (like water hyacinth) becoming nuisances and others (like silver wattle) largely viewed as positive and incorporated into farmers' agricultural strategies.²⁶

Community. Alien plants are the foundation around which village life is built in this rural region. Eucalypts and acacias, once strangers, are now intimate companions in farmer-shaped, densely populated landscapes. They furnish the wood used to make the beds people sleep in and the mortars and pestles that they use to husk their rice. Without them the carved wooden balcony might not have become an icon of local architecture. The fragrance of eucalyptus hangs over woodlots where charcoal is being made; it impregnates homes where it is the principal cooking fuel. Their scent of its flowers is captured in honey. Alien trees feature in popular music and have become accepted in sacred landscapes around tombs and former royal seats. They are used to mark territory, to claim land. Challenges to these community-shaped landscapes—whether colonial forest plantations, protected area expropriations, or foreign land acquisitions for industrial agriculture—have long been a source of protest or instability.²⁷

Environment. In Madagascar's smallholder farms, native birds use alien trees as perches and nourish themselves in rice fields, in so doing dispersing forest tree seeds far beyond the natural forest edge.²⁸ Likewise, lemurs feed on eucalyptus flowers, strawberry

guavas, and other alien plants, and use tree plantations as corridors for travel.²⁹ Fruit bats also consume introduced plants, including eucalyptus pollen, guava fruit, and sisal pollen.³⁰ Alien trees also contribute to carbon sequestration and provide supplies that reduce pressure on native forests. For example, at the fragmented forest frontier in the eastern highlands, our data show that villagers near the forest predominantly use introduced tree species for their construction supplies and fuelwood, while villagers within the forest still use native forest trees.

The Domestic Forests of Southeast Asia

Smallholder farmers in Southeast Asia are well known for their skill in cultivating forests that look very similar to natural landscapes. Cultivated forests usually form blocks of several tens of thousands of hectares extending between open farmlands and natural forests. <TQ>Figure 3</TQ> In Indonesia, they cover an estimated 6 million to 8 million hectares. These domestic forests provide income from forest products and a buffer against economic risks, at the same time as providing biodiversity protection and other environmental services.³¹

Productivity. In these landscapes, forest fallows are enriched by tree species planted for fruit production, to restore soil fertility, or to facilitate hunting. In the lowlands of Kalimantan and Sumatra, rubber agroforests produce not only latex but also food, construction material, and game. In Kalimantan, rattan is intercropped with upland rice in the swiddens. The neighboring native forests are interplanted with useful plants like sago palm or benzoin. All these systems benefit from high labor productivity and overall output. In Indonesia, cultivated forests provide 8% of the processed and exported rubber latex, 80% of the dipterocarp resin, and 95% of the benzoin resin traded in and outside the country, and roughly 95% of the various fruits and nuts marketed in the country.

Community. These farming systems prevent the marginalization and impoverishment of smallholders. They incorporate large numbers of people: In Indonesia, around 40–65 million inhabitants live on forestlands; in the Philippines the number is 24 million. Local populations possess a diverse portfolio of resource management practices that they harness depending on fluctuations of markets and prices. Moreover, in such socioecosystems, the cultural link between human and forest is strong: Beliefs and religions, myths and history depend on forest components. Likewise, forest resources are the material and symbolic foundation of domestic units, and thus each group has a strong sense of identity and belonging linked to particular domesticated forests.

Environment. Such agroforests harbor a considerable number of plant species and play an important role in the conservation of biodiversity. They are difficult to distinguish in ecology and physiognomy from natural forests, and are therefore sometimes called “invisible.” The duration of fallowing can attain 40 to 70 years in the case of rubber forests, which minimizes the frequency of disturbances at the landscape scale. Such planted forests enriched by natural regeneration of native species cover significant areas. Smallholder rubber gardens cover 2 million hectares in Kalimantan, and damar resin agroforests have been planted on 50,000 ha in southern Sumatra.

Agroforestry in Cameroon

The rainforest landscape of southern Cameroon consists of slash-and-burn shifting cultivation, used to grow staple food crops, and a strip of managed, permanent forests established at the edges of most forest villages. This multistoried agroforestry system produces mainly cocoa, but also hosts numerous other trees of both native and introduced origin that support a social way of life based on the maximization of opportunity to collect goods as required. Local empirical know-how and practices are based on the mimicry of

ecological processes in order to produce more without changing local ecosystem functions, making the whole socioecological system more resilient and sustainable.³²

Productivity. Cocoa agroforests have produced diverse goods for more than a century. Typically, after people open an area of forest, for the first few years they grow common food crops, many introduced, like cassava, bananas, plantains, taro, yams, and peanuts. When the field is fallowed, the colonizing vegetation is enriched over a 10- to 15-year period with introduced species like cocoa, various shade trees, and a wide variety of introduced species that provide many goods and services: fruits (including mango, papaya, jackfruit, coconut, avocado, citrus), wood (eucalyptus), ornaments, and pharmacopeia. These complex agroforests also provide additional resources through gathering, hunting, and trapping activities that take place in them. They are resilient, in that when the price of cocoa falls, people find other resources to use and sell.

Community. These agroforests are an important component of village social life. The process of land clearance and subsequent perennial planting has allowed villages, lineages, and families to stake a legal claim to land. Villagers hope to expand their plantation so that each son can inherit a large parcel. The agroforests guarantee people a minimum income each year for health and education expenditures, as well as culturally important rituals and ceremonies. Labor exchanges organized for clearance, maintenance, and harvesting build social cohesion and ancestral ties, with migrants returning from the cities to help out, and families camping together in the forest during harvest time.

Environment. Cocoa agroforestry systems harbor levels of native and introduced biodiversity higher than slash-and-burn areas, coffee shade plantations, or forestry plantations, but less (as far as native species) than in mature tropical forests. However, the physical structure of the agroforests mimics natural forest, and these forests are comparable to natural secondary forests in terms of plant, bird, mammal, and insect diversity. For that reason, they play an important role in provisioning and regulating services like pollination, seed dispersal, carbon storage, and soil conservation. Finally, these widespread agroecosystems serve as buffer zones around protected areas. Villagers hunt less in these parks because they can earn money through their cocoa agroforests.

Melting-Pot Landscapes

The case studies document durable, robust systems that are making do. These landscapes—places mixing significant populations of native and alien species, constructed jointly by smallholding farmers and natural ecological processes, and contributing positively to economic productivity, community well-being, and biodiversity conservation—could be referred to as “melting pots.” Melting pots blur boundaries between human and natural, native and alien, production and conservation. They are palimpsests of land and lives created over time. In them, people have accommodated, propagated, or eradicated native species, and they have introduced animals and plants from elsewhere, directly or indirectly, creating heterogeneous mosaics.³³ More formally, we might define melting pots as landscapes characterized (i) by a heterogeneous mosaic of “human” and “wild,” ranging from crop fields, woodlots, and orchards to forest fragments and spontaneous field edge vegetation; (ii) by higher aggregate diversity than that of either wild habitat or farmland alone; and (iii) by the efforts of local people to build the landscape and gaining livelihoods and/or cultural meanings from it.

This “melting pot” concept seeks to both challenge and complement “hot-spot” approaches to conservation (Figure 7) Biodiversity hot spots are defined as places with both high endemism and significant loss of natural habitat.³⁴ Despite expectations that the conservation of hot spots will provide diverse human benefits, this approach’s focus on native biodiversity may rarely benefit sustainability in its broader sense. By definition, a hot-spot

approach is opposed to most of the land use activities of rural societies, and thus results in restrictions on people accessing natural resources, which can have problematic socioeconomic consequences.³⁵ Hot-spot conservation and other protected-areas strategies are often a spatially restricted, sometimes impractical, solution to the demand for ecosystem functions and services across all landscapes.³⁶

Our melting-pot concept suggests that wild biodiversity is not the only kind of biodiversity that should be recognized, celebrated, and protected.³⁷ Hot-spot analysis and other mainstream biological conservation approaches were not built to cope with a world dominated by anthropogenic and productive spaces where people introduce species and build a different kind of biodiversity. The melting-pot concept promotes a focus on hybrid biological and social processes, rather than emphasizing distinctions between people and nature, or between aliens and natives.³⁸

Hot spots and melting pots are complementary forms of biodiversity; the richness of the former depends in many cases on functional relationships with the surrounding countryside, while the latter is enriched by the presence of portions of “wild” landscapes. The melting-pot concept focuses attention on the viability of hybrid, humanized, alien-and-native landscapes that serve both people and nature. The cumulated “local goods” of melting pots—sets of places contributing to productivity, community, and environment—are just as valuable as the “global good” of biodiversity. Melting pots are arguably more sustainable than hot spots (Figure 8) as they occupy a position on a continuum between the extremes of monocropped fields (ecologically unsustainable) and locked-up nature reserves (socially unsustainable).

Conclusion

The rubber gardeners of Indonesia, the cacao farmers of Cameroon, and the rice and eucalyptus smallholders of Madagascar should be encouraged and promoted in their stewardship of their melting-pot landscapes. These tropical smallholder farming systems combining native and alien trees can be sustainable sources of products useful to subsistence and economic activities, locally and beyond. They can facilitate vibrant and resilient rural communities rich in culture, free from socially disruptive interventions (like expropriation for industrial agriculture, or eviction for conservation), and where people are active participants and creators of a landscape. And people here can be resilient contributors to regulating and supporting services for the functioning of local and global biophysical systems.

Such agroecological landscape matrixes, constructed through the idiosyncrasies of local geography, history, and farmer practices, play many roles. Their heterogeneity, their incorporation of native and alien species, and the natural and cultural knowledges and practices they support are key to the resilience of rural landscapes. The recognition of melting pots and their associated farmer practices is key to their perpetuation and to their continued service as buffers for natural landscapes. Focusing conservation and development efforts on encouraging and protecting melting pot landscapes is, for us, the missing link in the paradigms of conservation and sustainable development. This can be achieved through a broad suite of policies and interventions, ranging from land tenure protections to infrastructure investments, rural school and health commitments, tax and market stimuli, and finally to agroecological extension services.

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FIGURES

Figure 1. Melting pot on eastern flank of Madagascar highlands. In zone of natural forest, image shows valley bottom developed for agriculture—irrigated rice in distance, dryland crops in foreground (cabbage, peach, sugarcane). Natural forest is interspersed with *Acacia dealbata* (to left), *Eucalyptus* (foreground), and bamboo (center).



Figure 2 Smallholder landscape in seasonally dry, central highland Madagascar. Irrigated rice occupies the valley floor, while rain-fed crops and diverse fruit trees are planted in hillside grasslands. Eucalypts, with some pine and acacia, grace the hilltop.



Figure 3 Irrigated rice agriculture backed by forest gardens blending into natural montane forest, Bali, Indonesia.



Figure 4 Multi-tiered agroforest in southern Cameroon. Above a herbaceous layer one finds a tier of cocoa and other small useful trees planted by farmers. A third stratum of tall trees provides other utility and protects the cocoa trees with a good ratio of shade, humidity, and sun. Most of these species are introduced.



Figure 5. Cocoa fruit. The cocoa tree was introduced to Cameroon from Central America at the end of the 19th century. Its seeds are the principal component of chocolate and cocoa butter. Ninety-five percent of the worldwide production comes from family and small-scale farms.



Figure 6. Vervet monkey eating *Duboscia macrocarpa* in Cameroon. The vervet is an abundant native species and contributes to the dispersal of native and introduced plant seeds between forests and agroforests.



Figure 7. The “melting pot” concept both challenges and complements the “hot-spot” vision of landscapes and biodiversity.

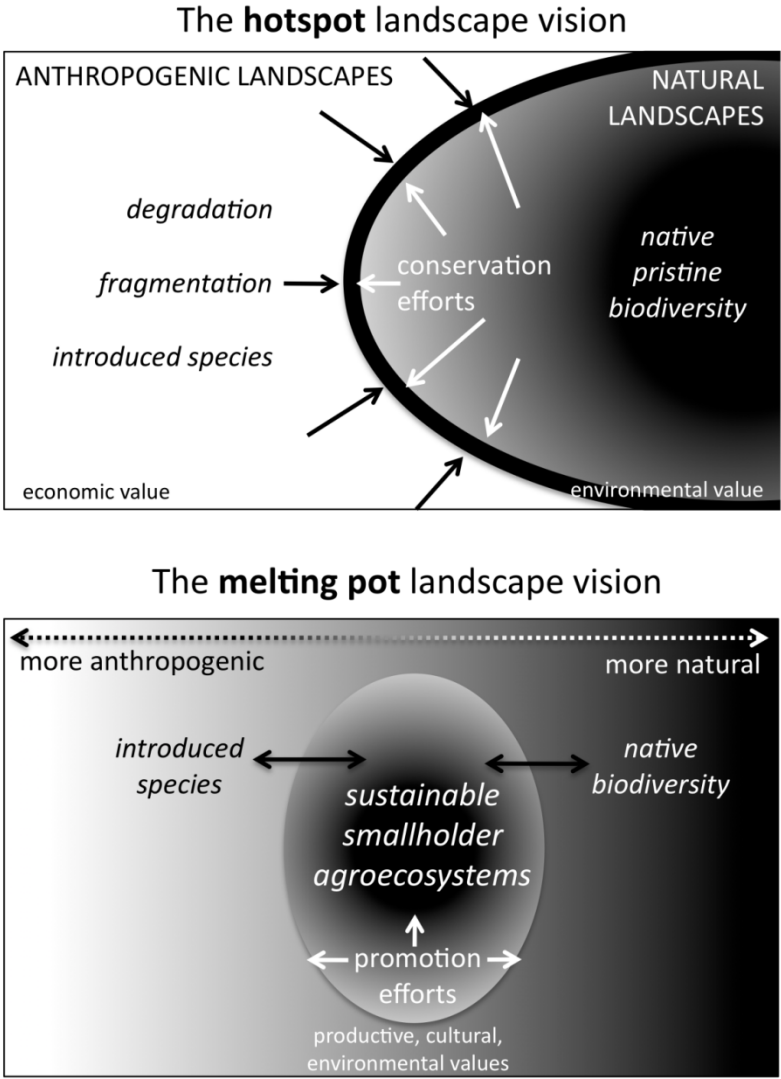
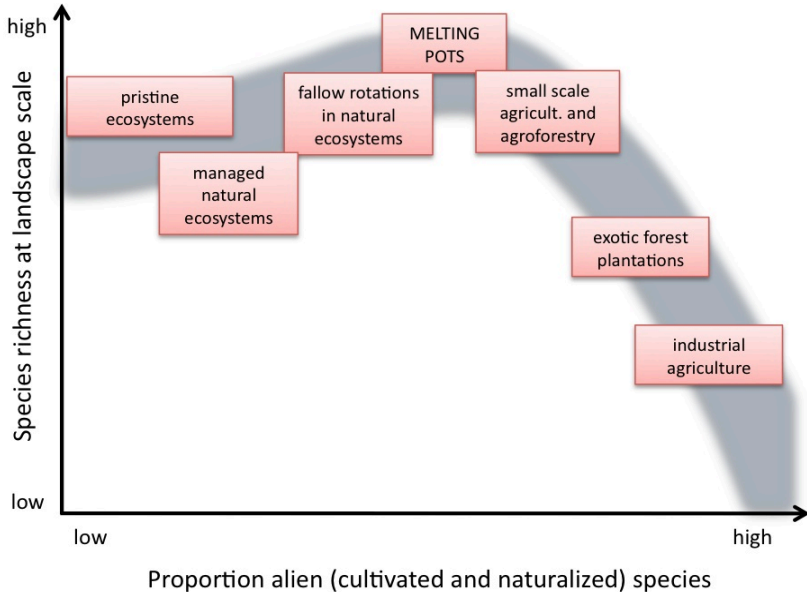
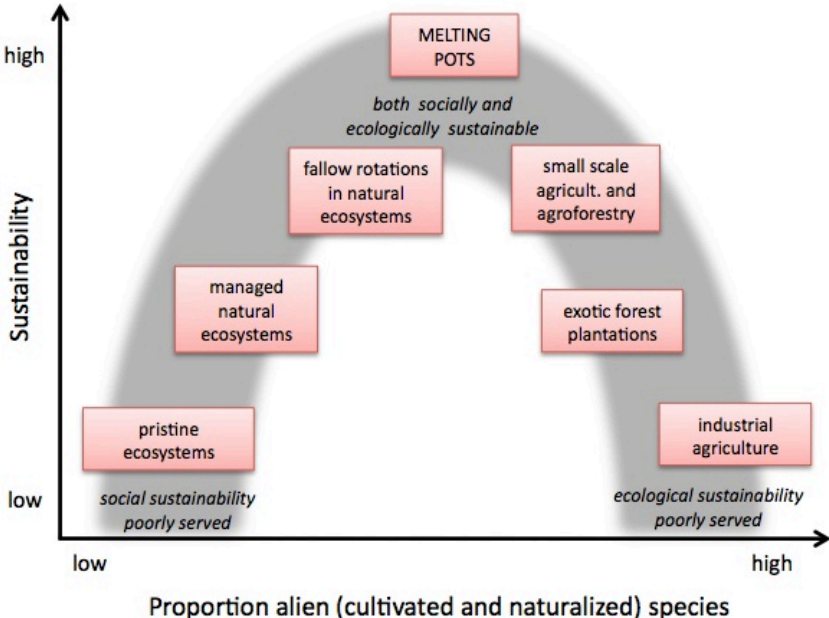


Figure 8. Where do melting pots fit between wild nature and industrial agriculture in terms of sustainability (top) and biodiversity (bottom)? A hypothetical analysis of different natural and agro-ecosystems graded by proportion of alien to native species.



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