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Hybrid improved tree fallows: Harnessing invasive woody legumes for agroforestry

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Abstract: For several decades, agroforestry specialists have promoted the planting of fallow fields with nitrogen-fixing, fast-growing trees or shrubs to accelerate soil rehabilitation and provide secondary products like woodfuel. Yet, such 'improved fallows' have not been widely adopted, in part due to the costs of labour and seedlings. In some situations, however, farmers have developed novel approaches to agroforestry fallows by taking advantage of spontaneous invasions of woody leguminous tree species present in the vicinity of their fields. In this paper, we examine cases from Réunion, highland Madagascar, the Bateke plateau in Congo, and the Palni hills of southern India where farmers have adapted their cultivation practices to take advantage of the invasive characteristics of Australian acacias that were introduced earlier for other reasons. We focus on the key social, economic, and environmental factors that influence farmers in these places to gain opportunistic benefit from these introduced tree species that biologists have been deemed invasive and damaging to local ecosystems and biodiversity. We conclude that opportunistic fallowing of invasives can be viewed as a hybrid strategy combining elements of natural fallows and improved fallows – which we call 'hybrid improved fallows' – in that it takes advantage of the 'weedy' characteristics of introduced leguminous tree species in the landscape and offers a cost-effective and pragmatic strategy for soil and vegetation management for farmers.

Introduction

The burgeoning field of invasion biology sits uncomfortably with agronomic and forestry practices that use plant species with vigorous reproductive and spreading characteristics for large-scale afforestation or medium- and small-scale agroforestry. Invasion biology is based on a normative stance that such plants, particularly if they are 'non-native' species introduced from other parts of the world, are 'invasive' and damaging to both the local agricultural economy and ecosystem health (Davis 2009). Indeed, given that many of the popular agroforestry tree species have been selected primarily for their widespread dissemination, high seed production, fast growth and tolerance of poor soils, it is not surprising that they may be regarded as invasive and deemed problematic in the places where they have been introduced. As several invasion biologists note, these introduced agroforestry species can overrun areas of valuable native vegetation, may have damaging effects on soil quality, and disrupt catchment hydrology (van Wilgen and Richardson 1985; Witkowski 1991; Holmes and Cowling 1997; Richardson et al. 2004).

Proponents of agroforestry have often found it difficult to defend their decisions from the vigorous criticisms of invasion biologists regarding the invasive potential of woody species that they promote for soil rehabilitation, reforestation, commercial production or other agronomic uses such as fallow crops (Hughes and Styles 1989; Hughes 1994; Richardson 1998; Binggeli 2001; Richardson et al. 2004). Their muted response to these criticisms has been in the form of an invasive species policy published by the World Agroforestry Centre (ICRAF 2004) which recommends that new agroforestry introductions be subject to weediness risk assessments. In a review chapter co-written by invasion biologists and agroforestry advocates (Richardson et al. 2004) for an edited volume on *Agroforestry and Biodiversity Conservation in Tropical Landscapes* (Schroth et al. 2004), the authors point out that, "Very little has been published about invasions as a direct result of agroforestry. Indeed, the very concept of invasion is meaningless or absurd to some agroforesters…" (p. 373). Indeed, there is some substance to their observation; until a recent special issue (Jose 2011) it was near impossible to find an article in a journal such as *Agroforestry Systems* or any other agroforestry journal that explicitly addresses the conflicting perspectives of agroforesters and invasion biologists. At most, there may be general statements warning against invasiveness (McNeely 2004) or a few examples of localised problems with invasiveness (e.g. Roder et al. 1998; Kanmegne and Degrande 2002).

Debates over the use of potentially invasive plants in agroforestry reflect a wide range of perspectives and conflicts of interest regarding their role in local and regional landscapes (Slaats, 1995; Kuotika and Rainey, 2010). Stakeholders bring very different concerns to the table, expressed through terms such as 'miracle trees', 'weeds', 'alien invasives', or 'exotics', that may reflect the livelihood concerns of farmers or environmental managers' worries over impacts on biodiversity and hydrology. Geography matters too, in terms of the scale at which these plants are present in the landscape, the type of land tenure, and location (Rangan and Kull 2008; Tassin et al. 2009). Shackleton et al. (2007) highlight these dimensions by showing how some invasive leguminous tree species whose costs outweigh benefits at the national level may offer benefits that outweigh costs at the rural landscape scale. In other words, the issue of potential invasiveness of trees or shrubs introduced through agroforestry practices remains debatable because the species are usually chosen for their usefulness and their ability to succeed in a variety of environments with minimal inputs of labour and capital. Hence, even though they may be labelled as 'invasive' by environmental managers or biologists, they may still be regarded as useful and continue to be cultivated or incorporated as resources for local livelihoods.

Several studies have revealed unexpected situations where invasive woody legumes are considered as valuable socio-economic or agricultural assets by local rural populations despite their invasive characteristics (Geesing et al. 2004; de Neergaard et al. 2005; Kull et al. 2007; Shackleton et al. 2007; Tassin et al. 2009; but see Mwangi and Swallow 2005). Farmers facing new weeds and plant invasions have long been adjusting their farming systems to the constraints and advantages they offer (McWilliam 2000). One striking example, which is the focus of this paper, is the use of invasive woody legumes for fallowing agricultural land. In this case, farmers take advantage of, or harness, the invasive potential of these species for intentional improvement of soil for cultivation. Fallows improved through the invasion of woody legumes can be considered as opportunistic fallows, they represent the *conversion* of plant invasions, which can be regarded as problematic or negative, into productive agroforestry systems by farmers. In this paper, we examine cases where Australian acacia species have been utilised in this manner, using examples from published literature as well as from our respective fieldwork (farmer interviews and site visits) in highland Madagascar, the island of Réunion, the Bateke plateau near Kinshasa, Congo, and the Palni hills of southern India. We provide a brief outline of fallowing and agroforestry, and review the different factors that are taken into consideration by farmers as they place their lands under fallowing cycles. This is followed by a discussion of the methods and strategies used by farmers in these sites to harness and utilize the invasive characteristics of Australian acacias in different phases of a fallow cycle so as to benefit from both fallowing the land and sale or use of products from these areas. The concluding section reflects on the opportunistic and adaptive strategies of farmers and suggests that their approach represents a newly recognized agroforestry strategy that is best understood as a hybrid between natural fallows and improved fallows, hence our use of the term 'hybrid improved fallow'.

Fallows and agroforestry

Fallowing, or resting the land, is a practice that is as old as agriculture itself. It involves a decision by the farmer to not cultivate a part of the field or plot of land that has been previously cultivated so as to enable the soil to regain its fertility and alter the conditions for agricultural pests. Fallowing may occur over a single agricultural season, a whole annual cultivation cycle, or several years, depending on the type of soil and the crops being cultivated. Shifting cultivation, which is an archetypical example of agroforestry, involves clearing wooded or forested areas, farming, and subsequent fallowing for several years or decades before being returned again to cultivation. During the fallowing period, the local vegetation whose seeds and roots remain in the soil, and whose seeds can be spread from nearby plants by dispersal agents like wind, water, ants, birds, or herbivores, have the opportunity to regenerate and reoccupy the previously cultivated area.

Long fallow cycles, particularly those associated with 'slash-and-burn' shifting cultivation, have usually been criticized from the perspective of modern, western agriculture as wasteful and destructive to savanna and forest ecosystems. Cognisant of growing populations and reduced availability of land for low-density cultivation, agroforestry experts have since the 1980s promoted the idea of 'improved fallows' that use fast-growing, nitrogen fixing leguminous shrubs and trees to shorten fallowing periods, speed up organic fertility, and provide useful products (Young 1989; Roder et al. 1998; Place and Franzel 2000; Kanmenge and Degrande 2002; Styger 2009). Instead of abandoning their fields to recolonization by local 'pioneer' species or native successional vegetation, farmers are encouraged to use introduced 'improved' species that are fast growing, fertility-boosting and/or commercially productive. However, the adoption of 'improved fallows' among smallholder farmers tends to remain low due to a variety of reasons that include costs involved in accessing, buying, and seeding or planting appropriate species (ICRAF 1997).

In classic agroforestry approaches to improved fallows, researchers and practitioners are usually concerned with farmer *adoption* of agroforestry technology ‘packages’ that combine particular leguminous species with associated cultivation and management techniques (Franzel 1999). According to Swinkels and Franzel (1997; also Franzel 1999), the adoption of agroforestry techniques has three components: feasibility, profitability (or, more broadly, utility), and acceptability. They note that the willingness to adopt new agroforestry technologies is determined by the extent to which these three components match up with farmers’ goals, means, and constraints. Taking this into account, we suggest that the key factors that influence farmers’ decision to adopt agroforestry technologies for improved fallowing are: 1) *input costs*, i.e., buying seeds, seedlings, and other chemical inputs to establish the fallow; 2) *labour costs for establishment*, either in terms of the farmer’s own/household labour investment or in wage labour; 3) *labour costs for management and maintenance*, i.e., thinning during the fallow period, harvesting at end of fallow, or controlling weediness during crop cycle; 4) *cash income*, such as sale of wood, charcoal, fodder, and other non-timber produce from the fallowed area; 5) *multipurpose use*, in terms of grazing animals, producing compost, etc. in the fallowed area, and 6) *duration* of the fallow, i.e., how long it takes before the land can be returned to crop cultivation. For large farmers, improved fallow technologies may prove profitable due to economies of scale, but small farmers with limited land and access to capital may find that both direct and indirect costs associated with improved fallows outweigh the cash benefits they might offer.

There are some situations, however, when farmers can derive the benefits of improved fallowing without significant investment in input or labour costs. This happens particularly when native or exotic leguminous trees and shrubs are already present in abundance in the rural landscape. As we mentioned earlier, the characteristics of tree species recommended for improved fallows (fast-growing, nitrogen-fixing, light-demanding, high tolerance of poor soils, and seed longevity) are shared by many invasive plants (Richardson et al. 2004). Farmers may consider these plants as ‘weeds’ if they compete with cultivated crops, but may welcome them in areas set aside for fallowing (Buresh and Cooper 1999; Koutika and Rainey, 2010). By adopting a pragmatic attitude toward these invasive yet useful woody legumes, farmers are able to develop an alternative ‘opportunistic’ fallowing method that is similar in input and labour costs to natural fallowing but more efficient in restoring soil fertility over a shorter period of time, and more profitable in yielding cash income over the duration of the fallow. Likewise, its low input and labour costs make it more economical yet as profitable and effective as improved fallowing, and therefore makes it a more feasible and acceptable fallowing method for cash-strapped small farmers.

We would argue that the opportunistic use of invasive woody legumes in the agricultural fallow cycle should be conceptualised as a ‘hybrid’ combination of natural and improved fallows. This strategy follows the same processes of recolonization and succession as natural fallows, with the ‘pioneer’ species being local ‘invasive’ woody legumes alongside other local successional vegetation. They are similar to ‘improved’ fallows because the invasive woody legumes share similar characteristics to agroforestry tree species promoted for improved fallowing. This kind of opportunistic fallowing system can be termed ‘hybrid improved fallow’, a pragmatic, adaptive, and innovative approach that enables farmers to achieve their livelihood goals within dynamic ecological and social conditions and economic pressures.

Australian acacias in hybrid improved fallows

General context of agricultural use of Australian acacias

Australian acacias are popular forestry and agroforestry species, which have widely been promoted for a variety of uses ranging from woodfuel and fodder to industrial raw material (Boland 1989; Doran and Turnbull 1997; Brockwell et al. 2005; Reubens et al. 2011; Kull et al. 2011). The global spread of Australian acacias as forestry species goes back to the 19th century, when many countries sought to introduce plants from various parts of the world that could be utilised for industrial, land improvement or infrastructure development purposes (Cossalter 1986, Turnbull et al. 1998; Kull and Rangan 2008; Kull et al. 2008; Carruthers et al. 2011; Griffin et al. 2011). For example, French colonial officials in Madagascar distributed *Acacia dealbata* seeds to enterprising highland farmers to encourage afforestation of grassland areas and supply fuel for the country's railway (Kull et al. 2007). *Acacia mearnsii* was widely planted by farmers on the mountain slopes of Réunion in order to provide fuel for essential oil distilleries (Defos de Rau 1960). The same species was cultivated on medium-sized holdings by settler farmers in South Africa, and by the Indian government's Forest Service in massive forestry plantations in the Nilgiri and Palni hills, to supply tannins for leather-processing industries (Rangan et al. 2010). Over the past three decades, tropical varieties such as *Acacia auriculiformis, A. mangium,* and *A. colei* have been promoted for both large-scale forestry and small-scale agroforestry around the world (Kull et al. 2011). In several cases, they have been promoted specifically for improved fallows (Buresh and Cooper 1999; Faye et al. 2000; Lesueur et al. 2000; Yossi et al. 2000; Rinaudo and Cunningham 2008; Verchot et al. 2008).

Agricultural development projects have introduced Australian acacias to farming systems, via improved fallows, with the express goal of enhancing soil fertility, particularly in West Africa. In these cases, Australian acacias facilitate the cycling of nutrients like phosphorus between the soil and vegetation, fixing nitrogen at the root level, and enhancing soil biological activity by providing shade (Harmand and Ballé, 2001). In certain agroecosystems soil macrofauna is more abundant beneath these trees than in open land, reaching levels higher than those in forests (Mboukou-Kimbatsa *et al*., 1998). Acacia root and litter decomposition can increase the soil carbon content and the C/N ratio, improving soil organic matter (Serpantié and Ouattara, 2001). In some situations, there may be a decrease in soil carbon and nitrogen, which has been documented during the first years of acacia growth but this becomes positive again after this temporal threshold (Bernhard-Reversat, 1996). Last, some phyllodinous species (i.e., *Acacia holosericea*) may not improve the soil organic matter because their litter contains a high level of tannins (Harmand and Nijiti, 1998).

Depending on the length of their presence in these regional or local landscapes, these Australian acacia species are classic examples of useful yet invasive woody legumes that can be opportunistically harnessed by farmers for 'hybrid improved fallows' (Rakoto Ramiarantsoa 1993; Roder et al. 1995; Tassin et al. 2009). In regions invaded by Australian acacias such as those we survey below, a fallowed cropfield is likely to be colonized almost exclusively by acacias. As the fallow progresses, the rapid growth of acacias allows them to maintain and even expand this dominance

The viability of Australian acacias as 'hybrid improvers' depends on their individual biological traits and behaviour in introduced landscapes. However, as we mentioned earlier, they share many characteristics in common with other useful leguminous trees and shrubs. Legume seeds are long-lived, can be dispersed by ants, cattle and birds, or by abiotic forces like water flow and wind, and can germinate relatively easily (Richardson et al. 2000). Most leguminous trees have a short juvenile phase and heavy fructification, which together ensure sufficiently large seed rain and seed bank in the landscape to create the necessary propagule pressure (Pyšek et al. 2006) and preconditions for hybrid improved fallowing to be undertaken by farmers.

The creation, use, and management of hybrid improved fallows can be understood under three broad categories of activity: preparation for 'invasion', managing growth, and harvesting 'invasive' plants and other products from the fallow before it is returned to cultivation of other crops. As **Figure 1** illustrates, the comparative advantage of hybrid improved fallows, particularly for small farmers with limited capital, lies in its low input and labour costs for establishment and management, the generation of cash income from the invasive plant, multipurpose use, and relatively short time for land to be returned to crop cultivation. These differences rely on specific life-history traits of invasive legume species. They consist, on one hand, in an abundant and long-lasting seed-bank, a high germination rate enhanced by burning and/or hoeing, a very high growth rate even on low acidic soils, a fast decomposition rate, a high density of nitrogen-fixing plants, rapid nutrient cycling through an abundant release of leaves and pods, and weed suppression. While many of these characteristics are appreciated by farmers, they can also render these species difficult to control during the cultivation phase, and may require additional labour for thinning. The following sections draw on case studies and examples from highland Madagascar, the island of Réunion, the Palni hills, and the Bateke plateau (**Figures 2 – 5**) to illustrate how Australian acacias have been harnessed and utilised by farmers through hybrid improved fallowing systems.

Preparation for 'invasion'

The first phase of a hybrid improved fallow system is the creation – usually unintentional – of the right conditions for fallow invasion by woody legumes: a widespread, abundant seed bank. The duration of this phase depends on both biophysical and economic factors, and ranges between a few years and several decades. During this phase, invasion by woody legumes proceeds at the landscape level and results in the accumulation of seeds over much of the terrain.

Australian acacias have been present for half a century or more in all case study sites other than the Bateke plateau, and thus have significantly large seed banks stored in the landscape and in fields. Species like *A. dealbata* also spread by vigorous suckering, and fields may have sufficient remnant suckering rootstock from previous fallow cycles that may have survived in the soil during cultivation of other crops. Farmers in highland Madagascar refer to *A. dealbata* as '*zavatra sarobidy*' or 'precious thing' because it grows for free in people's fields (CK interviews 1999, 2006). Australian acacia seeds respond favourably to heat treatment for germination, and it is common practice in acacia plantations to burn areas where seed banks and remnant rootstock exist in the soil so as to facilitate germination and regeneration (Sherry 1971; Itoh et al. 1990). In the case of promoting 'invasive' acacia fallows, farmers usually rely on the acacias' natural tendency to recolonize and regenerate in cleared areas and hence leave their harvested fields to allow this process to happen. In some situations, if farmers feel that the existing acacia seed bank is inadequate for healthy regeneration, then they may add acacia seeds in the area set aside for fallow. For example, in previous decades when farmers in Réunion rotated their fields between *Pelargonium* (geranium) cultivation and acacia fallows, they would collect acacia pods and cover them with burnable litter to ensure successful germination of fallows after harvesting the *Pelargonium* crop (JT interviews 2001). Farmers in the Antsampandrano highlands of Madagascar also spread additional acacia seeds from time to time in their fallowed crop fields to ensure vigorous and ample regeneration of acacias (CK interviews 2006). Overall, the labour required for re-establishing fallows is minimal because acacias germinate or resprout easily.

Managing growth

The second type of activity in hybrid fallows is the management of the growth of invasive woody legumes in the fallow field. Australian acacia seedlings can grow at very high densities in fallowed areas, and may need to be thinned at intervals so as to yield commercially valuable produce over the full duration of the fallow cycle (Shackleton et al. 2007). The supply of fresh and readily decomposable organic matter to soil may have significant impact on soil biological processes, acting as a mulch or a green manure. In the Antsampandrano plateau of Madagascar, farmers thin the regenerating acacias within a year or so after establishing the fallow so that bigger trees are available for charcoal production in 3 or 4 years, and bigger poles for use as building material can be harvested after 5 to 8 years (Rakoto Ramiarantsoa 1993; CK interviews 2006). Similar strategies have been used by farmers in Réunion (JT interviews 2001) and the Palni hills (HR interviews 2008). Again, the labour investment or costs involved in managing the fallow is minimal, and is often part of the activity involved in harvesting the products for sale.

Utilising and harvesting fallows

The final activity is the use and harvest of the fallow vegetation before preparing to reuse the land for crop cultivation. Fallows, whether natural, improved, or hybrid, are used for a variety of purposes while soil fertility is being restored and agricultural pests are reduced or removed from the fallowed area. Cattle grazing may occur, comestible insects may be harvested, and naturally occurring medicinal and edible plants may be gathered from these areas. Cattle are sometimes allowed to graze in fallowed areas a few years after establishment so that they keep a check on grasses, shrubs, and acacia seedlings while also fertilising the soil with their dung. Acacia seedpods are protein rich and provide the necessary nutritional forage to keep cattle healthy during both dry seasons and winter months.

The most significant assets in the fallowed area are the acacias themselves (Berenschot et al. 1988; de Neergaard et al. 2005; Aitken et al. 2009). Their wood can be harvested for charcoal production, fencing and roof poles, the bark for use in leather tanning and for folk medicine, the leaf litter made into compostable fertilizer, and the gum used as artisanal glue or sometimes in local foods (JT interviews 2001, CK 2006, HR 2008; Kull et al. 2007; Tassin et al. 2009; Rangan et al. 2010). On the Bateke plateau, farmers practicing 12-year fallow rotation with *Acacia auriculiformis* can produce about 24 tons of charcoal on each harvested hectare; the combined income from charcoal production, honey collection, and subsequent maize (*Zea mays*) and cassava (*Manihot esculenta*) cultivation on a 25 ha farm can reach up to US$ 4000 per year, which is roughly equivalent to an urban professional's salary in Kinshasa (Bisiaux et al. 2009). In Réunion, *A. mearnsii* is harvested and sold as firewood, with farmers processing one batch every 3 months or so (Petrequin, pers. comm. JT). Until the 1960s, this wood was the primary source of fuel for commercial distillation of *Pelargonium* oil (Tassin and Balent 2004; JT interviews 2001). In areas around the Ankaratra range in highland Madagascar, acacia fallows are regularly harvested for firewood and charcoal production and dispatched daily on a convoy of trucks to be sold in major towns and cities (Kull 2004; Kull et al. 2007). In the Palni hills, farmers maintain *A. mearnsii* fallows as kind of savings account, harvesting the trees in bulk at the end of the fallow cycle to gain access to a lump-sum amount for major household expenses. Depending on the acacia stock, the harvested wood may be sold as poles, the bark stripped and sold to tannin producers, or the wood sold as raw material to the paper and pulp industry (Rangan et al. 2010; HR interviews 2008). The labour investment or costs related to these activities are compensated in terms of cash income earned from the sale of products, or as 'savings' that accrue from not having to purchase materials needed for household subsistence.

Duration of fallow cycles

As we mentioned at the outset, one of the main aims of natural fallowing is to rest the land from cultivation and enable it to restore its fertility before it is put back into crop cultivation. The aim of improved agroforestry fallows is to speed up this process by planting leguminous trees that fertilize the soil through their nitrogen-fixing root nodules and rich leaf-litter (Schrot and Sinclair 2003). Depending on the ecological conditions and capital constraints, farmers may seek to shorten their fallow cycles through distinctive crop-fallow rotations. For example, in highland Madagascar, rotations involve cultivation of potatoes and maize for 1 to 3 years followed by hybrid improved fallowing with *A. dealbata* for 3 to 4 years for charcoal production or firewood extraction (Rakoto Ramiarantsoa 1993; Bertrand 2001; Blanc-Pamard and Rakoto Ramiarantsoa 2003; CK interviews 2006). In Réunion, *Pelargonium* is cropped for two to six years followed by *A. mearnsii* fallows for 3 to 10 years or more (Perret et al. 1996). Farmers in the Palni hills alternate between cultivation of potatoes and vegetables for 3 to 4 years, and *Acacia mearnsii* fallows for 6 to 8 years (HR interviews 2008), while government researchers have also tested acacia rotations with *Pelargonium* and fodder plants such as *Pennisetum clandestinum* and *Trifolium repens* (Agarwal et al. 1995).

Discussion and Conclusion: The Tao of Weedy Agroforestry

An important feature of 'hybrid improved fallows' is the active agency of the woody legumes – due to their biological propensity to grow fast and reproduce profusely – to speed up the soil enrichment through their nitrogen-fixing qualities and provide additional resources that are useful to farmers. Humans may have originally introduced acacia seeds and seedlings in these regions concerned, but recolonization of these woody legumes usually occurs through 'natural' processes of 'invasion' in fallowed fields. Whether this fallowing process is considered as 'natural enrichment' by non-local pioneer species or as 'improvement' by a 'naturalised introduced' species is a matter of academic debate. As far as the farmers are concerned, the acacias are valuable because of their biological properties and utility, and accept them as part of their farming culture and local landscape.

The agroforestry practices we have described can thus be regarded as hybrids of natural fallows and improved fallows: regeneration of woody legumes in areas set aside for fallowing takes place without much human mediation or expenditure of labour, and the fast-growing, 'invasive' trees are exploited for their fertility and utility. The integration of such invasive plant species within agricultural production systems illustrates how rural communities and households can be remarkably adaptive and opportunistic in their livelihood strategies and seek to improve their welfare within the constraints of the ecological systems in which they reside (Serpantié 1993; Shackleton et al. 2007). The case studies from Réunion, Bateke plateau, Madagascar, and the Palni hills indicate that farmers have 'adapted' (cf. Adger et al. 2005) their farming system to take advantage of 'invasive' species instead of viewing them as bad and trying to eradicate them from their lands. They have gained experience and practical knowledge of how these trees fit within the regional ecological and agricultural systems and, by and large, made pragmatic decisions to manage the invasive tendencies of acacias to their own advantage and purpose.

The biological characteristics of these woody legumes is both the key advantage and potential disadvantage of 'hybrid improved fallows': an advantage as it facilitates (or forces) farmers to derive opportunistic benefit from their 'invasiveness', but also a potential disadvantage because it may create conditions where the plants become 'weedy' by competing with cultivated crops or by making cultivation more laborious, thereby cancelling the benefit of low labour and opportunity costs. They may also prove disadvantageous if they dominate pastures and other areas of local biodiversity that are utilised or valued by rural communities. However, farmers may still accept such disadvantages if the overall benefit is high enough (CK interviews, Madagascar, 2006), or find ways to reduce such disadvantages with strategies that require minimal labour or capital. For instance, fallow clearance in the highlands of Madagascar is often timed to take place before winter so that low temperatures and frosts keep the sprouting of new acacia seedlings to a minimum before the land is brought back into cultivation (Rakoto Ramiarantsoa 1993).

Nevertheless, tensions can and do arise over the acceptability of using invasive trees in fallows. People who view this hybrid improved fallowing system at different scale of analysis may arrive at conclusions that are diametrically opposed to those held by farmers. At the very immediate and local scale, there may be neighbouring land users who may wish to prevent acacia invasions in their properties. At regional or landscape scales, biologists concerned with changes in biodiversity or water managers concerned with the effects of these trees on catchment hydrology may disagree with such fallowing systems. Acceptability thus becomes a matter of broader social and political debate between different interest groups regarding the goals and priorities for landscape management. These debates will necessarily have to balance the ideals of preserving native biodiversity and landscapes with the pragmatic feasibility of achieving such outcomes in landscapes that have been 'hybridised' over long periods of time through different kinds of human activity and land uses. In the meantime, however, farmers who need to earn a livelihood from lands that have been blessed (or cursed) with seed banks of invasive woody legumes are likely to make the most of their situation by utilising these trees in ways that are feasible and acceptable to them.

The opportunistic use of invasive woody legumes by farmers constitutes a novel and previously unrecognized form of improved agroforestry fallows. While the implications of the presence of invasive species in the landscape are a matter for broader societal debate, it is imperative that such pragmatic strategies for soil and vegetation management through 'hybrid improved fallows' be recognized for the benefits they offer and supported through appropriate collaborative research and extension work by ecologists, environmental managers, and agroforesters. In particular, we would recommend further investigation of the dynamics of soil fertility, plant competition, and crop yields of hybrid fallows in different biophysical and socio-economic contexts for different weedy woody legume species.

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Figure 1. Hypothetical differences in input costs and outputs between different fallow systems that would influence their adoption (see text for explanation). We assume that the crops yields are the same in each case, and explore the hypothetical differences in inputs and non-crop outputs.

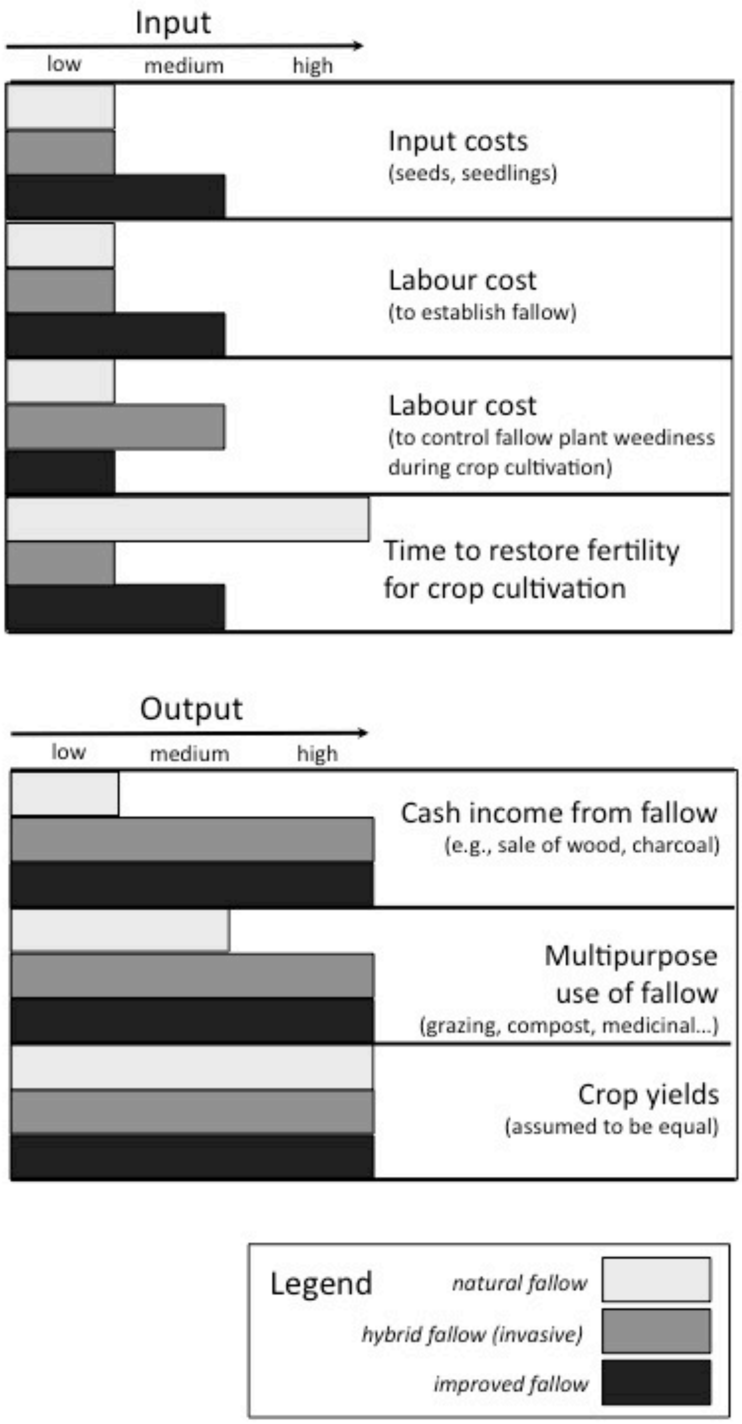

Figure 2. Madagascar: A field with uniform, dense growth of *Acacia dealbata*, and older fallow of same species behind on the Antsampandrano plateau (altitude >2000 m). Photo 2006: CK.

Figure 3. Reunion Island: Sign indicating a distillery of *Pelargonium*, and fallow of *Acacia mearnsii* behind. Photo 2009: CK.

Figure 4. Palni Hills, India: *Acacia mearnsii* bundles and people in foreground, with acacia patches interspersed among agricultural terraces. Photo 2008: HR.

Figure 5. Congo: maize crop on the Bateke plateau following a fallow of *Acacia auriculiformis*, and older fallow of same species behind, showing wild yam growing on the stems. Photo 2008: Dominique Louppe.