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The potential and risks of using exotics for the rehabilitation of Ethiopian dryland forests

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Climax tree species normally would fulfill the ultimate function at the end of the succession chain when land is rehabilitated. In the natural forest such trees would eventually be the veterans of the primary forest that usually replace pioneer trees of the secondary forests. Exotic trees, when used for plantations, usually fill the role of pioneers because they capture a degraded site easily. Such capturing of the site would depend on the site conditions as well as the adaptation of the species being used. Once the species grow well, it may be a deliberate decision not to replace such pioneers with climax forest species, the reason being the useful role that exotic species could play in the economy of the region concerned. However, there also may be risks involved in using exotic species in such an interrupted succession chain.

Case studies from South Africa are discussed to, firstly, illustrate the potential of exotics, especially eucalypts, in providing much needed timber while also protecting the natural forest. These species, when genetically improved, can reach yields of more than 20 $m^3 \cdot ha^{-1} \cdot year^{-1}$, even under relatively dry conditions. Secondly, the risk of using exotics, such as eucalypts and Australian *Acacias,* e.g. in terms of water use, uncontrolled spread and destruction of local biodiversity, is discussed and examples are given of management procedures to manage the risks. Finally, some suggestions are proposed on strategies to be followed for the use of exotics in the Ethiopian highlands, especially on the questions how much, where and how to use them. It is pointed out that, with sufficient control, including spatial planning, policy and legislation, exotic species could play an important role in filling economic and social demands that need not be in conflict with environmental objectives.

Key words: Invasive species, biodiversity, risk assessment, replacement forest, landscape planning

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Introduction

Succession in vegetation is one of the wonderful expressions of evolution designed to create healthy ecosystems. Even the stable looking canopy of an undisturbed rain forest is in a continuous state of flux (Whitmore 1996). The forest gets disturbed, either through natural events like fires or hurricanes, or through some action by man like willful harvesting of timber. The natural process of succession simply is nature's way to heal such wounds. This process is a field of scientific study on its own due to the intricate relationships existing in nature, especially in environmentally balanced ecosystems. A gap in a forest usually is colonized by pioneers who then eventually get replaced by climax species – the trees that become the giants of the forest if they are allowed to live that long. Prevailing conditions at the relevant site play an important role in the healing process of the forest. Soil and topography would determine species composition, and climate would contribute to rate of rehabilitation of disturbances. Tree species are specially adapted to act as either pioneers or climax species.

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The rain forest example is simply an illustration of the ideal situation. The same may be true in other vegetation types like the grass or tree savannas of Africa. Often these biomes are more subject to disturbance pressures due to the presence of man. Population pressure and wild fires pose enormous threats to continued existence of forests in areas that are also suitable for habitation by people. Clearly, all natural areas cannot be preserved in a pristine state if economic development becomes a priority in any specific area. Such development would dictate the specific requirements for a specific area or region. For instance, is the highest priority for human needs, for environmental preservation, for local economy, or for a combination of these? If the latter, how can the concept of sustainable management be built into the overall planning?

Once economic development becomes part of the activity in an ecosystem, it means that the natural processes of succession and ecosystem development are modified, or are even interrupted. This interruption of succession need not be totally taboo but if it happens, or is allowed to happen, some questions need to be asked. What is the purpose of the disturbance? How much should be allowed? What are the ecological consequences? How does the community living around view it? Would it need any repair? If so, how much? What would be the appropriate intervention? Appropriate action would need careful evaluation (of damage), planning, implementation and monitoring of progress in rectifying specific problems.

Economic development and consequent pressure on the environment is inevitable in any country. While some areas could be earmarked for conservation of natural reserves or wildlife sanctuaries, other areas are needed for infra-structure development. This leads to establishment of towns, cities and all the concomitant amenities that are required. Town planners are well aware of the need for recreation opportunities and normally include green areas in their plans. However, this ideally structured urban development is not the only reality in most African cities. Perimeters of cities and peri-urban areas are often subject to population influx and informal settlements due to people moving to cities in search of employment. Such areas are not always enjoying all the benefits of proper infra-structure development, over-population becomes common and people are forced into a struggle for survival. Along with social problems this hardship brings pressure on the environment near to the affected areas. Normally there is no pollution control, firewood is in short supply and water resources get depleted. The consequence of this is the gradual destruction of natural resources in ever growing circles around towns and cities.

Ideally the destroyed areas need to be rehabilitated. However, it is unrealistic to consider that such areas should be rehabilitated to their natural state. Some modified form of the natural condition should be aimed at – hence “interrupted succession”. Scientists and land use planners can combine forces to determine the degree of rehabilitation that is required. If the area is not to return to its original state, what then is the objective? Could it at least be developed into a new, “artificial ecosystem” that is environmentally friendly, socially acceptable and economically viable? What do communities think about such ecosystems? What do communities suggest from their indigenous knowledge? How closely correlated could such development be to the natural ecosystem?

The importance of vegetation cover in land rehabilitation is unquestionable. Trees play an enormous role in most interventions aimed at land rehabilitation. This is because of the many options that exist to find trees that would co-exist with other vegetation or that would eventually grow on their own to provide that needed link at the end of the succession chain. Often these trees could be indigenous species. However, sometimes exotic species could be found that would suit the intermediate or eventual purpose of rehabilitation interventions. This is so because the relevant exotics have evolved in other parts of the world where they have been subjected to the conditions that are developing in the local problem environments of the relevant cities or towns.

The introduction of exotic trees to a new environment cannot be done without planning. Critical evaluation of the “problem at hand” will indicate the potential for the use of exotic tree species. Careful matching of candidate species and provenances with environmental conditions must be done. This could be done through computer simulations (Booth 1990) as well as physical introduction of suitable trees (so-called species and provenance trials). This could not been done without a clear understanding of the objectives of growing exotic trees. Surely it will not be for the rehabilitation of the site only without considering other products and benefits. These products would include creation of biodiversity, recreation, timber, non-timber forest products, etc.

Potential of exotics

Why should one consider growing exotics?

In many countries the introduction or growing of exotics is an emotional issue. However, often the economy of a country and even the environment can benefit from growing exotics. Zobel et al (1987) discuss the following main reasons for growing exotics:

- Exotic species often grow faster than indigenous species and they often produce wood with high utility value, making them more economically feasible.
- Indigenous species are often very site specific, while certain groups of exotics like *Pinus* species, are broadly adapted to a range of conditions.
- The silvicultural management of exotic plantation species is easier than of indigenous species.
- The biology of a limited number of exotic species is better known than that of a variety of indigenous species.
- Seed of exotics often is readily available. However, if these seeds need to be imported, it can imply the use of foreign currency, which may not be available to farmers.
- Exotics are often grown on lands that are less valuable or have been degraded to some extent.
- The local forest industries could be developed by reducing the need for imported wood products thereby improving the trade balance.

Indigenous species could be useful for rehabilitation purposes, both at the beginning and at the end of the succession chain. Many areas of Africa have a low rainfall and indigenous species adapted to such conditions normally grow slowly. They are suitable for protecting the land, but once they have been over-exploited and the land becomes bare, they are not always the best and fastest colonizers. Most often they are useful for amenity or general purposes but do not serve well as timber producers, especially if needed on short rotation cycles for uses such as construction timber. But in a country dealing with population pressures, with scarce indigenous timber resources and lack of sufficient rainfall, exotics could make an enormous contribution for land rehabilitation, as replacement/complimentary forests and as elements of agroforestry systems.

Exotics for land rehabilitation

There are several species of willow (*Salix*), poplar (*Populus*), *Casuarina*, *Acacia*, *Robinia* and even *Eucalyptus* that can be considered for reclamation work, especially on eroded soils. They grow fast, have large root systems and are adapted to similar site conditions as the degraded land. These site conditions often are dry with friable soils that wash away during heavy thunder storms that are common in the dry tropics. In Southern Africa, where erosion sometimes reaches huge proportions, good use has been made of poplars, willows, and a number of ground covers and shrubs.

Another example is the sand dunes near Lake St Lucia in South Africa that contain titanium warranting economical mining operations. This leads to total destruction of the dune vegetation but concerted efforts by the mining company helped to restore vegetation cover. The indigenous *Acacia karoo* plays an important role in this process but other species like *Casuarina equisetifolia*, an exotic tree from Australia, has also been used extensively for sand dune reclamation work in South Africa. This species is well adapted to grow in sandy soils and to tolerate see breezes laden with salty moisture. However, although it might look acceptable, the dune vegetation will take many decades to recover to its original state containing many taxa such as *Cleistanthus*, *Suregada*, *Monodora* and *Croton* (Low and Rebelo 1998).

Replacement forests

The concept and importance of exotics as replacement forests is often overlooked. Many countries do not have sufficient indigenous forest resources. With a natural forest index between 4 and 0.08% in 2000 (Geldenhuys 1997), South Africa is a clear example of this. Already in the 18th century this was realized and efforts were made to conserve indigenous forests. In the 19th century it was realized that plantations of exotic forests would help to alleviate the pressure on indigenous forests (Poynton 1979). Afforestation with fast-growing introduced timber species in South Africa, mainly pines, eucalypts and wattle, was started in 1890 (Geldenhuys 1997). Decades of intensive silvicultural management, yield regulation and timber utilization options have built out the South African forestry industry into a world class supplier of forest products. The country is now self-sufficient in timber products, earns foreign currency through exports and enjoys the highest percentage of environmental certification of plantations in the world with 27% of the world's FSC certified plantations and 91% of the ones in Sub-Saharan Africa (EarthTrends 2003). All of this has made it possible to decrease the pressure on the remaining indigenous forests and to conserve and manage them on a sustainable basis.

The South African forestry conditions are extremely variable. Climate varies from sub-tropical wet to desert dry conditions. Soils and topography are very variable, but due to low rainfall only one percent of the land surface area is suitable for forestry. Management options are adapted to match specific site conditions. Under the most favorable site conditions yields of up to 50 $m^3 \cdot ha^{-1} \cdot year^{-1}$ are obtained on an annual basis. On marginal sites yields may be as low as 10 $m^3 \cdot ha^{-1} \cdot year^{-1}$. On both favorable and marginal sites impressive yield improvements have been possible through intensive genetic and silvicultural improvement programmes.

Agroforestry systems

Exotics do not only contribute to local economies through timber plantations. In Africa and other parts of the world they also have staked a claim in agroforestry systems. Many examples exist of agroforestry systems and technologies that help to improve the quality of life for rural people. Home gardens, alley cropping, shelter belts, shifting cultivation, taungya and many more technologies are well known (Nair 1993). Agroforesters are all familiar with the impressive site amelioration that is possible with tree fallows and the use of N-fixing trees such as *Sesbania sesban* and *Leucaena leucocephala* (Nair and Muschler 1993).

Risks of exotics

Description of risks

While exotics could bring many benefits to livelihoods and local economies it would be irresponsible not to point out that there are also risks involved in the use of exotics. As a point of departure, one should heed the warning of Sutherland (1996) that species management is an admission of failure. It is therefore of paramount importance to strategically plan any introduction of exotic species since we know that invasion ranks among the most important global impacts on biodiversity (Primack, 2000).

Exotic trees may become invasive through competition for dispersal agents (Cordeiro *et al.*, 2004), herbivory tolerance (Rogers & Siemann, 2002) or rapid juvenile growth rates resulting in large numbers of introduced species outcompeting native trees (Webster *et al.* 2005). They may also have negative impacts on the soil-water environment by their increased transpiration rates (Fetene & Beck, 2004) and on the soil fertility by altering the decomposition and nutrient cycle (Rothstein *et al.*, 2004) and reducing the topsoil organic carbon (Zinn *et al.*, 2002). Exotic species furthermore replace native habitat-providing species (Sax *et al.*, 2005) and may consequently cause recruitment limitation of indigenous species (Lejju, 2004; Lichstein *et al.*, 2004). In addition, exotic species often reduce the functional biodiversity of the ecosystem. For instance, by reducing the soil macro-invertebrate biodiversity (Steenkamp & Chown, 1996) or avifauna biodiversity (Ramos, 1996; Wethered & Lawes, 2005), exotic species indirectly decrease soil fertility and dispersal capacity.

In example of this risk is the interesting history of combating drift sands in the Southern and Western Cape, South Africa. During the late 1880s, when the rudimentary forestry department started training field officers, their Eurocentric instruction was the cause of management practices that had severe and long-term impacts on the environment. The introduction of fast growing Australian *Acacia* species to stabilize coastal dunes proved to be problematic on two fronts. Firstly, these species invaded the stable surrounding vegetation at an alarming rate, according to the 'enemy release hypothesis' (ERH) in invasion ecology (Colautti et al 2004) mainly since they did not have associated biological control agents such as pathogens, parasites and predators. Secondly, the legacy of this unsound decision has had profound effects on the water yield of the entire southern part of the country. Only in recent years, with the introduction of biological control and a co-ordinated eradication programme, has the situation been stabilized. The most important management implication in drift sand "reclamation" and "stabilization" is to leave such areas alone since usually it is simply part of a long term oscillation of the edges (Olsson & Rapp 1991, Sandford 1993, Skarpe 1991). Responding to irregular rainfall, desert fronts in the southern Sahara may oscillate in a 200 kilometer band which proves that invalid desertification descriptions may be based on naturally occurring cyclical phenomena.

There are also similar examples in Ethiopia with some species such as *Opuntia ficus-indica* and *Prosopis juliflora* (Abiyot Berhane and Getachew Tesfaye 2006).

Plant species invade for a number of reasons, all of which are caused by human activity. Some of these include increased levels of soil disturbance, increased incidence of fire, and enhanced light availability, to which exotics may be able to adapt more readily than native species. It is important to remember that the effects of habitat fragmentation, habitat degradation and pollution may be stabilized and reversed over time, but exotics invasions may become so entrenched that it may be impossible to remove them entirely. Dean et al (1986) summarized the information on seed biology characteristics of invasives in Southern Africa as follows:

- the place of origin is climatically and edaphically similar to the place of introduction
- the invasive species are adapted to germinate and establish in disturbed habitats;
- they are characterized by long-distance dispersal agents (including man);
- the species-specific seed predators or pathogens are absent in the place of introduction;

- the invasive species often carry multi-seeded fruits;
- they have a large annual seed production;
- the seeds of invasive species often show dormancy mechanisms and are long-lived;
- invasive species frequently have many means of vegetative regeneration.

Considering the physiological adaptation of, for instance, *Eucalyptus*, it conforms to at least six of the above characteristics. In addition, one must consider added threats to biodiversity, water yields from catchments due to high evapotranspiration, depressed soil nutrients as well as an increased fire danger. Furthermore attention needs to be given to multiple vegetation strategies, where dependence on a single crop is ameliorated by having mixtures of species and clones (Garvi 1999).

A sometimes overlooked aspect of exotic plantations, especially in dry savanna conditions is the problem of fundamental biological fertility changes that may occur (Bernhard-Reversat and Huttel 2001), usually in terms of mychorrhizal dynamics. In many cases biodiversity may even be improved through increased organic matter, but certainly this should never be taken for granted.

Need for risk management

All of us are familiar with fire and the warning “don’t play with fire”. It simply means that we normally would rather manage fire than play with it. Similarly, one might say “don’t plant exotics”. But if we can manage fire, why can’t we manage the risks of planting exotic tree species? Fire is simply one of a larger assemblage of factors that will impact on the term “risk”.

Only too often are projects initiated without a proper socio-economic and environmental impact assessment. Only when properly conducted, will the true socio economic and environmental risks and benefits of the venture truly come to light. Recent enrichment plantings in denuded dry Miombo in the Kilombero Valley of Tanzania has shown that the risks of such management options lie mainly in economic expectations in the short term, which may de-motivate communities to bring projects to fruition (Schultz 2000). European investors are planting teak (*Tectona grandis*) in this area, and in order to attain Forest Stewardship Council accreditation, are investing in enrichment planting as an exercise in biodiversity enhancement. This is particularly valid in cases where outside investors stand to gain more financial benefits than the participating communities.

Options for handling the risks could include policy and legislation, appropriate management and control, and, education and training, all of which are discussed in the next sections.

Policy and legislation

A conscientious decision about the issues rehabilitation, indigenous versus exotics and economic development needs to be made. In other words, a clear understanding is needed on the priority of each of these issues. This should be done following clear guidelines, which can only be obtained through a participatory process that should include the blessing of relevant authorities. Authorization is best obtained through appropriate policy and legislation. Writing the policy should be the result of well researched options (including socio-economic and environmental impact assessments) on the pros and cons of using tree species (indigenous and exotics) for rehabilitation and their contribution to sustainable development. Policies may include bans, guidelines and incentives. Imposing a ban on planting certain exotics, which proved to be aggressive invader species, may prove necessary over a whole territory. Furthermore, management of exotics needs to be included in guidelines for good environmental practice of forestry companies, state forest administration, etc. For example, if a species is known to affect soil properties or to provoke soil erosion when planted in high densities, a management guideline can set minimum spacing. Finally, incentives (financial and others) can be used to eradicate invader species, or to promote the use of native species (e.g. distribute native seedlings at cheaper rates than exotics).

Appropriate management and control

Once a decision is made to use exotics and the risks of possible invasiveness have been assessed, the rehabilitation programme should be strictly managed. Management includes spatial planning to ensure that, for instance, sensitive habitats are conserved. An integrated development plan is needed that would spell out benefits as well as risks, and takes into account the needs of communities. The management plan will assist in ensuring that operational personnel understand the value of high production forests while also dealing with threats from invasives. Appropriate monitoring and timely control is imperative. For example, if gully erosion is detected under a *Eucalyptus* plantation in a low rainfall area, a more intensive thinning scheme may be introduced to allow native vegetation to recover and reduce erosion.

Education and training

Education of the public should start with involving them right from the start, i.e. already as a stakeholder in the policy writing process. Communities should know and understand the benefits to be derived from the use of exotics, but they should also be well informed about related risks.

Participatory forestry management will bring acceptance of policy implementation as farmers and communities will experience actual benefits. This will bring about a feeling of well-being and give security to communities. But also, foresters themselves need more up-to-date information on the risk and control of afforestation with exotics, The thematic should be included in forestry curricula at all educational levels.

Exotics in the Ethiopian highland

There is a need and a willingness to restore the vegetative cover of the Ethiopian highlands given the alarming rate of soil loss and the depletion of wood resources. Future rehabilitation efforts should be structured in land use planning at all scale levels from national to local. The sustainable use of exotics should become an essential aspect of such integrated land use planning. It should be part of a grand plan, which is the result of consultation among authorities and communities, and which finds its place in national, regional and local laws and bylaws. Important actions include:

- get participation by local communities using techniques such as Participatory Rural Appraisal (PRR), Environmental Impact Assessment (EIA);
- educate at various levels; get buy-in;
- identify a target area e.g. peri-urban area with most destruction;
- write a development plan;
- consider appropriate technologies for rehabilitation and amelioration.

The use of exotics on the Ethiopian highlands should be made dependent on some guiding principles, coinciding with the how, what and where question. The "how" question refers to the context of using exotics. For the Ethiopian highland we propose an approach which supports to a maximum the conservation and sustainable use of indigenous tree species. The "what" question refers to the species selection and the prevailing principle here is that it should be based on local and foreign success and failure stories. The "where" question represents the necessity of a spatial approach, where it is decided on what places in the landscape the use of exotics is suitable.

How? Conservation and sustainable use of native species

The native vegetation can be considered the combination of species best adapted to local climate condition including dry spells and other risks. As a consequence, it is a naturally optimized compromise of acceptable production at low risk. Local species offer a variety of wood qualities for specific uses and a panacea of other products like resins and gums, honey, medicine, fibres, etc., which form an intrinsic part of traditional livelihood (Kindeya 2003). Nevertheless, the lack of biological and silvicultural knowledge is often mentioned as a major argument for not using them. Therefore, planting exotics must be considered as a complement to rehabilitation with local species, not as a replacement. It must go hand in hand with a series of measures aiming at increasing knowledge on and conservation of indigenous forests. Some concrete measures to include in a programme are:

- Set up conservation projects in relic forests (church forests and other forest fragments) and exclosures (in situ) and in nurseries (ex situ);
- Develop alternatives for exotics by selection and genetic improvement of indigenous species;
- Provide native species in all nurseries and forest rehabilitation schemes;
- Add native species to all plantations of exotics;
- Use exotics as a nurse crop for the establishment of native climax species.

What? Site and species selection based on land suitability assessment

Land suitability assessment is the matching of a species with the local site conditions. Traditionally land suitability assessment will match a species with the biophysical growing conditions of the site. Recently land suitability will also include other aspects of suitability like socio-economic and environmental potentials and risks, or even local preferences.

The biophysical growth potential of a species can be determined by looking at existing tree plantations of known age in the area of concern or in adjacent areas with similar site conditions. If not available it is highly recommendable to establish species and provenance trials (planted in small homogeneous blocks), spread over the most important site types of a region. Such an establishment of forest arboreta is a very valuable long-term investment.

Where? Build a landscape

As mentioned above, exotics have benefits and risks. Good management of exotics will imply their plantation in areas where they can maximally provide their benefits, as well as their removal from areas where they present an important environmental risk. This spatial aspect of managing exotics is essential but often not addressed. It can be translated in some ruling principles:

- Exotics should not be planted everywhere but in suitable places and according to a written strategy;
- Suitability of land for exotics should not only be based on growth potential, but also on land availability, land tenure, socio-economic and environmental concerns;

- Plantation of exotics should be part of an overall rural planning;
- Plantation should result from a stakeholder based spatial multicriteria decision exercise;
- Large-scale monocultures always cause increased risks. Mixtures of species and provenances are highly recommended.

A spatial approach of planting exotics in the Ethiopian highlands can be better illustrated imagining a virtual landscape with the following typical elements: urban area, villages, roads, croplands, relic forests, grazing lands and exclosures. For each of these elements a strategy for the use of exotics is needed.

Urban areas are characterized by a high population pressure, a high demand for fuelwood and timber, an increasing need for recreation and waste water treatment. Urban areas could therefore implement the following strategy:

- Create large peri-urban forests with dominance of exotics for wood production. This is the case in Addis Ababa. It does provide the necessary fuelwood for the capital, and a lot of employment (e.g. some thousand woman are collecting large bags of leaves, twigs and bark every day from Entoto and sell them in the city after paying a small amount of tax). On the other hand, the monospecific character of the Entoto plantation frequently causes large floods in the capital. A GTZ project tries to promote indigenous shelterbelts to prevent these destructive floods.
- Native plant species along roads and paths and as a future climax vegetation under the canopy of the exotics in order to make the forest attractive for recreation.
- Use non-recreative parts of the forest for sewage water treatment. Slow movement through the root zone of the forest will purify the water. Water and nutrients will offer strongly increased wood yields.
- Actions should mainly be driven by centralized public initiative.
- See a more complete analysis on urban forestry in Ethiopia in the paper of Horst (2006).

Village areas (including *croplands*) are characterized by a moderately high population pressure and demand for fuelwood and timber, and an important need for erosion control. The production function is oriented towards diversification. The recreation function is less important. Village areas could therefore implement the following strategy:

- Plant a mixture of exotics for timber and pole production, native trees as shade trees near homesteads and fruit trees for own consumption and market.
- Exotics are best planted along paths and roads and in small woodlots near gullies that can be irrigated with gully water.
- For soil stabilization at critical points adapted native species are recommended.
- Native and exotic N-fixing trees are recommended for agroforestry purposes in the cropland. *Faidherbia albida,* which is shedding its leaves in the rainy season and as such not competing with the crop, is a beautiful example of such a useful tree.
- Actions should mainly be driven by small initiative of individuals, families, groups.

Roads are an important condition to have market access. This makes roadsides an excellent place to grow marketable timber. Road authorities could therefore implement the following strategy:

- Plant a line or belt of productive exotics along the roadsides. Landscape planners together with local communities should decide on the width and density of the plantation, since dense plantation may obstruct the view over the surrounding landscape.
- A road side tree belt provides shade for people and the animals they bring to the market, and it allows recruitment of native trees
- Since roads can serve as corridors to increase landscape connectivity it will be important to follow-up the risk of unwanted spread of exotics from roadsides, which, in turn, could enhance seed dispersal.

Relic forests are islands of native biodiversity. Any further degradation of these forest fragments may lead to a catastrophic cascade of local extinction of species. For example, the cutting of some climax trees can lead to the extinction of a frugivore bird species, which can lead in its turn to the unsuccessful regeneration of more tree species. Local extinction of tree species is not only a loss of biodiversity but also an economic loss of land rehabilitation capability. As a consequence, the management strategy for relic forests should mainly be a conservation strategy:

- Grazing, cropland, enrichment planting with exotic trees and underplanting of cash crops should be prohibited. Exotic tree species should be removed.
- Active stimulation and protection of natural forest regeneration with native species in the forest itself and in adjacent exclosures. If not successful, enrichment planting with the natural climax species.
- Effective guarding systems should be put into place as a collaboration between church, forestry and local authorities.

- To maintain viable populations of seed dispersers, one should avoid placing plantations near larger forest remnants, increase the size of small patches, and where plantation forestry is unavoidable, placing plantations in the vicinity of small rather than large forest patches (Wethered & Lawes 2005).

Grazing lands are the most problematic area to establish and conserve trees because browsing by animals and woodfuel harvesting prevents their development. In Ethiopia the successful way to forest rehabilitation is the establishment of *exclosures.* They are areas closed for grazing, where the forest can restore naturally. They can be located in degraded areas, on steep slopes, in areas with low population density, or anywhere where soil, water and biodiversity conservation measures are needed. It is a rising issue whether exclosures should be enriched with exotic trees. It is our opinion to not plant exotics in exclosures, as explained in the following strategy.

- Exotics are not planted because the benefits are low (no professional management, far from homesteads, roads and markets) and the risks are high (high water consumption may lower phreatic water tables and decrease functioning of springs; invasive spread becomes impossible to control).
- Enrichment planting and pruning of native trees will allow for the establishment of high forest with bigger trees, which will serve as nurse trees and stepping stones for further recolonization.
- Cut and carry of grass and harvest of other non-wood forest products should be stimulated and regulated. At a later stage of development when trees are thick and out of reach of animals, temporarily controlled grazing may be allowed, as well as selective cutting, but only in the framework of a plan of sustainable management.
- Belts of non-invasive exotics may be established as visual boundaries against encroachment.
- If enrichment with exotics is preferred by local communities to ensure early benefits of the set-aside areas, spacing should be wide enough to allow further development of the native vegetation under the cover of the exotic tree species.

Case study for Central-Tigray along the road from Mekelle to Hagere Selam

In this case study we propose a vision on the landscape rehabilitation for the next 50 years in a semi-humid to semi-arid landscape with much degraded grazing land, and exclosures and little cropland, including the Geba river valley. In the case study we include the principles presented in the preceding section.

- Large urban forest (in the order of magnitude of 100s of hectares) of mainly exotics around Mekelle. The delineation is urgent because of the quick urban sprawl.
- Green eucalypt belt along the road from Mekelle–Hagere Selam. Because it is a scenic road, eucalypts can be planted four rows wide, 10 m apart in the row and pruned up to 5m branch free bole in order to allow vistas at all places.
- Well conserved church forests (Romanat, Chenferes, Mheni, …) with only native species and adjacent exclosures with native species and surrounded by a eucalypt tree belt of 4 rows wide in order to visualize the boundaries against encroachment.
- Exclosures are managed (enrichment planting, pruning, grazing control) to develop in the direction of high open forests of Olive and Acacia.
- Within the villages a “trees for farmers” project leads to shady environment, with a mixture of individual trees and road-side trees (native and exotic, shade and fruit trees). On cropland borders, tree rows with N-fixing *Faidherbia albida* can be established.
- Around the villages, especially on steep eroded areas and near gullies intensively managed eucalypt woodlots are established for quality wood production.

Conclusions

Foremost in our thinking about the introduction of exotic species should be the fact that alien invasion of natural habitats has been universally recognized as one of the major threats to species survival as well as global biodiversity. But, if we are scientific, and above all moral about what we plan in conservation and restoration management, this should not pose a problem. Considering the development of recent “state and transition” vegetation models, the planting of exotics might be considered appropriate treatment of areas denuded to a point where natural succession does not progress under normal conditions. Furthermore, it is apt to develop such projects using “best current practices” with the provision that the running of such projects shall be subject to appropriate management shifts when new data comes to light.

In the Ethiopian context exotics can play an important role in land rehabilitation with important socio-economic and environmental benefits, but only under condition that their establishment is part of an integrated and spatially explicit plan, in which exotics find their place and where their benefits can be maximized and their risks be kept minimal. In such a spatial approach an optimal strategy for every land use entity could be identified. A case-study showed the feasibility of this for an area in Central Tigray.

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