A Review on Benefits and Disadvantages of Tree Diversity

Markku Larjavaara*

Smithsonian Tropical Research Institute, Panama

Abstract: This paper presents the benefits and disadvantages of tree diversity in forestation. Maintaining diversity of trees in forestation enhances the conservation of trees and other organisms, decreases production risks and increases the possibility of natural regeneration. The value of forest products may be increased or decreased, but increasing diversity always complicates forest management. Species diversity could be increased by encouraging forest owners and managers to mix species; in order to achieve this, scientific information on lesser-known species and silviculture of mixtures must be compiled and disseminated.

INTRODUCTION

The structure of forests and their use varies drastically around the world. The common unifying theme in forest science has been timber production. However, in the most recent decades, other forest products and services than timber have gained relative importance. Researchers have realized that gathering in natural forests is crucial for survival of millions of poor in the developing countries and people in rich countries have started to appreciate recreational and biodiversity values. Therefore, the trend of decreasing natural forests and increasing exotic monocultural plantations optimized only for timber production has triggered a debate in many countries around the world. People have demanded conservation of natural forests and modifications in plantation forestry.

The naturalness of planted forests can be increased by using indigenous tree species and by mixing several species. These two possibilities are often discussed together. However, discussing them together can cause confusion as the mechanisms in which they influence the yield of products and services are different. When the focus is only on diversity, the mechanisms of influence are common around the world at the theoretical level. Despite this, I am not aware of a review covering most or all the benefits and disadvantages of tree diversity on forestation (both reforestation and afforestation) success. In this short review, I aim presenting mechanisms in which inter- and intra-specific tree diversity influences forestation success. The intention is not to review all relevant literature but to categorize the mechanisms in a comprehensive way and cite relevant examples.

Inter-specific diversity refers to the variability between species and intra-specific diversity to the variability between individuals within a species. The focus of this article is on genotypic tree variability within a forest (or stand) at a given time thus including both intra- and inter-specific diversity. Yet some of the information presented is also relevant to variability caused by the environment, at the landscape level or over time at a given location. Especially in non-scientific literature, benefits of biodiversity and vegetation cover are often confused. For example, erosion control is sometimes mentioned as one of the benefits of biodiversity, even though the level of erosion is dependent on the vegetation structure and not directly on the diversity of plants [1].

BENEFITS OF DIVERSITY

If the aim of forestation is to conserve biodiversity of trees, it is obvious that maximizing inter- or intra-specific diversity of trees planted, sown or naturally regenerated is vital. The justification for biodiversity conservation is well presented in numerous publications [2, 3], which focus on the economic values of diversity such as potential use in agriculture and the pharmaceutical industry, or on ethical and aesthetic concerns. It is often stressed that biodiversity should be conserved in nature in order to enable natural evolution, however it is equally important to emphasize that without intra-specific diversity, natural evolution is impossible.

A higher number of tree species increases the number of ecological niches and has also been shown to increase the number of associated species such as understory plants [4] and animals [5]. Therefore, planting numerous tree species on a site not only conserves more trees but other organisms as well.

While biodiversity conservation confers benefits at the global level, most impacts of tree diversity in forestation are local. Over 800 million humans live in the tropical forests and woodlands [6] and often rely on the wide range of food, medicinal plants or other products they can gather from forests. Similarly as foraging animals that benefit from diverse forests also smallholders who collect for their own use benefit more from diverse forests as it is better for them to be able to harvest small quantities of numerous products than an abundance of just one or two. However, as with biodiversity conservation, private forest owners may not have incentives to provide non-timber forest products for local people.

A greater diversity of trees considerably decreases the risks associated with forestation. For example, inter- or intra-specific variability in tolerance to biotic and abiotic stresses increases the probability that a small proportion of trees die but lower the risk of all of them dying. This is beneficial as the
value of a living tree is normally the higher the less there are
trees remaining and in many cases, a portion of trees dying is
only beneficial for stand development. Diversity increases the
likelihood that at least one species will produce well, if little of
the species or the site conditions is known, or if the conditions
are changing [7]. This effect has been called “insurance hy-
pothesis” in ecological literature especially in relation to cli-
mate change [7].

Diversity can also decrease the risk of tree mortality or
stagnation as a result of spatially spread agents [8]. Pests or
pathogens requiring proximity to host trees cannot infect
trees surrounded by non-host trees belonging to a species or
genotype that is not susceptible [9, 10]. In the same way,
non-flammable and tightly rooted trees can protect their
neighbours in a forest fire [11] or strong wind [12]. How-
ever, easily flammable or unstable trees at the same time
increase the risk of damage of their more hardy neighbors.

Theoretically, the more diverse a forest is, the more ran-
don is the pattern of dead trees after a disturbance. In a
monoculture, a spreading disturbance such as disease or fire
often kills a cluster of trees from one area and leave other
areas untouched [13]. The spatial pattern could be similarly
aggregated after a non-spreading disturbance such as drou-
h, if there is variability in edaphic conditions. The more
diverse the forest is, the more random is the pattern of dead
trees and the less harmful the disturbance will be, even if
proportion of dead trees is the same. This is because surviv-
ing individuals that benefit from the increased availability of
resources because their neighbor is eliminated, are more nu-
merous in a more random and less clustered mortality pat-
tern. In fact, their spatial pattern can be similar to that of
individuals removed in anthropogenic thinnings.

The risks related to uncertain values of timber and non-
timber forest products are lower in diverse stands containing
a large range of products. In addition, the composition of
diverse stands can be changed by selectively thinning only
 certain species or genotypes if their value drops unexpect-
edly.

Plant ecology theories suggest that competition between
individuals of the same species is more intense than competi-
tion between individuals of different species [14]. Kelty [15]
divided these mechanisms into “complementary resource use”
prising up from stratification in canopies or roots and more
efficient resource use and “facilitative improvement in nutri-
tion” related to nitrogen fixing species benefiting other
species (for e.g. see [16]). Furthermore, ratios of nutrients
uptake vary between species [17] and some soils might not
be able to support a monoculture of a species requiring
plenty of the particular element. Because of these reasons,
the productivity of e.g. timber, carbon or fruits, of a mixture
of trees is often higher on average than that of monocultures
[18, 19]. In the same way, intra-specific diversity could also
increase productivity of tree stands.

Mixed plantations enable numerous silvicultural tech-
niques that are not possible or feasible in a monoculture. For
example, trees can be planted or thinned out at different
times. Seeding of many valuable tree species cannot survive
in the open but requires shelter trees to adjust microclimate
and control weeds (for e.g. see [20]). Even if the seedlings
of valuable trees perform best in full sunlight, they might re-
quire a dense even-aged stand to produce good quality tim-
ber [15]. This is often best achieved by mixing it with an-
other species yielding early and perhaps regenerating nat-
urally. This secondary species can be later thinned out to re-
lease resources for the more valuable species requiring a
longer rotation period.

It is obvious that the functional variability resulting from
inter-specific diversity is much greater than of intra-specific
diversity. As most of the benefits of diversity are dependent
on the extent of functional variability, inter-specific diversity
is much more beneficial for example to reduce risks. How-
ever, self-incompatibility and inbreeding depression are re-
stricted to low intra-specific diversity and have nothing to do
with inter-specific diversity. Genetically, similar plants such
as siblings of some species cannot produce seeds due to self-
incompatibility, making regeneration in an isolated stand
with low intra-specific diversity impossible [21]. Even if
seeds are produced, their quantity or quality may be reduced
or the viability of the new generation significantly altered as
a result of inbreeding depression [22]. In addition, in-
ter-specific diversity increases the sustainability of rehabilita-
tion: the more tree species present with the potential to re-
produce, the higher the likelihood that viable undergrowth
will develop; thanks to the variability of sprouts and seed-
lings.

**DISADVANTAGES OF DIVERSITY**

Although the benefits of forest trees diversity in foresta-
tion are numerous, a majority of the world’s tree plantations
are monocultures [23], and many are established with little
intra-specific diversity [24]. One of the reasons for this is
that planting a monoculture with only one strongly bred or
naturally adapted and genetically narrow variety enables the
use of the best genotype of the best species whereas increas-
ing diversity inevitably requires the inclusion of inferior
genotypes or species. Even if a mixed stand performs better
on average for any of its components individually, it can be
outperformed by a monoculture of a highly bred variety [25,
26].

A totally different mechanism is via allelopathy. There is
some evidence that chemical interaction between species
have an adverse effect on growth [26]. Little is known how-
ever, on its importance, but it is presumably low.

Inter-specific diversity also complicates forest manage-
ment [14]. Management procedures, starting from seed han-
dling, are different for different species. Existing research is
often focused on economically important tree species with
well-developed monoculture management regimes [14]. The
possible combinations of species for mixtures are innum-
erable and optimal management is dependent on the propor-
tions of trees in the mixtures – simply having a stable mix-
ture and keeping all the species alive can be challenging,
especially if some species grow faster than others [27].

As already stated, diversity is beneficial to communities
gathering for their own use, as for them the marginal value
of a forest product normally decreases with increasing quan-
tity harvested. However, when products are harvested for
sale, their marginal value often increases with increasing
quantity. For example, assuming the same timber market
price for all species, it would be more profitable to harvest a
monoculture than harvesting numerous species in quantities
too small for efficient harvesting, transporting and marketing. Even if the marginal value of a product decreases with increasing quantity, it might be preferable to focus on producing one or only a few products using a monoculture if their value is significantly higher than products obtained from other tree species.

CONCLUSIONS

Ensuring diversity of trees in forestation enhances biodiversity conservation, decreases risks in the production of timber and non-timber forest products, and increases natural regeneration in the rehabilitated forests. While the productivity and value of the products produced may be either increased or decreased, increasing trees diversity complicate forest management. For this reason, monocultures are favored for timber production most plantations around the world. When biodiversity conservation is emphasized, however, polycultures are planted. In developing countries, free access to diverse rehabilitated forests provides rural people with food, medicines and other non-timber products that were once routinely gathered from natural forests. More research for example based on permanent plots on lesser used species and growing mixtures should be undertaken in order to change attitudes and encourage forest managers to use diversity and to meet the challenges involved with managing diverse stands.

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REFERENCES


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