Towards recovery of native dry forest in the Colombian Andes: a plantation experiment for ecological restoration
Groenendijk, J.P.

Citation for published version (APA):
Groenendijk, J. P. (2005). Towards recovery of native dry forest in the Colombian Andes: a plantation experiment for ecological restoration Amsterdam: Universiteit van Amsterdam, IBED

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
Introduction

Severe degradation of ecological systems in drylands has mainly been caused by increased human populations and subsequent over-exploitations. "Original" ecosystems are generally believed to have a high complexity and species diversity on the one hand, and high values for ecosystem functions related to water retention and soil conservation on the other. Hence, it is essential from the point of view of both nature conservationists and farmers to stop degradation processes and restore the natural vegetation to an acceptable level of biodiversity and other ecosystem functions. Most of the state-of-the-art knowledge on forest recovery in the tropics comes from the humid lowlands and humid montane areas. Dry montane areas are virtually unexplored in this respect.

Secondary succession (i.e., succession after disturbance) often proceeds too slow or takes a non-desired course due to abiotic or biotic barriers, such as increased and strongly fluctuating soil temperatures and decreased local soil humidity. A lack of seed dispersal is apparent in many abandoned fields: many forest species have been shown to disperse their seeds over a few tens of meters only. On top of that, seedlings often face competition with exotic pasture grasses for light, water, and nutrients.

Ecological restoration, defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed", can be put into practice in various ways, ranging from directly reassembling a predefined historic ecosystem with a certain set of species, to a mere halt to degradation and a redirection of a disturbed ecosystem towards an "original" one. The latter would be an effort that relies on subsequent natural recovery (soil formation processes, vegetation succession). The choice of restoration or rehabilitation methods depends (apart from the desired characteristics of the ecosystem) largely on the degree of site degradation, and might be aimed at halting disturbance, restoring soil properties, and promoting establishment of desired organisms. Experiences with plantation of native species are still relatively sparse, although many experiments have been initiated. Most of these are in the humid tropics. The importance of shrubs in the facilitation of succession, especially in areas with a Mediterranean climate, has been stressed.

This thesis reports on the onset of an restoration experiment of late-successional dwarf forest in the Checua River valley at the northern edge of the high plain of Bogotá, based on the idea of vegetation succession accelerated by canopy closure of planted woody species. While executing this restoration attempt, I gained basic knowledge on habitat requirements of desired species, growing site characteristics of the desired vegetation type, and propagule dispersal abilities. The principal research questions addressed were:

- Which types of vegetation are present in the study area, and which pathways of (secondary) succession are likely to occur?
- Is seed dispersal a limiting factor for the development of secondary scrub and dwarf forest?
- How do planted pioneer- and late-successional species perform in open secondary vegetation types?
- Can natural succession in pastures and scrubs be accelerated by plantation of native woody species?
- How do planted pioneer- and late-successional species perform in exotic *Acacia decurrens* forest?
- Does the planting of native species give prospects for conversion of exotics’ forests into native vegetation?

The fieldwork area was a semi-arid intramontane basin in the Eastern Cordillera of Colombia between 2550 - 2950 m.a.s.l., at the edge of the high plain of Bogotá, which is one of the most populated and intensely cultivated regions in the Colombian Andes. The study area is a mosaic landscape of grassland, scrubs, planted exotics' forest, and fragments of dwarf forest. Severe erosion formed crevices up to several meters depth throughout the area. The dry andean *Condalia* dwarf forest, endemic to the area, was defined as the “original” ecosystem for the area. Plantations with *Acacia decurrens* have been established in the 1980s for soil conservation purposes; however, an understory vegetation has hardly developed, and ecosystem function recovery is poor, as compared to the native dwarf forest.

**Results of this research**

In Chapter 2, I present a study on vegetation patterns in the study area, as a basis for the restoration experiment treated in Chapters 5 and 6. Successional pathways were explained by means of environment and disturbance history data. We laid out 101 releves in grassland and shrubland types in different stages of recovery, and in relatively little disturbed endemic *Condalia* dwarf forests. Based on a TWINSPAN classification we recognized two types of grasslands, three scrub types and a dwarf forest type. The dry pastures of the pediments mostly have a low overall vegetation cover and a relatively high abundance of (annual) asteraceous herbs. The higher-altitude sub-humid pastures had a higher cover of *Pennisetum clandestinum*, *Anthoxanthum odoratum* and other graminoids. Most woody species invading the pastures are asteraceous shrubs. *B. macrantha* reaches a co-dominant status together with *Dodonaea viscosa* in pioneer scrubs. Dwarf forest stands were mostly found on strongly sloping and relatively rocky sites, as compared to floristically similar pioneer- and late-successional scrubs. Probably, farmers ignored these rocky slopes in their cutting activities for livestock grazing, such that the relatively inaccessible parts were little disturbed. The severely eroded parts of the study area where Tertiary clay has become exposed mostly supported scrub stands dominated by *Dalea coerulea* and *Baccharis macrantha*. Understoreys were mostly species-poor, and the overall vegetation cover was relatively low. CCA was applied to relate
species composition to environment, disturbance history and to the spatial configuration of the relevées. Abiotic factors mostly related to species composition were soil nutrient richness and soil organic matter content. Invasion of grasslands by woody species is pioneered by *Baccharis macrantha* and *Dodonaea viscosa*. *Dalea coerula* was the predominant woody species on truncated clayey soils, which will probably not support *Condalia* dwarf forest. This exploratory study will be of use in the set-up of future succession-based restoration experiments.

Chapter 3 treats the successional affinity of the nine woody species used in the plantation experiment (*Baccharis macrantha*, *Dalea coerula*, *Dodonaea viscosa*, *Condalia thomasiama*, *Croton bogotanus*, *Duranta mutisii*, *Hesperomeles goudotiana*, *Myrsine guianensis* and *Xylosma spiculifera*), inferred from the structure, diversity and disturbance history of the vegetation where these occurred. The data for this study were obtained from the same 101 relevées as those used for Chapter 2. The disturbance history of sites over the last ~60 years was inferred from aerial photograph series (1941-1991). CCA and logistic regression were applied to relate species composition to diversity, environment and disturbance history. All species showed a preference for certain structural groups. Also, a clear relation between species occurrence and vegetation diversity was found. *Baccharis macrantha* and *Dalea coerula* appeared relatively tolerant to grazing, while the remaining seven species reacted negatively. Soil clay content, base availability and organic carbon content was also an important factor for occurrence of each species. Invasion of grasslands by woody species is most probably pioneered by *Baccharis macrantha* and followed by *Dodonaea viscosa*. *Dalea coerula* was predominantly found on truncated clayey soils, which will probably not support *Condalia* dwarf forest. The hypothesized classification of the nine planted species to either pioneers or late-successional was fine-tuned: *B. macrantha* is a true pioneer, while *D. viscosa* is a pioneer tending to mid-successional affinity. *M. guianensis*, *H. goudotiana* and *X spiculifera* are late-successional species, but not as clearly so as *C. thomasiama*, *C. bogotanus* and *D. mutisii*. One species was considered not to be part of the above-mentioned successional series: *D. coerula* is a woody pioneer on eroded clay soils, but persists and co-dominates old scrub stands on these soil types.

Chapter 4 reports on soil seed banks of five vegetation types (grassland, low scrub, high scrub, dwarf forest, and plantation forest), which were studied in order to assess the potential for regeneration of mature dwarf forest. Seeds in soil samples taken at 0-5 and 5-10 cm were allowed to germinate in a greenhouse for a period of 12 weeks. A total of 22429 germinated seeds were recorded, represented by 110 species, which were classified according to their growth form and position in the successional series of the vegetation in the area. Seeds from woody late-successional species were hardly recorded in pioneer vegetation types, where artificial seed supply or seedling plantation seem the best way to accelerate natural regeneration. Especially in grasslands, the only woody species abundantly found in the soil seed bank was *Baccharis macrantha*, an important species of the first woody stages of succession. Pioneer shrubs that act as perch or shelter deserve attention in conservation management in severely degraded areas.
The results of a plantation experiment with native woody species are presented in Chapter 5. We hypothesized that planted seedlings of native woody pioneers would perform best in open pastures, and that planted seedlings of late-successional shrub and tree species would perform better in shrubland. Additionally, we evaluated the effect of treatments with stones and fertilizer on seedling performance. Moreover, we expected natural succession in the matrix vegetation to be accelerated as an effect of canopy establishment by planted species. Plantation with species mixtures of pioneers, and of late-successional species, were applied in both pastures and shrublands. Seedling performance and matrix vegetation development were monitored from 2000 to 2004. Survival was low for some species, probably caused by drought and night frost. Seedling growth was generally low: pioneer species reached stem heights up to around 1 m, while the late-successional species mostly did not grow significantly. We concluded that pioneer shrubs performed better in pastures than in shrublands. Late-successional species survived better in pastures, but stem growth was higher in shrublands. Stone treatments enhanced survival for most species, while the fertilizer addition increased stem growth for late-successional species. A canopy of planted seedlings was established only with pioneer species planted in pastures. In these plots, species turnover rate did not differ from that of control plots. Hence, changes in species composition were not an effect of the planted canopy. However, total herb cover in these plots did increase as an effect of the plantation. We concluded that succession might indeed be accelerated by a planted canopy, but more time is needed to be able to detect successional changes as an increased turnover, different species composition and invasion of typical late-successional species. It is recommended to use mixtures of pioneer, mid-, and late-successional species in future plantation trials.

Chapter 6 reports on performance of planted seedlings of seven species (a subset of the nine species mentioned before) in the understorey of Acacia decurrens forests. A catalytic effect of exotic tree plantations for natural regeneration, mostly by mitigating soil temperature and humidity fluctuations, has been shown by many authors. However, whether such a plantation is catalytic or not depends on management (disturbance), planted species (possible allelopathic effects), distance to natural forest (seed supply), site degradation (soil properties), and grazing. Consequently there are many examples of hampered understorey development in the tropics. We examined the possibilities for conversion of Acacia decurrens plantations to native Condalia dwarf forests, by inserting native woody species under the planted canopies. Performance of planted seedlings in Acacia forest was compared with that in open secondary vegetation. Moreover, we investigated the effect of site differences, Acacia canopy cover and fertilizer application on seedling performance. Late-successional species generally performed better in Acacia plantations than in open vegetation, while the reverse was true for pioneer shrubs, which had very low survival rates under plantations. We concluded that planting of late-successional Condalia dwarf forest species give good prospects for conversion of Acacia forests into native vegetation.
Conclusions and recommendations

Accelerated succession by means of plantation of woody species could possibly be achieved in the future, but no substantial succession has been shown to occur in the first four years of this project. Other vegetation characteristics of the experimental plots have generally changed very little over the period 2000 – 2004. Both pasture types are still far from similar to the woody vegetation types. Some scrub plots are floristically relatively similar to Condalia dwarf forests, but the vegetation stature of these plots is clearly lower and less dense. Successional changes were probably not linked to any canopy closure of the planted seedling assemblage, but merely to a cattle exclosure effect. The only response that was statistically detected was an increase of total herb cover in the plots planted with a pioneer mixture. However, I expect that, in the coming years, stronger changes will occur in the plantation plots as compared to the unplanted control plots, at least in pastures. Currently, the canopies have reached a cover of up to 20% only and moreover, this cover was achieved only recently. Environmental characteristics might just have started to change, and facilitating conditions might not have been very strong to date. We need monitoring data of microclimate to measure a possible relation between air humidity and species turnover rates.

Apart from environmental effects, understorey development in the study area was limited by propagule supply. The time scale in which a “substantial” turnover will take place thus depends on site characteristics and species traits (reproductive strategy, life history, germination demands, etcetera). Prolonged monitoring of the experimental plots is therefore needed to obtain an idea of the development of Condalia dwarf forest from pastures and from scrubs, either with or without plantation of seedlings. To date, the bulk of the publications addressing plantation of native species for restoration practices have focused on performance of the planted seedlings. To my knowledge, no monitoring data are yet available of pasture development after plantation of woody species, apart from those presented in Chapter 5 of this thesis.

The differences in performance between pioneer species on the one hand, and late-successional species on the other, might be explained by differences in strategies for nutrient uptake and photosynthesis. Although generalizations are very hard to make, it appears that late-successional species are generally more easily affected by desiccation (by declining photosynthetic rates) than pioneers. One might expect that pioneer species take up nutrients relatively easily when the concentration of soluble nutrients is low as compared to late-successional species, and that pioneers might be limited by other nutrients than late-successional species. However, this remains to be investigated for the species of the dwarf forest region, and probably also for the plant species of most other successional seres worldwide.

Further succession-based restoration experiments

Baccharis macrantha – Dodonaea viscosa scrubs seem an essential stage to be passed in the course of vegetation succession towards Condalia dwarf forests. Further plantation exper-
ments in the study area therefore should include *B. macrantha* and *D. viscosa*. In one single plantation effort, seedlings of pioneer shrub and mid/late-successional treelet species could be planted. I would expect that the pioneer shrubs form a relatively closed canopy within five years or so, after which the dwarf forest species start to grow.

Seed dispersal limitation might be overcome by supplying seeds of desired species. Sowing experiments might be carried out for dwarf forest species in scrub types with different overstorey and understorey covers, in order to define a “threshold-scrub type” in which development of dwarf forest species might be successful.

For the conversion of *Acacia* forest into “natural” woody vegetation, planting of *Condalia* dwarf forest species might give promising results. More experiments are needed to determine when the *Acacia* canopy should be thinned or cleared, and to assess the effects of this activity on growth rates of the planted species and vegetation succession. Since *A. decurrens* is able to sprout from roots, the complete eradication might be laborious and should be done repeatedly. In spite of the bad reputation of exotic tree species in plantation efforts—which I do not dispute for *Acacia decurrens* in monocultures—we should perhaps not completely exclude them as candidates in plantation efforts to force an initial jump-start in succession. *A. decurrens* might be applied in the initial phase of catalytic scrub establishment, in a mixture with *B. macrantha, D. viscosa* and some mid- and late-successional dwarf forest species. Since *A. decurrens* is a fast canopy expander and possibly an N-fixer, the plantation might profit from this. Monitoring and management would be needed to control the *Acacias* and thin or remove them at a certain stage.