



Tree improvement

Improving planting material used in forest management and restoration in Rwanda

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The present report has been prepared by CIFOR-ICRAF as part of a study for the World Bank to provide Technical Assistance in Forestry and Rural Development in Rwanda under PROGREEN (https://www.progreen.info/about_page).

The development objective of the study is to support the identification and design of incentive mechanisms and the development of technical readiness for improved landscape management, biodiversity conservation, nature-based solutions, and livelihood development in the Congo-Nile Ridge (CNR) landscape in Rwanda.

The study had four tasks: Review of and recommendations for 1) tree improvement, 2) forest management planning, 3) development planning for biodiversity conservation and tourism development, and 4) developing stakeholders' incentives and appropriate financing mechanisms.

This report is on Task 1. It is composed of a synthesis (the Proposed Tree Improvement Strategy for Rwanda) and three sub-studies (Parts 1–3).

Cover photo: A five-month old seedling of *Markhamia lutea* within a breeding seed orchard in Rwanda, established to provide high-quality tree planting material for forest landscape restoration and broader tree planting. Photo by Fabio Pedercini/CIFOR-ICRAF

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Overall Contents

About the authors **v**

Acknowledgements **v**

Proposed Tree Improvement
Strategy for Rwanda **1**

Synthesis

Part 1. **25**

Priority landscapes for tree-based
restoration in Rwanda

*A spatially explicit approach to
prioritize areas for intervention in
Rwanda*

Part 2. **65**

Selection of a master list of priority
tree species, including some
potential seed sources for tree
improvement in Rwanda

Part 3. **126**

Tree seed sector analysis

*Seed-seedling demand and
certification of seed sources*

About the authors

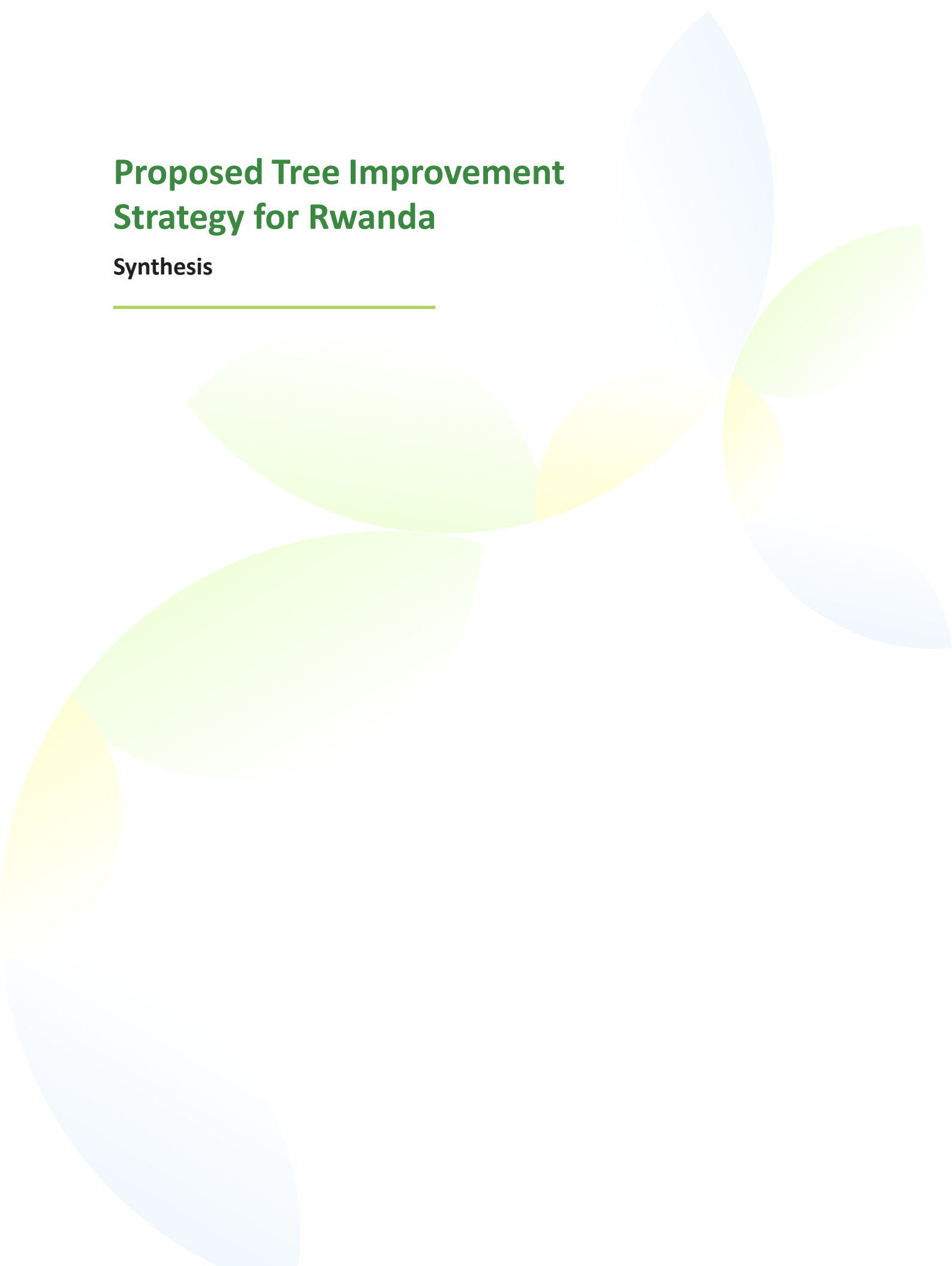
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Proposed Tree Improvement Strategy for Rwanda

Synthesis



Contents

1	Introduction	5
2	The geographical, sectoral and institutional context of a tree improvement strategy	6
2.1	Findings of the studies presented in detail in Parts 1 to 3 of this report	6
2.2	Current support to tree improvement in Rwanda	12
3	Recommendations and elements for a tree improvement programme in Rwanda	14
3.1	Recommendations for a tree improvement programme	14
3.2	Elements and capacity needs of an encompassing tree improvement programme	18
4	Operationalizing the tree improvement programme	19
4.1	Investment requirements for a tree improvement programme	21
4.2	The rationale of the proposed programme	22
	References	24

List of boxes and tables

Boxes

- | | | |
|---|--|----|
| 1 | Well-functioning tree seed and seedlings systems, and the approach of One Acre Fund in Rwanda | 8 |
| 2 | The genetic quality of tree seeds, the OECD Forestry Scheme, guidelines on forestry reproductive materials and tree seed zones | 11 |

Tables

- | | | |
|---|--|----|
| 1 | Indicative implementation plan for improving planting material used in forest management and restoration | 20 |
| 2 | Indicative investments for improving planting material used in forest management and restoration | 21 |

1 Introduction

The objective of the current study is to review and provide recommendations for tree improvement in Rwanda, including identifying potential improvements in the productivity of current privately- and publicly-owned forests, by addressing, among other things, low stocking of existing forests and the poor genetic quality of planting material.

Tree improvement is often used synonymously and narrowly to mean tree breeding, referring to the practices of applying knowledge of genetics to develop genetically improved trees. Here, however, we use the term in a broader sense to mean the practices needed to support the conservation, development, production and delivery of high-quality planting materials of trees in the form of Climate Appropriate Portfolios of Tree Diversity (CAPTD), in support of productive and resilient landscapes (Kindt et al. 2023). This broader view can also be thought of as an integrated strategy for sustainable management of tree genetic resources – or in short form a tree improvement strategy – where sustainable management comprises conservation, improvement and wise use of the genetic diversity of selected priority tree species.

While the management of genetic resources is based on the same principles for all tree species, in the current report we distinguish between exotic and native trees, noting that often much less is known for the latter category. The commercial interests in planting for the two tree categories also often differ.

The synthesis section of this current report – as presented here – summarises the findings of the following studies (or sub-studies) reported in detail in Parts 1 to 3 of the present report. The synthesis first provides context for a tree improvement strategy for Rwanda, based on the findings of the separate studies, and including information on current support. Second, the synthesis provides information on the needs and opportunities for a tree improvement programme, together with the elements it should contain and recommendations on steps to take. Finally, an overall plan for the operationalization of a programme, together with investment requirements, is given. The study focuses on Rwanda's Congo-Nile Ridge (CNR) landscape, but it also provides information that is relevant country-wide.

The three separate sub-studies, compiled here as Parts 1 to 3 of the present report that follow the current synthesis section, cover the following topics:

- Part 1 presents a spatial prioritization of landscapes for restoration interventions, to provide the context for relevant tree improvement contributions to sustainable landscape development;
- Part 2 identifies potential priority tree species for improvement, based on current knowledge of preferences across Rwanda, as well as on the environmental conditions of the CNR landscape in terms of vegetation and climate; and
- Part 3 provides a description and an assessment of the existing tree seed and seedling delivery sector, which a tree improvement strategy should contribute to enhancing.

2 The geographical, sectoral and institutional context of a tree improvement strategy

2.1 Findings of the studies presented in detail in Parts 1 to 3 of this report

2.1.1 Priority areas for restoration

As a tool to inform the development of an action plan for delivering improved genetic material of native and exotic tree species, and to support the design and implementation of an improved landscape management strategy in the CNR landscape of Rwanda, a spatial prioritization of landscapes for tree-based restoration interventions was prepared (see Part 1 following). The prioritization was made based on land suitability, considering current land characteristics (potential natural vegetation, current land cover, unconverted [natural] or converted [typically agriculture] land categories), and eight indicators of restoration value (biodiversity, climate change adaptation, climate change mitigation, market access, land degradation, slope, soil erosion, and tree cover gap). The prioritization led to recommendations for land management interventions, such as conservation, reforestation, enrichment, agroforestry and plantations.

For the CNR landscape, the results of the land prioritization analysis showed that, within the total CNR area, 45 percent of the land – equivalent to about 1,900 square kilometres – was of priority for tree-based restoration in the converted land domain. This land is dominated by agricultural landscapes, peri-urban areas and commercial plantations. In this context, the focus for restoration efforts is on active interventions to restore and enhance ecology. Possible interventions are agroforestry, improved management of small- to large-scale plantations, silvopastoralism and urban forestry. The goal of these interventions is to foster an improved balance between human needs and environmental conservation, by promoting sustainable land-use practices and preserving ecosystem services. A prerequisite for interventions to be successful is the availability and delivery of high-quality tree planting materials, in the form of Climate Appropriate Portfolios of Tree Diversity (CAPTD; see Kindt et al. 2023).

Additionally, 14 percent of the CNR land area – equivalent to around 600 square kilometres – was identified as of priority for interventions in the unconverted land domain. These areas are in natural or semi-natural landscapes, such as forests or other relatively untouched ecosystems (such as Gishwati-Mukura and Nyungwe national parks), which are showing signs of degradation and disturbance. Here, restoration should focus on approaches such as assisted natural regeneration and enrichment planting, relying on the availability of adequate sources of tree seeds for natural regeneration, and/or the provision of CAPTD (in the latter case, implementing the CAPTD approach as with prioritized converted land areas). The aim of promoting such interventions is to accelerate the recovery of degrading patches of natural ecosystems, while also promoting participation and a sense of ownership in the conservation of protected areas within local communities.

The remaining 41 percent of the CNR region falls within the ‘low priority’ category, either in converted or unconverted landscapes.

The key finding of the current analysis of areas for landscape restoration is: In the CNR landscape, 1,900 and 600 square kilometres of converted and unconverted lands, respectively, are identified as priorities for landscape restoration. Based on the use of the multi-indicator approach applied in the current study, and framed within a national-level analysis, the CNR landscape is identified as a hotspot for tree-based planting interventions in Rwanda. Forty-five percent of the CNR landscape area, which is equivalent to 1,900 square kilometres, was identified as priority converted land for tree-based landscape restoration, while another 14 percent of the CNR landscape area – equivalent to around 600 square kilometres – was identified as priority unconverted land for tree-based landscape restoration.

2.1.2 Priority tree species for planting

To identify priority tree species for use in planting interventions, analyses based on information on users' preferences documented by projects across Rwanda, and based on information on the environmental and climate suitability of species, were undertaken, and were complemented by the mapping of all known information on specific seed sources (see Part 2 following). Ninety tree species (52 native and 38 exotic to Rwanda) from an initial total of 458 species (267 native and 191 exotic) were identified as candidates for possible improvement, and a baseline tree seed source register (including 183 seed sources of 32 species) was prepared, noting that very few of these seed sources are of adequate (known) quality. The attributes of the prioritized species were described from different sources of information, and their suitabilities for climate zones in the western region of Rwanda (the CNR landscape) were identified.

The key finding of the analyses of priority species is: Ninety tree species are identified on a 'long list' of priorities for planting, but the seed sources available to support the planting of these species are limited. This initial list of prioritized trees was composed about equally of native and exotic tree species to Rwanda. Of the initially prioritized species, only 32 were identified as having known national seed sources, with 183 seed sources indicated in total for the species. Among these seed sources, only 17 were of native trees, covering nine species, which indicates a lack of diversity in the availability of native tree species sources. Most of these identified native tree seed sources were also of unknown genetic quality, and the use of the sources was poorly documented. Together, these observations indicate insufficient attention to genetic quality, and sub-optimal tree planting.

2.1.3 Assessment of the tree seed and seedling delivery sector

Through a combined desktop review and key stakeholder interviews, the current use of tree planting materials was documented (see Part 3 following). Key findings are summarized below.

Findings on the scale of seedling raising:

A Rwanda Forestry Authority (RFA) seedling survey of expected production for 2023 provided useful information on seedling numbers across the districts of Rwanda and the different organizations involved (no information on species compositions was however available for the present study). A desktop review of organizations active in tree planting in Rwanda identified 64 organizations, including ones identified in the RFA seedling survey. One Acre Fund is the most prominent tree planter in Rwanda, with seedling production dominated by the exotic *Grevillea robusta*.

The key finding on tree nursery production is: The RFA survey for 2023 indicated an expected total production of 57 million tree seedlings across the country. Considering the districts of Western Province specifically, seedling commitments were generally higher for the districts in the southern part of the province than elsewhere. According to the 2023 survey, Rutsiro District, in the centre-north part of Western Province, had the lowest number of seedlings in nurseries for any district in Rwanda as a whole, which may indicate a particular gap in production capacity.

The key finding on species diversity in seedling production is: Most seedling production in Rwanda's tree nurseries is of a limited range of exotic tree species. Taking the example of One Acre Fund (see Box 1), its records indicate that with a production of more than 20 million seedlings annually, it is responsible for around one-third of all currently documented tree seedling production in Rwanda. Most of the seedlings it produces, however, are of exotic trees, with the exotic *Grevillea robusta* (grevillea) responsible for over three-quarters of its total production in 2022. Assuming that the data of One Acre Fund are representative of the types of tree seedlings being raised by other tree nurseries in Rwanda, it is evident that only a low diversity of tree species is being promoted through tree nurseries in the country, with only a limited supply of native tree species seedlings being generated for planting.

The key finding on the geographical distribution of tree planting is: Current tree planting programmes are broadly spread across Rwanda. A desktop review of 191 documents revealed a total of 64 projects or programmes in Rwanda containing a tree planting component. Coverage was relatively broad across Rwanda, with 217 operational sites identified. Taking the case of One Acre Fund (see Box 1), it is active in 27 of Rwanda's 30 districts. These observations indicate an underlying geographically widespread institutional capacity across Rwanda that it should be possible to build on for scaling tree planting.

Findings on the roles of stakeholders and the structure of the sector:

Box 1. Well-functioning tree seed and seedlings systems, and the approach of One Acre Fund in Rwanda

A well-functioning tree seed and seedling system provides high-quality planting material to tree planters. Such a system must be based on four pillars: (i) rules and regulations that support the development of a thriving input supply industry of seed and seedling producers who compete to produce the best possible genetic quality planting material, based (ii) on sustainable management of genetic resources of trees in a network of documented seed sources with guidelines on seed source-to-site matching. The input supply system must be governed by knowledge about genetic quality and the availability of seedlings of the demanded seed sources such that (iii) the effective demand by smallholder farmers can be satisfied by (iv) an effective supply of seed and seedlings.

Considerable investments in tree planting have been made through a broad range of sustainable land management projects across Rwanda. New investments from the World Bank, amongst others, will also stimulate significant demand for tree seed production in the CNR landscape. The role of large projects that drive tree planting (with a strong focus on native species) also needs to be considered when developing a suitable planting strategy.

The main customers of the tree seed and seedling sector in Rwanda are widely dispersed smallholder farmers who individually demand relatively small quantities of seeds and seedlings, but collectively require large quantities. The main entities in efficient production and distribution networks for seeds of exotic tree species – which are small and medium enterprises – will be relatively decentralized to efficiently cater for the demand. The demand from smallholder farmers will predominantly be quality planting material for known varieties of fruit trees, particularly mango and avocado; and exotic wood-producing species, typically eucalypt species and grevillea. Immediate seed sources for these exotics can be identified in farmlands and in plantations, and decentralized production and distribution could be supported. Quality vegetative planting materials – scions and rootstocks – of fruit tree varieties are well known and are already produced in orchards across the country. This production could possibly be further decentralized.

The situation is different for native tree species. The Rwandan National Tree Seed Centre (NTSC) should obtain permission from protected area authorities to identify and document seed sources in remaining natural forests in the humid highlands. The NTSC should also support standards for seed collection, such as the minimum number of trees to sample from sources. Many of the tree species will have desiccation-sensitive seeds. These need to be distributed almost immediately to tree planting projects, as they cannot be stored for any period of time by the NTSC. Meeting supply and demand for native tree species therefore requires a well-developed information and distribution system, which links supply from somewhat centrally controlled collections with the demand of many geographically-distributed planters.

continued on next page

Box 1. Continued

It is commonly observed in Africa (including Rwanda) that governments and NGOs favour centralized tree seedling nurseries at the expense of small private nurseries (Holtne 2012; Lillesø and Derero 2019; Lillesø 2020). However, information from One Acre Fund in Rwanda, with its current one-third of all tree nursery production in the country, on its current nursery production strategy is pertinent in indicating alternatives. Although the Fund has four central nurseries for fruit tree seedling production, most seedlings will be produced in decentralized nurseries. The expected production in 2023 of over 20 million tree seedlings was predicted to come from 1,847 decentralized nurseries across 27 districts – which equates to a mean of around 11,000 seedlings per nursery (One Acre Fund, email to present report authors of 12 September 2023). This approach provides a model for the development of a decentralized network of a more extensive range of seed and seedling sources (interview with One Acre Fund in 2023). One Acre Fund intends that, after a start-up phase, the small-scale nurseries they support will become financially independent.

One Acre Fund's nursery network could be the backbone for developing the other services that can support the production, distribution and management of high genetic quality tree seeds and seedlings; for supporting networks of tree seed source custodians managing and producing quality seed; and for enhancing information and distribution networks that inform on the demand for, and the availability of seeds and seedlings of, particular tree species. A key present impediment to the development of such networks, however, is the stipulation by Rwanda's Forest Reproductive Materials Guidelines (FRM Guidelines 2018) that all tree seed production and distribution in the country is the sole responsibility of the NTSC.

The Rwandan NTSC is the only authorized tree seed seller in Rwanda, currently working with 10 seed cooperatives in the collection of seed. In the years 2016–2019, the NTSC sold seeds of 55 species, of which the top 10 were all exotics. Very few of the 183 seed sources registered (see above) can be considered suitable for immediate use, and may not be utilized as a source of seed by the seed cooperatives authorized to collect seed for the NTSCs. The remaining natural populations of native tree species in Rwanda occur in protected areas, but the NTSC has not documented and registered any seed sources of native species in these areas. Formally, the seed cooperatives do not have access to collect such seeds.

While several of the 183 noted sources could be utilized, there is little or no documentation with respect to their genetic quality, and most sources are distant from seed cooperative locations. Therefore, there is no assurance for the seed sources producing seed that the seed is better than from collections elsewhere in agroforestry landscapes. The seed cooperatives have limited access to transportation, and interviews with them therefore unsurprisingly indicate that they collect from trees available in agroforestry landscapes in the vicinity of their respective locations. In summary, logistically it is difficult for the cooperatives to collect from currently registered seed sources.

The key finding on seed supply from the NTSC is: Most of the seed supplied by the NTSC is of exotic trees. The 2016 to 2019 records of the NTSC indicated the sale of seed of 55 tree species, with this seed originally being sourced both nationally and globally. Of the 55 species, the top 10 distributed in terms of seed numbers (as estimated by seed weight conversions) were all exotic trees. The top three ranked species by seed number were all eucalypts, the fourth ranking was *Alnus acuminata*, and the fifth was grevillea. Considering that the NTSC is the only authorized tree seed seller in Rwanda, these data support tree nursery observations (see above) that a relatively narrow range of tree species, mostly exotics, dominate tree planting in the country.

The current National Tree Reproductive Materials Strategy (National TRM Strategy 2018) lists many strengths and weaknesses in tree seed and seedling systems in Rwanda, amongst which the lack of availability and quality of seed sources, and the absence of production and distribution channels, are particularly important challenges that have been insufficiently addressed. The present strategy suggests a degree of privatization of seed production and distribution to improve efficiency. The main thrust is based on “massive production” by clonal reproduction of high-quality seedlings from imported exotic tree reproductive materials. The assumption is that the future production of seeds from newly planted seed stands, and of clonal materials from clone banks, will be carried out by private producers.

The key finding on private sector engagement is: To date there has been limited private sector involvement in tree seed supply in Rwanda. Further ongoing assessment of the tree seed and seedling sector in Rwanda in work coordinated by CIFOR-ICRAF has involved review of the Government of Rwanda’s current National TRM Strategy, and broader sectoral assessment. As part of the sectoral assessment, the current roles of stakeholders in the sector have been analysed. An important group of stakeholders are the seed cooperatives that sell seed to the NTSC for onward sale. These cooperatives are not authorized to sell seed directly to tree nurseries in what would be a more decentralized and potentially more sustainable and scalable model of tree seed supply. Overall, the sectoral assessment shows that there has been limited implementation of private sector involvement in tree seed supply, despite the National TRM Strategy making provision for this. This hinders the development of a sustainable tree seed and seedling sector in the country. The National TRM strategy, and the action plans derived from it, are currently being revised by the Government of Rwanda, and this will provide opportunities to make changes to the strategy and action plans to support private sector involvement, as well as to introduce other changes that support the tree seed and seedling sector.

However, production of tree seed from newly-planted seed stands will take several years, even for eucalypts, and development of adapted clones will have to be proven by trials in Rwanda before “massive production” can produce reliably superior material. Lillesø et al. (2018) described such a case in Vietnam, where domestication of acacias involved around 30 years of collaboration and funding from government organizations in the country and in Australia. Once improved material had been identified through trials, improved access to quality-attested, genetically-improved planting materials at affordable cost were provided through a network of local seed production areas, nursery hedge gardens and tissue culture laboratories.

The acacia case in Vietnam is one of a few examples where smallholder industrial plantation forestry has been a major success. For Rwanda, it is important to highlight that the privatized tree reproductive material input supply system envisioned by the National TRM strategy can only materialize several years after superior material becomes first available in Rwanda. While such efforts are important, it is also imperative to deal with the immediate short-term need for reproductive materials. As discussed above, an important element of this is the need to focus on many more species than those that can be clonally reproduced for industrial forestry purposes.

The current practice by the NTSC/seed cooperatives in Rwanda is to collect from tree seed sources of unknown genetic quality, and to transport the collected seed to the NTSC, which controls seed physiological quality but not genetic quality. For these tree seeds, at issue is how much – and through what mechanism – the NTSC can delegate responsibilities of tree seed production and distribution. The current system has limited documentation of the genetic quality of tree seed sources that can be controlled by the NTSC. However, with the required documentation of seed sources to ensure genetic quality, it may be difficult for the NTSC to manage a very large number of seed sources in the future. On the other hand, a network of documented seed sources would make it possible for the NTSC to oversee a more decentralized production and distribution system. Thus, a delegation of responsibilities may help the NTSC in ensuring genetic quality. The NTSC could achieve this by documenting (immediate) seed sources in farmland, natural forest and plantations. The seed cooperatives working with the NTSC could then be allowed to sell seed directly from seed they have collected from NTSC-approved seed sources managed by seed source custodians.

The recognition of genetic quality in Rwanda is based on the OECD Forestry Scheme (OECD 2022), which is only in part of relevance for the tree seed and seedling sector in the country (see information on the OECD scheme and further context in Box 2).

Box 2. The genetic quality of tree seeds, the OECD Forestry Scheme, guidelines on forestry reproductive materials and tree seed zones

OECD and forestry reproductive material guidelines

In Rwanda, recognition of the genetic quality of trees is embedded in the guidelines on forestry reproductive materials (FRM Guidelines 2018), which are based on the OECD Forestry Scheme (OECD 2022). However, it is important to take into consideration that the OECD scheme is more relevant for temperate forestry than it is for the tropics, with limitations for example when it is applied to agroforestry plantings in East Africa. The basic assumption in the OECD rules is that planted forests consist of large areas of even-aged, mono-species plantations, and this informs the classification of seed sources through the assumption that genetically superior trees can be selected in such homogenous stands.

In Rwanda's FRM Guidelines (2018), farmland seed sources are not defined, and for species in natural vegetation, the seed source is classed as "Region of Provenance" ("*Seed Sources are only ever registered at region of provenance level [or for native species at seed zone level]*"; FRM Guidelines 2018, p. 6). "There are no selection criteria relating to the quality of the Basic Material for source-identified FRM. The only restriction is that the collection must be made within the boundaries of a single region of provenance or seed zone. However, collection can take place at more than one site. Entries for Seed Sources in the National FRM Register will only be described at the region of provenance level, and in addition, by seed zone for indigenous species" (FRM Guidelines 2018, p. 6).

In contrast, "Stands are the only type of Basic Material which may be registered for seed production in the category Selected" (FRM Guidelines 2018, p. 10). Approval of basic material in this category implies that the stand shows visual superiority in important characteristics. In practice, this means that only seed sources of exotic tree species (for example of eucalypts) need to be described in Rwanda. Considering that native tree species are high on the agenda for forest landscape restoration in Rwanda, however, sources of native species need to be described in sufficient detail to ensure their genetic quality.

The OECD Scheme and Rwanda's FRM guidelines (2018) do not include a classification that can describe farmland and natural vegetation sources of tree seeds in a meaningful way. Farmland and natural vegetation sources can be described using specific quality criteria including the overall condition of the stand and the potential for the outcrossing pollination needed to effectively produce seed. Probably many of the utilized sources for exotic species could also be described as farmland seed sources (see Appendix 6 in Part 3 for a brief deliberation on definitions of tree seed sources and compliance with the OECD Scheme).

For farmland and natural vegetation sources, agreements should be made with the seed source custodians, including on incentives for maintaining and managing the trees for seed production, building on models for community participation in sustainable conservation that are already practiced in Rwanda (Umuziranenge 2019). Collection from protected areas will require clear guidelines on how seed cooperatives can be delegated authority by RFA, RDB and REMA to do so.

It is notable that while five African countries (Burkina Faso, Kenya, Madagascar, Rwanda and Uganda) are members of the OECD Scheme, only Kenya has frequently participated in OECD technical meetings. Consequently, African countries have had minimal influence on the development of the OECD rules (personal observations by J-PB Lillesø, who has participated in and followed the development of the OECD Scheme over the last 15 years). With greater participation of African countries, the rules could be better adapted to the continent's tree seed systems.

continued on next page

Box 2. Continued**Tree seed zones**

The genetic quality of seed for both annual crops and trees largely determines the yield and product quality of resultant plants. For annual crops, the growing conditions can to some extent be manipulated during the short growing season. In contrast, trees must stay in place for many years, and the role of the planting environment is more important than for agricultural crops. Relevant issues for genetic quality for trees were summarized by Lillesø (2020) with reference to information collected over the last 50 years. An important aspect of high genetic quality for a planted tree is that the seed source is well matched to the planting site. Doing this matching requires an understanding of the patterns of adaptation to environment in a tree species' distribution. Fundamental to such an understanding are provenance tests and common garden trials conducted over a range of conditions. These have demonstrated that different tree seed sources vary in relative performance when evaluated in different environments, and that they often, but not always, do this in a predictable manner. Such trials are an integral part of the tree improvement programme that RFA implements in Rwanda together with CIFOR-ICRAF.

The genetic quality of tree seed sources therefore depends on reliable matching with the target environment. Under the OECD Scheme, Region of Provenance, where the reproductive material is collected, will be delineated by the designated authority in the manner described in Rule 2 (OECD 2022).

2.2 Current support to tree improvement in Rwanda

An incipient tree improvement programme for Rwanda's Eastern Province has been initiated within the framework of the Transforming Eastern Province through Adaptation project (TREPA), which is a Green Climate Fund (GCF) initiative for the Eastern Province of Rwanda that runs between 2021 and 2027 (<https://www.greenclimate.fund/project/fp167>). The tree improvement activities of TREPA ('enhancing tree seed and seedling supply to provide diverse and climate adapted species and varieties within the framework of TREPA 2022–2027' – TREPA Tree Seed) cover policy support, the development of decision-support tools, tree breeding, and capacity enhancement of the tree seed and seedling sector, focusing on Rwanda's Eastern Region. The total GCF investment for this tree improvement programme, including technical assistance, amounts to USD 2.3 million.

A similar programme for the Western Region has recently been launched with support from the Bezos Earth Fund for 2024 to 2026 in the project entitled Strengthening Expertise in Production of Quality Tree Seed and Seedlings to Accelerate Landscape Restoration and Conservation in Africa's Rusizi Basin and The Great Rift Valley project (QT-Seed). The inception of this project in Rwanda was initiated in the second quarter of 2024. The investment of this programme in Rwanda, including technical assistance, amounts to approximately USD 1.4 million.

A multi-country regional programme supported by Germany (IKI) for the period 2024 to 2029 entitled The Right Tree in the Right Place-Seed project (RTRP-Seed) is concerned with supplying high-quality tree planting material of native tree species for landscape restoration in sub-Saharan Africa, and includes Rwanda as one of the implementing nations. The investment of this programme in Rwanda amounts to approximately USD 2.3 million.

The above three projects are all being implemented in collaboration with RFA, and will all contribute to establishing a stronger tree improvement programme in Rwanda in the next 5 years. However, the investments are not adequate to develop and sustain a nationwide programme to service the restoration, conservation and development needs of the country in the medium to longer term. Investment requirements, operationalization and rationale are outlined in more detail in the following sections.

The strengthening of tree improvement in Rwanda will contribute to enhancing the impact of other investments in the natural resource management sector, such as the Forest Investment Programme: Development of Agroforestry for Sustainable Agriculture (FIP-PRODAR) (RFA; ADB 2023; FIP 2023). Landscape restoration projects can contribute by demanding high genetic quality tree seeds from documented sources and by supporting input supply chains (seed source owners – seed collectors – nursery managers) that promote the genetic quality of tree seeds and seedlings.

3 Recommendations and elements for a tree improvement programme in Rwanda

3.1 Recommendations for a tree improvement programme

3.1.1 Priority areas for restoration

An approach for identifying priority areas for tree-based restoration is documented in the present report (see Part 1 following). Priority indicator layers for where action is recommended can be made available through online digital libraries (e.g., Zenodo), and be used to create an online decision-support tool to facilitate access and utilization by practitioners and project managers. When combined with an online platform of ‘what to plant where’, this could be used by implementers to identify climate appropriate species and seed sources (corresponding to a similar tool developed by CIFOR-ICRAF for Ethiopia and already in development for Eastern Rwanda specifically). Such tools can empower users to improve the quality of their demand, and nurseries to provide an adequate supply, provided that issues of diversity and quality in current tree seed supply are addressed.

The identification of: priority landscapes for restoration; priority types of land management interventions; priority tree species and their potential seed sources; nursery sector organization and infrastructure; tree seed sector organization and infrastructure; and forest management and biodiversity priorities (as addressed in parallel reports to this one), will, in combination, provide for the identification and operationalization of CAPTD for productive and resilient landscapes (Kindt et al. 2023), which will involve the implementation of a national tree improvement strategy (Hendre et al. 2022).

The first key recommendation (R1) on improving tree planting material is: A multi-indicator spatially-based approach for identifying priority locations for landscape restoration should be applied to Rwanda in combination with a community-based assessment of restoration priorities. The multi-indicator approach for priority setting applied in the present study (Part 1 ahead) is a useful systematic method to identify priority areas for tree planting interventions in the CNR landscape. These interventions should be based on agroforestry, diverse plantations and silvo-pastoralism in priority converted landscapes; and enrichment planting and assisted natural regeneration in priority unconverted landscapes. The findings of the current approach to priority setting should be presented in an open access, digital decision-support tool on prioritized land areas that has previously been unavailable for Rwanda, and the spatial indicators used should be further adjusted to embrace a greater range of socioeconomic variables. A multi-indicator spatial approach is however clearly insufficient in itself for guiding priority locations for tree planting-based interventions. To further guide location priorities and planting options, additional work should combine the current ‘desk-based’ multi-indicator spatial approach with findings from community-based approaches for setting restoration priorities. By defining priority areas for intervention, key locations for establishing tree seed and seedling delivery infrastructure will also be determined. An additional factor, not considered in the current analysis, is how targeted areas for landscape restoration support connectivity between existing natural forest blocks in the regional landscape. Future spatial modelling could take this factor into account by looking to minimize ‘travel times’ through intervening landscapes, by focusing on locations capable of supporting similar vegetation types to the areas being connected. This would support strategic regional conservation.

3.1.2 Priority tree species for planting

A key requirement for an effective tree seed sector is the provision of ‘know-how’ in the form of lists, maps, apps and guidelines on what species and seed sources to plant where, and how. Such resources

will inform national and local decision making in the context-appropriate planting of species well matched to planting site and purpose, and their conservation.

Current tree seed supply systems focus on relatively few species that are insufficient to serve restoration efforts, and fail to account for diverse users' preferences, the importance of biodiversity, and the provision of broad ecological services. Relevant institutions and communities need to identify, document, collect, propagate, improve and multiply diverse tree seed sources of priority species. Such sources will be both for immediate use and for establishing additional diverse sources for the future, constituting a diverse multi-species tree breeding *cum* conservation programme.

A second key recommendation (R2) on improving tree planting material is: The preliminary 'long list' of priority tree species identified for planting in the current study should be further prioritized with local communities, and suitable seed sources determined or established for final species choices. Tree planting in the CNR landscape should take the preliminary list of 90 prioritized species identified in the present study (Part 2 ahead) as a starting point for consultation with local communities, including local businesses, to establish final priorities for specific locations. This is in order to align priorities fully with community needs, and support focused action. For the majority of the trees on the current preliminary priority species list, current findings indicate a lack of well documented, high-quality seed sources. Therefore, after community prioritization, efforts are needed to define, register and (where necessary) establish suitable seed sources for the final species choices. It is recommended that this should be done in collaboration with the existing tree seed cooperatives currently working with the NTSC to support tree seed supply. The approach used to define the seed sources should be based on five defined categories of source that allow an assessment of source quality and availability, and help direct sub-sectoral interventions, as follows: seed from natural tree stands; seed from farmland trees; seed from plantation trees; seed from seed orchard trees; and, finally, clonally propagated 'seed' (in fact, vegetative propagules rather than seed) from mother block trees (these five sources are described by Lillesø et al. 2024). In addition to defining and establishing seed sources for tree species on the final priority list, the development of propagation and field management methods should be undertaken where these are not yet available.

Many small-scale private informal sector tree seed suppliers and nurseries exist in rural areas (Part 3 ahead). However, they often focus on exotic species, and lack both knowledge about native species and enough demand for these species to consider supplying them as alternatives. If they are to reach the level of activity needed to properly support current restoration commitments, they need to be 'networked' at landscape scale with each other and with seed source custodians and customers.

The protected areas of the CNR region contain remaining populations of native tree species that could function as sources of tree reproductive material. Therefore, seed sources and local seed source custodians should be identified and documented in the protected areas, to enable the sourcing of high-quality seeds for propagation of native tree species. Furthermore, seed production of native species should be supported by information networks on the demand from tree planting projects, to ensure timely delivery of seeds directly to nurseries.

A third key recommendation (R3) on improving tree planting material is: Native tree species should receive greater promotion attention for planting in the CNR landscape to better reach landscape restoration goals. Although exotics trees will continue to have an important role in the supply of tree products such as timber, a move away from the dominance of exotic tree planting in Rwanda is recommended to better meet biodiversity and broader landscape restoration goals. In support of this, tree seed sourcing interventions should focus especially on promoting the availability of native tree species by identifying, mapping and developing native tree seed sources. In the case of planting in the CNR landscape, particular attention should be given to developing natural populations of native tree species still remaining in the unconverted parts of the landscape as seed sources. The use of native trees for planting also requires considerable effort in developing protocols for tree propagation and management, and in sharing these methods and the building of capacity in their use. These activities should therefore also be priorities. Specific skills gaps that need to be addressed in order to enhance seed supply for native tree species in Rwanda have already been identified

in a training needs assessment, and the measures that have already been outlined to address these gaps should be referred to and supported (Ouedraogo et al. 2024).

The knowledge of tree seed centres and researchers on sourcing and managing seeds and seedlings of native tree species needs to be integrated into existing seed supply and nursery infrastructure. Establishment of pilot training nurseries in important restoration areas, raising a diverse range of species, is an important means of sharing theory and practice widely at the nursery operator level. Such pilot model nurseries can assist to provide for broader upgrades in nursery seedling-raising practice and in business development.

3.1.3 The TRM Strategy and stakeholder engagement

The state of the natural resource base points at several investment needs and opportunities. The need to diversify current tree-based systems (see Parts 1 and 2 following, as well as parallel studies) indicates that the tree seed and seedling sector must be transformed to accommodate the planting of a much larger number of tree species than now.

The tree seed and seedling baseline survey (Part 3 following) shows that using a central overview of the number of seedlings planted by species would enable the NTSC to plan for the needed seed production from seed sources. Approved seed sources should be described in a way that enables evaluation of their genetical quality, such that they can be included in a public certification system of seed sources.

An approach that would describe the seed sources in an easily understandable way, that at the same time is compatible with internationally accepted rules for genetic quality, is recommended.

An updated National TRM Strategy for Rwanda should clearly define genetic quality (seed sources) as the cornerstone of tree seed and seedling systems.

It is recommended to build the updated National TRM Strategy on two sets of seed sources: (i) immediate sources in natural forests, farmlands and plantations. Combined, such sources will cover both native and exotic tree species, and documentation of genetic quality will ensure that the sources deliver the best possible genetic quality for these source types and (ii) future sources, including seed orchards and mother blocks. In the genetic improvement programme that RFA has initiated with CIFOR-ICRAF as part of ongoing projects, these stands include 'Breeding Seed Orchards (BSOs)' to breed priority native and exotic species and 'Bulk Breeding Seed Orchards' (also called 'Seedling Seed Orchards' and 'Seed Production Areas') for mass production with genetic gain. The stands also include 'Mother Orchards' (or 'Mother Blocks') of selected clonal materials of fruit trees and commodity crops (for example, of mango, avocado, coffee and tea).

The current organization of the tree seed and seedling is sub-optimal (refer to Part 3 following), and criteria for genetic quality for reproductive material are absent, except for exotic fruit trees and commodity crops. A strategy must be based on a consensus of how to organize the tree seed and seedling sector in a way that leads to more efficient production and distribution of quality planting materials.

The technical and organizational issues and opportunities are intertwined, and a tree reproductive material strategy must therefore be built in collaboration with the necessary actors brought to consensus on how to organize the sector.

The approach by One Acre Fund holds promise for widely distributed, small-scale entrepreneurial tree seedling production across the country, which could be supported by decentralized production and distribution chains for the immediate production of seeds. (The One Acre Fund approach was presented in Box 1, above.)

A fourth key recommendation (R4) on improving tree planting material is: The Government of Rwanda's ongoing revisions of the National Tree Reproductive Materials Strategy and associated action plans should fully implement commercial stakeholder involvement in tree seed and seedling delivery. During the revision of the National TRM Strategy and associated action plans, it is recommended that a more

equitable environment for the different stakeholders involved in tree seed and seedling supply in Rwanda is supported. Instead of the NTSC having the major role in direct tree seed provision, it is recommended that it focuses on quality-assurance, initial seed sourcing and technical guidance for other stakeholders, including the private sector, to produce most of the tree seeds and seedlings for planting. A particular focus should be on supporting relatively decentralized small and medium enterprises that can reach growers more easily with planting materials. To enhance the role of these enterprises, it is recommended that the Government of Rwanda test models for their involvement in the sector with the collaboration of One Acre Fund. This is because One Acre Fund supports a large number of decentralized nurseries across Rwanda, and already has plans in place to support the commercial development of these nurseries. Once the new National TRM Strategy and action plans are in place, it is recommended that detailed planning and implementation should be supported by a stakeholder engagement platform, where roles and responsibilities among stakeholders in the sector are further discussed, and actions are aligned.

3.1.4 Guidelines for the use of seed sources

As indicated already, significant support for tree improvement is ongoing in parts of Rwanda. To build on this momentum and guide future investments, the National TRM Strategy has the potential to serve as an overarching national policy and plan for tree improvement. Such a framework would support the sustainable use of seed sources for all types of tree planting. The term ‘seed sources’ is used broadly to include both seed and seedling origins, encompassing clonally propagated materials as well.

The National TRM Strategy should be complemented with additional guidelines for the use of seed sources. A key element of this enhancement is the introduction of a formal seed source quality certification scheme. This scheme should accommodate a multi-species programme that promotes both conservation and production, addressing a much larger number of species than is currently covered.

The certification scheme should include two categories of seed sources: (i) immediate sources of priority native and exotic tree species found in natural forests, farmlands and plantations; and (ii) future sources developed through genetic improvement programmes initiated by RFA. These include long-term breeding of priority species for mass production, using seed orchards and clonal material from mother orchards of fruit trees and commodity crops (see text above for further description of these sources).

To ensure effective use, the certification scheme must provide guidance through decision-support tools, helping determine which species and seed sources are appropriate for specific landscapes and functions. This guidance must be based on verified assessment, approval and certification using recognized standards, and should be communicated through a national registry of certified seed sources.

Implementation requires the establishment of an independent technical committee responsible for the certification and registration process. Meeting current and future demands for tree planting also depends on the physical mobilization of seed sources. This entails the intensified identification and protection of immediate seed sources across the country, including within protected areas, especially for priority species for planting (considering the species list identified in the current study). It also requires scaling up the establishment of BSOs and Mother Blocks to serve as future sources.

The scheme should support the availability of high-quality tree planting materials through appropriate policies, partnerships, supply models and integrated conservation strategies. Strengthening the normative role of the NTSC, as well as fostering the active involvement of seed source custodians and users, is essential.

A fifth key recommendation (R5) on improving tree planting material is: The National Tree Reproductive Material Strategy should be complemented with additional guidelines for the use of seed sources.

To enhance the quality and sustainability of seed sourcing, a formal, multi-species seed source quality certification scheme should be introduced. This scheme must encompass both immediate and future seed sources, with a strong focus on genetic improvement. To support informed decision making,

the development and dissemination of decision-support tools will be essential, guiding the selection of species and seed sources based on landscape functionality. Certification should rely on verified assessments grounded in internationally recognized criteria, and be backed by a national registry of certified seed sources. An independent technical committee should be established to oversee the certification and registration processes. Additionally, efforts to identify and protect immediate seed sources, particularly those within protected areas and involving priority species, should be intensified. The establishment of BSOs and Mother Blocks must be expanded to secure future seed supply. Strengthening the role and across-province presence of the NTSC will further reinforce the system. Capacity building in seed source quality should be prioritized across seed cooperatives, custodians, nurseries, tree planters and support organizations operating in various sectors. Finally, fostering collaboration and knowledge exchange through information-sharing and engagement networks among stakeholders is vital for promoting the use of high-quality seed sources.

3.2 Elements and capacity needs of an encompassing tree improvement programme

The establishment of an encompassing tree improvement programme is a long-term venture. Short- and medium-term (2–5 years) quality improvements can be achieved via a better enabling environment; an immediate effort to provide quality seed sources efficiently linked to the nursery and planting sectors; and a massive training and communication programme, while an investment in a multi-species combined breeding and conservation programme will bring huge returns in the longer term (5–15 years). To reap the full benefits of investing in such a programme, the timeframe should be no less than 15 years. While here we present initial investment options for five years, we recommend that in the near term an investment plan for three consecutive 5-year periods be prepared.

A tree improvement strategy leading to an encompassing tree improvement programme needs to consider five elements: the current ‘enabling’ institutional and policy framework; the knowledge and know-how on management of tree genetic resources that is available; current availability of species and seed sources, and sources of vegetative propagules; the capacity of suppliers of tree seed; and the capacity of the nursery sector.

The enabling institutional and policy framework refers to the tree seed and seedling sector itself as well as the ‘larger’ sectors it is going to serve, such as forestry, agroforestry, agriculture, horticulture, environmental protection and biodiversity conservation. These, in combination, largely define the demand for tree seeds and seedlings that the tree seed and seedling sector should meet.

The proper role of the tree seed and seedling sector in supplying quality seeds and seedlings for planting involves, first, the ‘productive’ function of providing good tree seeds and seedlings; and second, the application of appropriate ‘normative’ functions that guide and monitor planting material distribution. High functionality requires efficient linkages and careful role allocation between the different stakeholders involved from the public and private, and formal and informal, sectors. A tree seed network or a stakeholder engagement platform can provide for such linkages, information sharing and collaboration.

Current capacity to meet the challenges of improving quality and diversity in mass propagation is insufficient in Rwanda and needs to be strengthened. A substantial training and education programme for formal and informal tree seed and nursery system actors is required, as well as support to develop and enhance facilities and institutions (tree seed centres/‘nodes’), including the production and dissemination of training and extension materials (also refer to parallel studies to the present one). A training needs assessment undertaken for TREPA in 2023 and 2024 (Ouedraogo et al. 2024) provided 13 priorities for skills development. Nine of these are related to the NTSC and ‘similar’ partner institutions, and four are related to the seed cooperatives. Several of the NTSC recommendations relate to skills development in support of the seed cooperatives.

4 Operationalizing the tree improvement programme

Operationalizing the tree improvement programme will consist of implementing the five elements recommended above as part of an encompassing strategy:

1. Creating an enabling institutional and policy environment
2. Mobilizing and providing knowledge and know-how
3. Mobilizing and building tree genetic resources for tree planting, including tree breeding
4. Capacity development of the tree seed sub-sector
5. Capacity development of the nursery sub-sector

Some of the elements are currently being supported by the three projects mentioned above (TREPA, QT-Seed and RTRP-Seed). Further operationalization would need to be coordinated and aligned with these ongoing efforts.

For the purpose of operationalization, the five elements can be subdivided into specific activities for implementation (Table 1). Action already underway as part of ongoing support varies in. The extent in terms of geographical coverage, number of target species, infrastructure setting, and public and private sector involvement. Actions underway and those suggested for the future are in many cases of the same kind. There will however be differences in geographical space (provinces, districts, sectors, cells, villages); in biological space (ecosystems, species, genes); and in ‘societal’ or institutional space (institutions, comprising various entities such as individual land owners, communities, cooperatives, government services, education and research organizations). The five elements may be developed and implemented at different paces in the various spaces. Considering ongoing support, the various projects can briefly be characterized in terms of geography, species focus, target institutions and reach. Although significant, ongoing projects all have their limitations in time and space as is evident from the following paragraphs:

TREPA is mostly limited to Eastern Province, focusing on a broad spectrum of native and exotic species of value for livelihoods, and mostly based on delivery through the formal tree seed system with RFA and its associated tree seed cooperatives. The targets are to identify seed source priorities of up to 100 species, and possibly build better seed production and clonal multiplication units of up to 25 tree species, while training both RFA staff and a few selected major stakeholders in the seed and seedling sector.

QT-Seed is operating in the Lake Kivu and Rusizi River Basin (in Western Province) in collaboration with a more informal group of stakeholders identified by the World Resources Institute (WRI), who are referred to as ‘restoration champions’. This project is also working with a mix (but limited number) of exotic and native species that are of primary interest to the restoration champions. The targets are to identify seed sources of interest for the restoration champions, and to establish a few mass multiplication units to function as demonstrations of how such units may serve a more decentralized general approach, with engagement and training platforms including the restoration champions.

RTRP-Seed is a countrywide project, but will focus on selected native tree species’ geographic areas in Rwanda, with a focus exclusively on planting native trees. In practice the plan is to first work in the north. The expectation is that it will be possible to work with a limited number of 10–25 tree species, mostly with partners that have a specific interest in native trees, and that capacity building activities will be for these partners.

With respect to the enabling environment, these three projects will cover an assessment of the national tree seed and seedling sector and a review of current policies affecting the sector. While these

projects' activities will provide important contributions to prime a sustainable tree seed sector, the mainstreaming of good practice and policies to encompass all tree seed and seedling users – including the often overlooked group of tree seed source custodians – will remain a major challenge in the decades beyond these projects' lifetimes. The five key recommendations of the current study cut across the first three operational elements, and are all intended to provide for such mainstreaming of good practice and policies to take effect in the longer term, supported by the capacity development of the two last operational elements.

Table 1. Indicative implementation plan for improving planting material used in forest management and restoration

Provisional outputs and activities	Yr 1	Yrs 2–5	Yrs 6–10	Yrs 11–15
1. Enabling institutional and policy environment (R4 and R5)				
1.1 Tree seed and restoration sub-sectoral assessment				
1.2 Policy and governance support development for the revised National Tree Reproductive Materials Strategy				
1.3 Implementing a sectoral stakeholder engagement platform				
2. Mobilization and provision of knowledge and know-how (R1 and R2)				
2.1. Integrate spatial multi-indicator prioritization for restoration with community-based assessment of restoration priorities				
2.2. Undertake further, community-based prioritization of priority tree species for planting				
2.3. Update and consolidate climate appropriate species priorities, distribution maps and deployment zones				
2.4. Assess conservation status and needs of priority species				
2.5. Establish a web portal <i>What to plant where</i> to guide users on species, seed sources and seed-seedling suppliers				
3. Mobilizing and building tree genetic resources for tree planting (R3 and R5)				
3.1 Identify, document (describe) and manage seed sources of priority species, especially of native tree species				
3.2 Collect and acquire reproductive material of priority tree species for new planting-material production stands, and development of propagation protocols				
3.3 Establish and manage new planting-material production stands in relevant deployment zones				
4. Capacity development of the tree seed sub-sector				
4.1 Capacity needs assessment with respect to training, infrastructure/equipment and management/governance of the sub-sector, especially with reference to native tree species				
4.2 Develop and implement a 'capacitation' strategy, including training of stakeholders				
4.3 Provide for facilities and facilitation (including incentives) in accordance with the capacitation strategy				
5. Capacity development of the nursery sub-sector				
5.1 Capacity needs assessment with respect to training, infrastructure/equipment and management/governance of the sub-sector, especially with reference to native tree species				
5.2 Develop and implement a 'capacitation' strategy, including training of stakeholders				
5.3 Provide for facilities and facilitation (including incentives) in accordance with the capacitation strategy				

Note: Suggested responsibility for the implementation of activities will be the Rwanda Forestry Authority working with CIFOR-ICRAF.

While the five elements are continuous, their initial operationalization requires different periods of time. Over an initial five-year period, the operationalization can be divided in two periods with Year 1 being a feasibility period composed of 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 3.1, 4.1 and 5.1 at a cost of approximately USD 300,000, and Years 2–5 the first period of implementation. Two additional five-year periods of implementation are then proposed.

4.1 Investment requirements for a tree improvement programme

The initial provisional investment requirements to meet the recommendations provided above are presented in Table 2 for an initial five-year period with the elements of a tree improvement programme presented for two investment scenarios (high and low), and for two geographical regions: one for Rwanda nationwide and one limited to the CNR landscape of Rwanda.

While a nationwide approach is preferable overall, efficient implementation relies on decentralized availability of resources, so investment needs are not at either the national or regional level, but at both levels. The number of species may be considered large, but with a necessity for diversification to meet adaptation requirements, there is a need to focus on tree diversity.

Table 2. Indicative investments for improving planting material used in forest management and restoration

Programme elements (over an initial 5-year period)	Budget, Rwanda nationwide (USD x 1,000)		Budget, Rwanda CNR landscape (USD x 1,000)	
	Low	High	Low	High
1. Enabling institutional and policy environment	350	1,000	200	500
2. Mobilization and provision of knowledge and know-how	450	1,500	200	300
3. Mobilizing and building tree genetic resources for tree planting	1,500 ⁽¹⁾	3,500 ⁽²⁾	1,500 ⁽³⁾	2,500 ⁽⁴⁾
4. Capacity development of the tree seed sub-sector	1,000 ⁽¹⁾	2,500 ⁽²⁾	300 ⁽³⁾	1,000 ⁽⁴⁾
5. Capacity development of the nursery sub-sector	500	1500	250	500
Total	3,800	10,000	2,450	4,800

Superscript-indicated references given in parentheses detail the numbers of tree species and the tree seed centre infrastructure involved for different investment scenarios at nationwide and CNR landscape levels. The numbers of tree species indicated in the investment plan scenarios are relatively large as there is a need to diversify tree planting – of native tree species especially, but also of exotic trees – in Rwanda.

- (1) Low investment scenario for Rwanda as a whole, involving a tree seed source programme for 100 species, low-input breeding *cum* conservation efforts for 10–15 tree species (both programme element 3), and two additional tree seed centre nodes (programme element four).
- (2) High investment scenario for Rwanda as a whole, involving a tree seed source programme for 200 species, low-input breeding *cum* conservation efforts for 25–30 tree species (both programme element 3), and an additional regional tree seed centre (programme element four).
- (3) Low investment scenario for the CNR landscape only, involving a tree seed source programme for 100 species, low-input breeding *cum* conservation efforts for 10–15 tree species (both programme element 3), and a single additional tree seed centre node (programme element four).
- (4) High investment scenario for the CNR landscape only, involving a tree seed source programme for 150 species, low-input breeding *cum* conservation efforts for 15–20 tree species (both programme element 3), and an additional sub-regional tree seed centre (programme element four).

4.2 The rationale of the proposed programme

A major challenge of tree-based restoration work is that it generally requires the use of many tree species at the same time. Where restoration is based on natural regeneration, it would thus require the presence of healthy and diverse seed sources and/or soil seed banks. When planting is necessary, whether for replenishment or enrichment, the supply of a broad spectrum of genetically diverse, healthy and productive tree species is generally not easily available. Traditional supply programmes focus on relatively few species, most of them of unknown genetic quality, and often with insufficient knowledge on adaptation to site conditions and adaptability to climate change.

The proposed programme addresses this major challenge by providing a multiple tree species programme able to provide:

- organizational setup of the tree seed sector, including stakeholder identification and roles and responsibilities, based on a sector analysis;
- species-specific knowledge for most priority tree species, including:
 - the plant ecological baseline for restoration
 - the potential natural distribution of multiple species and how they may be affected by climate change
 - identification of genetic variation patterns for priority tree species
 - an interactive knowledge and information portal for users;
- a build-up and establishment of tree genetic resources for the future, comprising exploration, mobilization, conservation, establishment, management and improvement; and
- capacity to monitor and deliver quality seed and seedlings of multiple species required for large scale restoration.

The outcome of the programme will be a tree seed sector enabled to provide high-quality tree seeds and seedlings of priority species for large-scale restoration plantings. In the theory of change, the fulfilment of the outcome will ensure forest restoration projects and tree planting actors in general having better information on the best tree species and seed sources to plant/restore (*knowledge of better and a larger variety of seeds*). The role of small-scale tree nursery operators within efficient tree seed and seedling systems will be understood and demonstrated, and will provide an impetus for actors to negotiate innovations in the agroforestry input supply sector (*better delivery of seed to end-users*). Suggestions will have been provided to policymakers on how to deal with current hurdles within tree seed policies, and collaboration is fostered within the sector, including public-private partnerships (*better regulation of seed production and delivery to end-users*). Breeding seed orchards *cum* conservation stands for important tree species will be established and in production. The value of breeding seed orchards will have been demonstrated and brought to scale (*higher production of quality seed*). Tools will be available to account for the potential effects of climate change when planning for regional tree seed production and distribution – and when planning for tree planting on farms, in restoration and other planting projects (*better match of what to plant where, and for what purpose*). A much better general understanding is obtained regarding the usefulness, effectiveness and possible integration of different botanic, genetic and genomic types of surveys for supporting the sustainable use and conservation of socioeconomically and ecologically important tree species (*better knowledge base for, and ability of making good investments in, tree planting and management*).

Through co-development of decision-support tools and capacity building, national institutions are better able to define priorities and select methods for tree genetic resource management, and more widely and effectively apply approaches to realize faster, more targeted and better-sustained genetic gains during tree domestication (*outcome - amount of high-quality tree seed of priority species produced*).

The more efficient delivery pipeline options and delivery support tools for tree-planting materials – developed with the NTSC in engagement with policymakers, the private sector, government extension services and business-development NGOs – enable input suppliers to provide growers with a range of more productive, site-matched tree planting material (*outcome - amount of high quality tree seed and seedlings of priority species distributed*).

These improved inputs increase the range and yield of tree products (e.g., timber, fuel, fodder, fruits) available for tree growers, supporting their incomes and diets, as well as restoring degraded lands (*impact – more land with higher survival and productivity (economic and environmental)*). When farmers and traders integrate these improved products into value chains, peri-urban and urban consumers benefit through increased supply and reduced unit production costs; and hence lower consumer prices (*impact – better livelihoods*).

Central to the theory of change is the assumption that all stakeholders are able to recognize the value of better quality planting material, and therefore support pathways to impact. An important role of the programme is therefore to characterize and demonstrate this value of quality, which is often not immediately apparent, and illustrate how it can be captured and mobilized.

References

- ADB (Asian Development Bank). 2023. *Rwanda - Forest Investment Program (FIP): Development of Agroforestry for Sustainable Agriculture*. <https://mapafrica.afdb.org/en/projects/46002-P-RW-AAD-002>
- FIP (Forest Investment Program). 2023. *Rwanda - Forest Investment Program (FIP): Development of Agroforestry for Sustainable Agriculture – Project Appraisal Report*. <https://www.afdb.org/en/documents/rwanda-forest-investment-program-fip-development-agroforestry-sustainable-agriculture-project-appraisal-report>
- FRM Guidelines. 2018. *Forestry Reproductive Material - Guidelines and standards controlling seeds, cuttings and planting stock for forest and tree production in Rwanda*. Kigali, Rwanda: Ministry of Lands and Forestry.
- Hendre PS, Graudal L, Klindt R, Hale I, Powell W, Jamnadass R, Thomson L, Dawson IK. 2022. *Operationalizing an innovative systems approach for breeding agroforestry trees*. InfoBrief No. 378. Bogor, Indonesia: Center for International Forestry Research and Nairobi, Kenya: World Agroforestry (CIFOR-ICRAF). <https://doi.org/10.17528/cifor/008758>
- Holtne N. 2012. *Assessment of the current status of small-scale nurseries in Kenya – effectiveness of input supply system*. MSc Thesis. Copenhagen, Denmark: Forest & Landscape Denmark, University of Copenhagen.
- Kindt R, Graudal L, Jamnadass R, Pedercini F, McMullin S, Hendre PS, Carsan S, Moestrup S, Abiyu A, Lillesø J-PB, et al. 2023. *Operationalizing climate appropriate portfolios of tree diversity*. InfoBrief No. 383. Bogor, Indonesia: Center for International Forestry Research and Nairobi, Kenya: World Agroforestry (CIFOR-ICRAF). <https://doi.org/10.17528/cifor-icraf/008850>
- Lillesø J-PB. 2020. *Defining and implementing quality of planting material for smallholder and restoration planting in sub-Saharan Africa*. PhD Thesis. Copenhagen, Denmark: Department of Geosciences and Natural Resource Management, University of Copenhagen.
- Lillesø J-PB and Derero A. 2019. *Consultancy on a tree seed sub-sector assessment. Discussion of the tree seed supply/demand situation in Ethiopia 2018*. Provision of Adequate Tree Seed Portfolios (PATSP0). Consultancy Report, February 2019. Nairobi, Kenya: World Agroforestry Centre and Copenhagen, Denmark: University of Copenhagen. <http://www.worldagroforestry.org/project/PATSP0/outputs>
- Lillesø J-PB, Harwood C, Derero A, Graudal L, Roshetko JM, Kindt R, Moestrup S, Omondi WO, Holtne N, Mbora A, et al. 2018. *Why institutional environments for agroforestry seed systems matter*. *Development Policy Review* 36: O89–O112.
- Lillesø J-PB, Dawson IK, Moestrup S, Quedraogo M, Daboué E, Muthemba S, Pedercini F, Carsan S, Jamnadass R, Graudal L. 2024. *Guidelines for assessing and developing the tree seed and seedling sector*. InfoBrief No. 407. Bogor, Indonesia: Center for International Forestry Research and Nairobi, Kenya: World Agroforestry (CIFOR-ICRAF). <https://doi.org/10.17528/cifor-icraf/009191>
- National TRM Strategy. 2018. *National Tree Reproductive Materials Strategy 2018–2024*. Kigali, Rwanda: Ministry of Lands and Forestry.
- OECD (Organisation for Economic Co-operation and Development). 2022. *OECD Forest Seed and Plant Scheme*. Paris, France: OECD.
- Quedraogo M, Dawson IK, Muthemba S. 2024. *Training needs assessment report for tree seed supply, the Transforming Eastern Province through Adaptation (TREPA) project, Rwanda*. Final report, 28 May 2024. Nairobi, Kenya: The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF).
- RFA (Rwanda Forestry Authority) (undated). *FIP-PRODAR. Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda*. Kigali, Rwanda: RFA. <https://www.rfa.rw/1/projects/fip-prodar>
- Umuziranenge G. 2019. Parks' governance and management in Rwanda: Opportunities and challenges of the community participation for a sustainable conservation – Case study of Nyungwe National Park. *International Journal of Environmental Protection and Policy* 7: 61–71.

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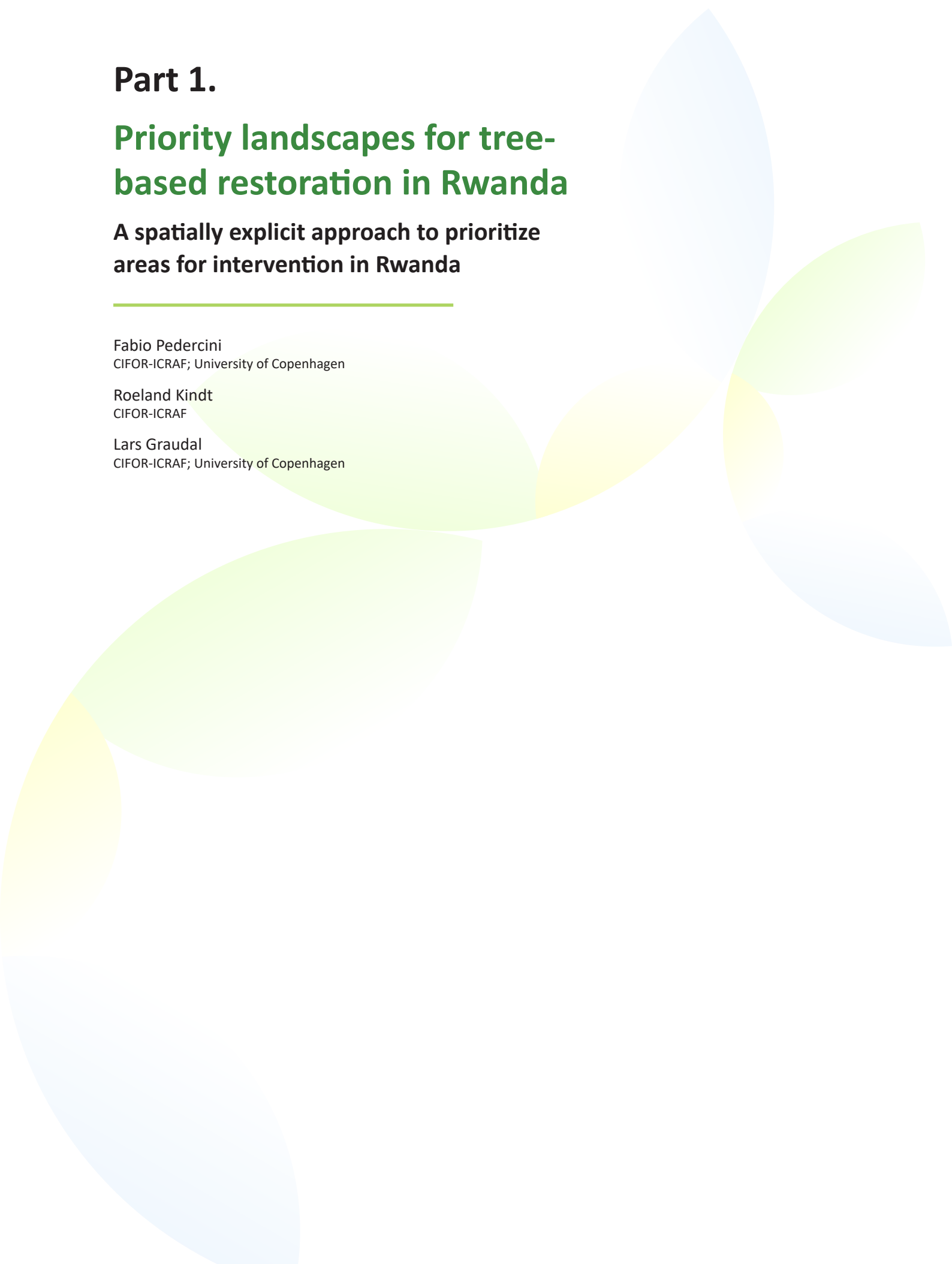
Priority landscapes for tree-based restoration in Rwanda

A spatially explicit approach to prioritize areas for intervention in Rwanda

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Contents

1	Introduction	29
1.1	Objectives of the study	30
2	Methods	31
2.1	Study overview	31
2.2	Suitability and spatial domains	32
2.3	Spatial indicators and priority setting	32
3	Priority landscapes	39
3.1	National approach	39
3.2	Sub-national approach	40
4	Model validation	41
5	Landscape restoration options	43
5.1	Intervention options	45
6	Implications for the Congo-Nile Ridge	46
	References	48
	Appendices	53
1	Potential natural vegetation reclassification approach	53
2	Reclassified spatial indicators	54
3	Priority areas by district for national approach	55
4	Priority areas by district for sub-national approach	59
5	Comparison of forest map and tree cover areas	64

List of box, figures and tables

Box

- | | | |
|---|--|----|
| 1 | Detailed methodology for developing indicators applied in our study to prioritize for intervention | 35 |
|---|--|----|

Figures

- | | | |
|----|--|----|
| 1. | Flowchart of our framework to identify priority areas for tree-based restoration in Rwanda | 32 |
| 2 | A) Land cover map of Rwanda sourced from ESRI WorldCover 2021; B) Potential natural vegetation map of Rwanda sourced from VECEA; C) Reclassified map based on A and B which identified areas suitable to tree (or shrub) growth; D) Suitable areas categorized into converted and unconverted domains for further analysis | 34 |
| 3 | Priority landscapes with national approach displayed spatially (A) and summarized in their area coverage by province (B, x axis in thousands of hectares – K hectares) | 39 |
| 4 | Priority landscapes with sub-national approach displayed spatially (A) and summarized in their area coverage by province (B, x axis in thousands of hectares – K hectares) | 40 |
| 5 | Bar chart showing indicators' average values and standard error across priority levels for the converted (A) and unconverted (B) domains - compared to a null model | 42 |
| 6 | Priority areas (in hectares) classified into land cover classes (A) and potential natural vegetation types (B) across converted and unconverted domain identified with national and sub-national approaches | 43 |
| 7 | Areas by category for size of tree cover areas (A) and tree species in plantations (B) based on available spatial data (REMA 2019; Du et al. 2022) | 44 |
| 8 | Distribution of priority landscapes within the Congo-Nile Ridge | 46 |
| 9 | Spatial overview of selected criteria for landscape prioritization | 54 |
| 10 | Overlay of land cover map (ESA 2021) and forest map (REMA 2019) which depicts the differences in classification | 64 |

Tables

- | | | |
|---|---|----|
| 1 | Summary of indicators applied in our study for identifying priority areas | 33 |
| 2 | Scores for the first two principal components of an analysis of a sample of climatic variables for baseline climate used for calculating the climate change adaptation indicator in Rwanda | 36 |
| 3 | List of potential natural vegetation (PNV) types found in Rwanda, with a column that specifies whether the PNV was included in the analysis – and thus whether tree (or shrub) growth is suitable in the area | 53 |
| 4 | Breakdown of total priority areas for each domain per district when adopting a national approach to prioritization | 55 |
| 5 | Breakdown of total priority areas for each domain per district when adopting a sub-national approach to prioritization | 59 |

1 Introduction

Globally, tree planting is regarded as a valuable strategy to restore the ecological, productive and economic functioning of degraded landscapes. Canopy cover can be promoted by active tree planting or assisted natural regeneration in both converted and unconverted landscapes. Target landscapes and motivation for planting are key criteria for determining whether, and which tree planting strategy is suitable to a given socioecological context (Brancalion and Holl 2020). When adequately planned, tree planting initiatives can contribute to the provision of income, food and energy to restoration practitioners while addressing global challenges such as climate change mitigation and biodiversity conservation (Holl and Brancalion 2020). Conversely, the afforestation of unsuitable areas – socially or environmentally – can cause dramatic losses in biodiversity and ecosystem services (Sunderland et al. 2007; Veldman et al. 2015).

Several frameworks have been developed to identify areas suitable for intervention (IUCN 2021c) as well as to prioritize landscapes within a given suitable range (e.g., Strassburg et al. 2020; de Mendonca et al. 2022). Some of these tools, such as the Atlas of Forest Landscape Restoration Opportunities developed by WRI (2014), have been criticized for identifying grassy biomes as suitable areas for afforestation and tree planting, which would threaten the conservation of native biodiversity, and compromise the natural functioning of these ecosystems (Veldman et al. 2015; Bond et al. 2019). In another case, the prioritization framework developed by Strassburg et al. (2020) has been criticized for not considering the social implications of the proposed restoration interventions (Fleischman et al. 2022). Hence, information on potential natural vegetation and socioeconomic context are key factors to consider when planning restoration activities. Recent studies such as Pedercini et al. (2021) and Srivathsa et al. (2023) have attempted to integrate some of these components when identifying suitable and priority areas for intervention.

Within the global restoration discourse, Rwanda has been described as a leading example for other African countries (IUCN 2020). In 2011, as part of its Green Growth and Climate Resilience Strategy, the country made a commitment to the Bonn Challenge, a global restoration effort which focuses on increasing forest cover as a measure to provide socioecological benefits to local communities (IUCN 2021a). Rwanda pledged two million hectares, equivalent to about 76 percent of its land area. A national study conducted by the Ministry of Environment in subsequent years identified restoration opportunities across the country (MINIRENA 2014). Thanks to both domestic and international investments, by 2018, Rwanda had achieved considerable progress in achieving restoration, reaching around 35 percent of its original tree cover target. Notably, the Ministry of Environment reported that Rwanda successfully achieved its national forest cover target of 30 percent tree cover by 2019 (Ministry of Environment of Rwanda 2019).

Rwanda is a small land-locked country that faces significant challenges. It has a population growth rate of 2.4 percent (World Bank 2023), and the country has a history of natural resource management problems, particularly heavy deforestation (Depicker et al. 2021). Additionally, there is a prevalence of forest-dependent communities that rely on biomass as their primary source of energy (Masozera and Alavalapati 2004; Ndayambaje and Mohren 2011). As a result, anthropic pressure on existing primary forest and woodland vegetation is high.

According to data from the University of Maryland and the World Resources Institute (2023) spanning the period from 2001 to 2021, Rwanda experienced a loss of 0.5 million hectares of primary humid forest. Although there has been some compensatory increase in tree cover outside natural forests, it has not fully offset the loss. Therefore, persistent and strategic reforestation efforts are crucial to alleviate anthropic pressure on natural forests.

1.1 Objectives of the study

This study provides a practical and reproducible approach to spatially prioritize landscapes as a tool to inform the development of an action plan for improved genetic material of native and exotic species. The action plan is intended to support the design and implementation of a larger programme, which aims to improve landscape management in the Congo-Nile Ridge (CNR) landscape in the Western and Southern provinces of Rwanda. Establishment of partnerships and green climate financing to implement such improved landscape management may be supported by PROGREEN.

This report is an output of a study for the World Bank to provide Technical Assistance in Forestry and Rural Development in Rwanda under PROGREEN (https://www.progreen.info/about_page).

The report has been provided as part of Task 1 of this study: analytical work and development of action plans for improved genetic material (native and exotic species), their productivity, promotion and distribution. This study takes a national perspective to make it relevant to other ongoing restoration projects and broader tree-based interventions.

The framework presented in this study identifies landscapes with optimal trade-offs compared with other areas, based on a chosen set of spatially explicit criteria (see section 2 and Box 1). These priority maps highlight landscapes where the promotion of tree-based restoration practices is expected to yield higher benefits compared to interventions in non-priority landscapes. It is important to note that these created priority maps should not be considered final, but as part of the process in identifying intervention areas. Key further steps in prioritization include stakeholder consultations and field observations.

The methodology employed in this study builds upon previous work conducted by Pedercini et al. (2021) in Ethiopia, as related below. The overall approach is structured as follows: first, the objectives of the tree planting initiative are identified; second, a set of relevant spatially explicit criteria is determined; third, areas suitable to tree planting are identified and categorized as “converted” or “unconverted” landscapes, representing non-natural and natural (or near-natural) areas, respectively; fourth, criteria are standardized in terms of resolution and values reclassified with deciles; fifth, a linear programming algorithm is applied to identify landscapes with best trade-offs across the study area; sixth, the results and overall approach are evaluated and adjusted accordingly; and finally, the results are disseminated.

2 Methods

2.1 Study overview

This subsection provides an overview of the methodology used in this study, with a more detailed description provided in subsequent subsections. The methodology, as mentioned above, builds upon the same approach to prioritization as outlined in Pedercini et al. (2021), but represents a step forward, specifically in the choice and computation of indicators and landscape domains. Figure 1 illustrates the methodology framework.

The approach consists of seven steps that lead to the identification of priority areas for tree-based restoration:

1. Reflection on motivations and project objectives: The motivation behind promoting tree planting, and the overall aims of the project interventions are considered (PROGREEN).
2. Data gathering: Open-access and spatially explicit data are collected to develop indicators relevant to the identified motivations and objectives. Indicators such as biodiversity, climate change adaptation, climate change mitigation, market access, land degradation, slope, soil erosion and tree cover gap are chosen.
3. Land suitability analysis: The suitability of land to tree or shrub growth is assessed across the country. This involves considering potential natural vegetation (PNV) and current land cover (LC). Suitable areas are further classified into ‘converted’ (non-natural) and ‘unconverted’ (natural or near-natural) domains. The unconverted domain comprises the current extent of protected areas plus a 1-km buffer, while the remaining landscapes are grouped into the converted domain.
4. Criteria assignment and homogenization: Indicators are assigned to a specific domain as criteria for prioritizing tree planting practices. Spatial resolution is homogenized to 30 arc-seconds, values reclassified using deciles (0 to 1 scale), and a common mask is applied to remove areas with missing data.
5. Prioritization within domains: Equal weighting is applied to the set of criteria within each domain. Priority areas are identified and categorized into classes of intervention based on land cover, land use and land management data, and grouped in key interventions (silvopastoralism, agroforestry and plantations).
6. Critical evaluation and adaptation: The results are critically evaluated, and the approach is adapted to address any identified issues. During this step, a spatial bias in the distribution of priority areas is identified due to regional differences in geomorphology, climate and vegetation. To address this, both a national and sub-national approach (provinces) are used for prioritization, and results are compared. The national approach segregates into converted and unconverted landscapes without considering provincial borders, while the sub-national approach divides landscapes into provinces and then into domains. The prioritization results are merged to obtain a comprehensive figure covering the entire country.
7. Finally, to ensure transparency and accessibility, we have thoroughly documented our approach and made the priority layers available online (<https://doi.org/10.5281/zenodo.8359253>). The ability for users to access, utilize and provide their assessment of our tool will contribute to its continuous improvement.

All data analysis and processes were conducted using the R statistical software (R Core Team 2020) with the assistance of *terra* (Hijmans 2021), *sf* (Pebesma 2018), and *tidyverse* (Wickham et al. 2019) packages.

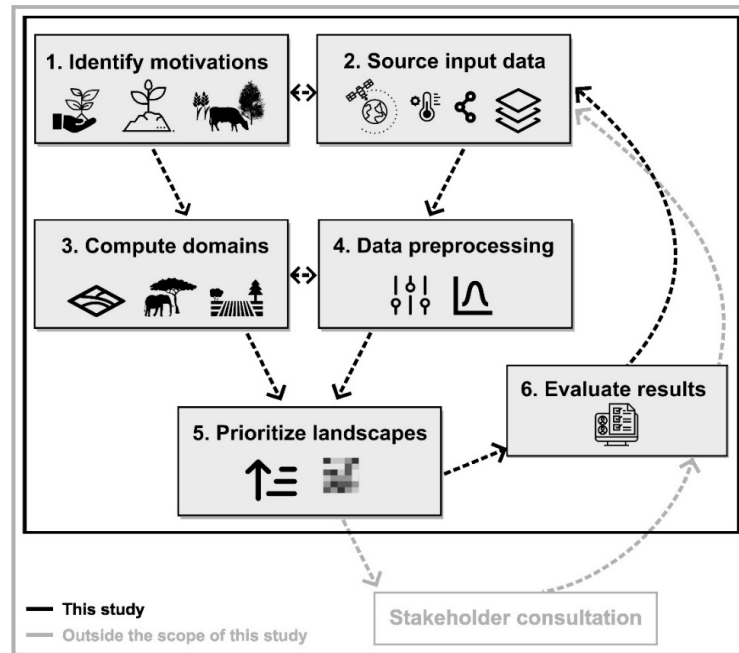


Figure 1. Flowchart of our framework to identify priority areas for tree-based restoration in Rwanda

2.2 Suitability and spatial domains

This section describes how we identified areas suitable to tree planting activities and classified them into ‘converted’ and ‘unconverted’ landscape domains.

We gathered current land cover data (Figure 2A) from Zanaga et al. (2022) and utilized this data to mask out urban areas, permanent water bodies and bare soil. Further, we extracted the geographic distribution of different potential natural vegetation types in Rwanda (Figure 2B) from van Breugel et al. (2015). Based on the detailed description of vegetation types (Kindt et al. 2011a, 2011b, 2011c), we excluded certain types (e.g., herbaceous grassland, desert, wetland and alpine vegetation) from our further analysis because they were considered unsuitable for tree-based restoration activities (Appendix 1, Table 3). Finally, based on the masks created from Figures 2A and 2B, we extracted the geographic range suitable to tree (and shrub) growth (Figure 2C).

Subsequently, we classified the obtained suitable range into converted and unconverted landscapes by assuming that protected areas (Hanson 2022; UNEP-WCMC and IUCN 2023), with a buffer zone of 1 km, are the only natural or near-natural (unconverted) areas left in the country. The remaining landscapes were classified as converted domain (Figure 2D).

The Centre of Excellence in Biodiversity has recently developed a map of ecosystem types in Rwanda that has been integrated into the Rwanda Biodiversity Spatial Assessment (<https://rbis.ur.ac.rw/map/>). This is regarded as the most accurate map of ecosystem types for planning purposes. However, it does not at present list the tree species occurring in each of the ecosystem types. It is therefore not at present possible to use this map for species suitability assessment.

2.3 Spatial indicators and priority setting

In this section we introduce the nature of the chosen indicators, whether we acquired them from published resources and reclassified or developed them specifically for this study. In the case of the latter, we outline the adopted methodology. We selected eight indicators – seven biophysical and one socioeconomic – based on their relevance to the objectives of the PROGREEN project (see Table 1).

For this study, we adopted a common spatial resolution of 30 arc-seconds (corresponding to about 85 hectares across Rwanda) per pixel or planning unit as the finest common resolution across all acquired data. We derived a masking layer by merging missing values in input data and unsuitable areas for tree growth, as depicted in Figure 2C and explained above. Before implementing the prioritization algorithm, indicator values were reclassified from 0 to 1 based on quantile distribution (deciles), where higher values were associated with higher predicted benefits of implementing tree-based restoration practices.

Two of the indicators (market access and soil erosion) are acquired from the published source and only reclassified, resampled and masked to match our approach. For the remaining six, we gathered relevant baseline data and modelled or extracted the desired variable.

The eight indicators are summarized in Table 1, which highlights the domain they were applied to, and their key features. Resampled indicators are depicted in Figure 9 (Appendix 2). Motivations and aims of planting trees in converted and unconverted landscapes are different, thus the set of indicators used to prioritize within each domain was also different. Detailed methodology to derive each indicator is provided in Box 1.

To set priorities, we implemented a linear programming algorithm through the prioritizr R package (Hanson et al. 2021) and via the gurobi solver (Schuster et al. 2020; Gurobi Optimization LLC 2021). Specifically, we select the best trade-offs across indicators, while also staying within a fixed budget (in our case given as total area). Budget areas were sequentially fed to the function as follows: 50, 20, and 10 percent of the total domain area to obtain three priority levels (lower to medium to higher, respectively). Additionally, we specified a boundary penalty (penalty = 0.001) to promote greater landscape connectivity. All indicators were weighted equally, although weights can be used to favour the representation of a given indicator. The outcome variable was of binary nature, with 0 and 1 values corresponding to non-priority and priority, respectively.

Table 1. Summary of indicators applied in our study for identifying priority areas

Name of indicator	Type of indicator	Key features of indicator	Landscape domain to which applied
Biodiversity value	Biophysical	Species richness of forest-dependent tetrapods estimated based on the habitat ranges of Rwandan tetrapod species. It indicates the biodiversity value of the habitat.	Unconverted
Climate change adaptation	Biophysical	Velocity of climate change based on current and future climatic conditions. It indicates to what extent climatic adaptation measures are needed.	Unconverted
Climate change mitigation	Biophysical	Gap in standing aboveground biomass (AGB) modelled with quantile regression, based on an existing AGB dataset and biophysical conditions. It indicates the potential for sequestering carbon in AGB.	Unconverted
Market access	Socioeconomic	Travel time to the nearest town by walking. It indicates accessibility to local markets for selling agricultural and forest products.	Converted
Land degradation	Biophysical	Changes in land productivity, estimated based on the normalized difference vegetation index, from satellite images. It indicates the positive or negative trend in primary productivity.	Converted
Potential tree cover	Biophysical	Potential maximum tree cover estimated with a random forest regression model based on bioclimatic variables. It indicates the gap in tree cover given the bioclimatic condition and current tree cover.	Converted
Erosion risk	Biophysical	Risk of soil erosion estimated based on machine learning from satellite images. It indicates the need of soil conservation strategies to prevent soil erosion.	Unconverted and converted
Slope	Biophysical	Median slope (in degrees) per planning unit extracted from a digital elevation model as a measure of slope intensity.	Unconverted and converted

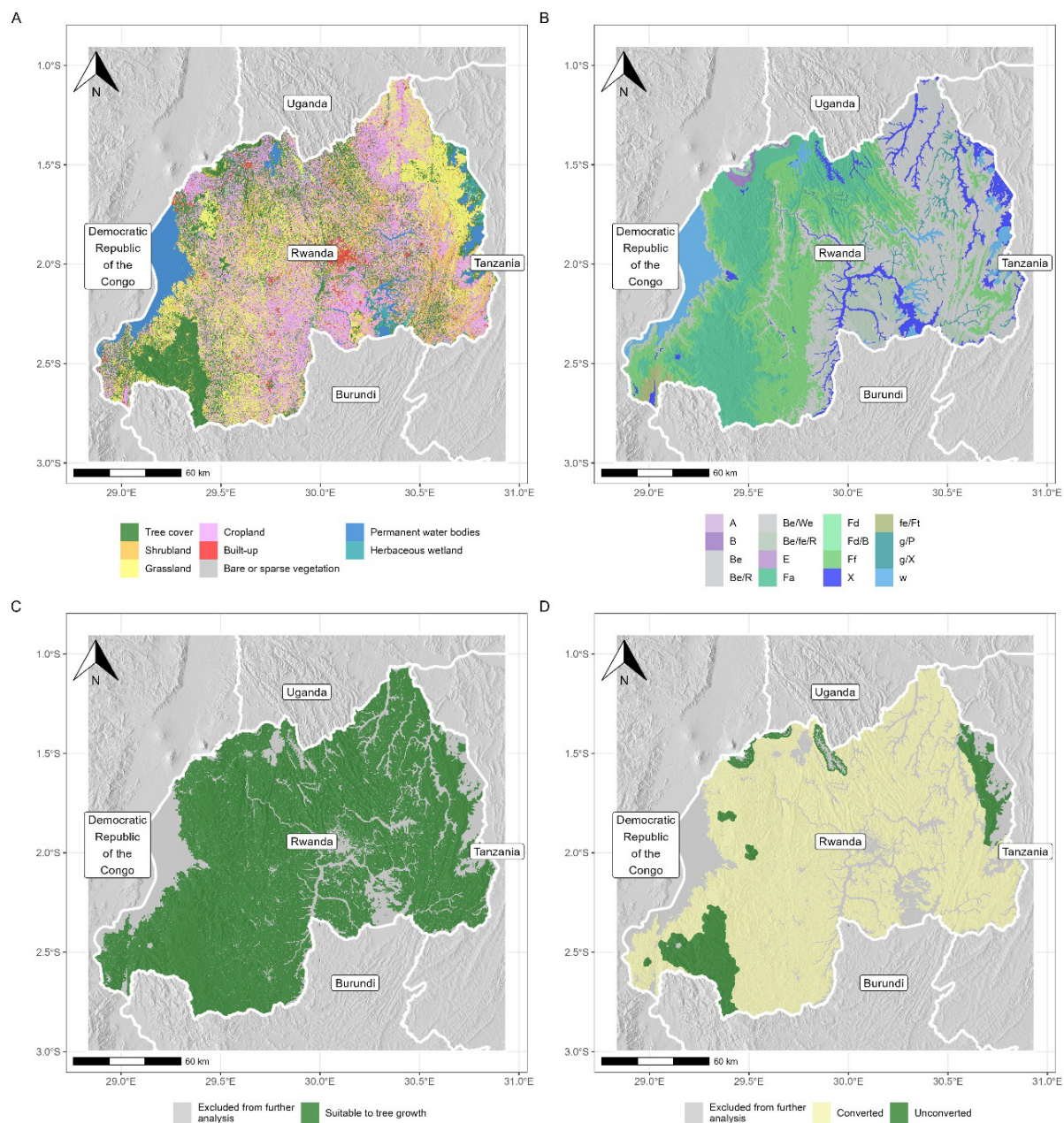


Figure 2. A) Land cover map of Rwanda sourced from ESRI WorldCover 2021; B) Potential natural vegetation map of Rwanda sourced from VECEA; C) Reclassified map based on A and B which identified areas suitable to tree (or shrub) growth; D) Suitable areas categorized into converted and unconverted domains for further analysis

Source: Du et al. 2022; Zanaga et al. 2022; van Breugel 2015.

Box 1. Detailed methodology for developing indicators applied in our study to prioritize for intervention

Biodiversity value (used as an indicator for ‘unconverted’ land)

This indicator of the potential biological diversity of each planning unit is based on the habitat ranges of local tetrapod species. Our indicator focused on mammals, reptiles, amphibians and birds because open-source spatial data on these species’ habitat ranges are the best that are available (better, e.g., than for plants and insects). Previous global prioritization exercises have also applied such tetrapod diversity as an indicator of ecosystem biodiversity (Strassburg et al. 2020). Spatial data on our collection of tetrapods were sourced from the IUCN Red List website (IUCN 2021b) and (for birds) from BirdLife International (BirdLife International and Handbook of the Birds of the World 2020). The pool of tetrapod species native to Rwanda was extracted by clipping single species global distributions to national borders. We then followed the same approach as in Hill et al. (2019), and selected forest-dependent species of tetrapods using the list produced by Tracewski et al. (2016). Species ranges were then overlaid on our planning unit grid, and the number of overlapping polygons counted, resulting in richness estimates of forest-dependent tetrapod species. Final values were re-scaled 0 to 1 based on the decile distribution (1 being the highest richness). The primary justification for including biodiversity as an indicator for prioritizing areas for the unconverted domain is that tree-based restoration, when adequately planned and implemented, can benefit local biodiversity by providing a favourable habitat matrix (Moguel and Toledo 1999; Benayas et al. 2009). In Rwanda, for example, higher tree diversity and tree cover was associated with higher bird diversity (Rurangwa et al. 2021). In our analysis, we applied the biodiversity indicator to unconverted landscapes.

Climate change adaptation (used as an indicator for ‘unconverted’ land)

This indicator estimates the relative velocity of climate change for each planning unit. It is based on the methodology of Hamann et al. (2015), where a velocity of climate change layer is computed using the metric developed by Loarie et al. (2009). Our indicator is based on the results of a principal component analysis on a subset of climatic variables considered by Hamann et al. (2015) which were selected by setting a maximum variance inflation factor of 10 (retained variables were: minimum temperature of coldest month, precipitation of wettest quarter, and potential evapotranspiration of driest quarter). Baseline climate was defined as the monthly averages of maximum and minimum temperatures and average precipitations for the years 1970 to 2000 (Fick and Hijmans 2017). Future climate was estimated by computing the average across 23 global climate models for the shared socioeconomic pathway “ssp-245” and the period 2061–2080 (2070s). This pathway is an intermediate scenario where emissions will peak by 2040 and then decline, bringing a 3°C temperature increase by 2100 (Tebaldi et al. 2021). Additional climatic variables for baseline and future were estimated using the *Envirem* package (Title and Bemmels 2018). The first two principal components of the analysis for Rwanda explained an overall high proportion of total variance, and were used for further modelling. For baseline climate, the first component (87% of variation) equally represented the three variables, and the second (14% of variation) was mostly related to precipitation of wettest quarter (Table 2). Final values of climate change velocity for planning units were re-scaled 0 to 1 based on the decile distribution (1 indicating the highest velocity). Justification for the use of this indicator is that tree-based restoration can promote landscapes’ adaptive capacities by enhancing ecosystem functionalities under multiple pressures of environmental change (Trumbore et al. 2015; Mansourian et al. 2017). Promoting landscape structural diversity and the presence of microhabitats both contribute to safeguarding forest biodiversity from the effects of climate change (Scheffers et al. 2014; Augustynczyk et al. 2019). Alongside, an increase in canopy cover by trees reduces the effects of extreme rainfall events (Zheng et al. 2008) that are expected to become more frequent with anthropogenic global warming (Billi et al. 2015; Myhre et al. 2019). Increased tree cover can also promote landscape connectivity that supports the adaptive migration of species in response to climate change (Noss 2001). For current purposes, we assume that the effectiveness of tree-based interventions is greatest where climate change is happening fastest.

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Box 1. Continued**Table 2. Scores for the first two principal components of an analysis of a sample of climatic variables for baseline climate used for calculating the climate change adaptation indicator in Rwanda**

Climatic variable	Climate	PC1	PC2
Potential evapotranspiration of driest quarter	Baseline	0.59	0.22
Minimum temperature of coldest month		0.58	0.57
Precipitation of wettest quarter		-0.56	0.80
Potential evapotranspiration of driest quarter	Future	0.35	0.94
Minimum temperature of coldest month		0.02	-0.03
Precipitation of wettest quarter		-0.94	0.35

Climate change mitigation (used as an indicator for ‘unconverted’ land)

This indicator estimates the potential gap in aboveground biomass (AGB) (and therefore carbon sequestration capability) of each planning unit, considering environmental conditions. Our indicator was developed using an approach inspired by Greve et al. (2013) and Brancalion et al. (2019). We sourced layers for aboveground biomass for the year 2018 from Santoro et al. (2018). To model the relationship between biomass productivity and environmental conditions, we performed a quantile regression using a similar approach to Greve et al. (2013) that tests for trends in any part of the distribution. The 90% quantile was used to model the potential maximum aboveground biomass that can be produced in each environment. Soil data were sourced from SoilGrids (Hengl et al. 2017), and bioclimatic predictors derived using the *Envirem* package (Title and Bemmels 2018), based on environmental data sourced from WorldClim (Fick and Hijmans 2017). Data were re-sampled to a common spatial resolution of 30 arc-second and grouped in a raster stack. A first model was fitted to the full data. Further, variables with a variable importance score < 10 were excluded from the model (Brandon et al. 2018). The selected variables (2 soil and 11 climatic) were used as predictors of potential AGB in a multivariate linear regression, where the response variable was the baseline AGB in Rwanda. Quadratic terms were computed for each variable to account for any non-linear relationships, and the best model was selected based on lowest AIC. Predictors from the best fitting model were utilized as independent variables in the 90% quantile regression model. The final model coefficients used are reported in Table 3. The model was then used to make predictions for maximum potential AGB. Baseline AGB values were then subtracted to estimate the potential (extra) AGB that could be achieved. Justification for this indicator is based on the observation that tree-based restoration can have significant positive impacts on landscape biomass productivity and carbon sequestration potential (Zomer et al. 2016), which is a key target of tree planting projects. Landscapes described by a larger gap in biomass production (e.g., areas that were previously covered by forests and were converted to annual cropland) have the potential to sustain a much higher biomass production. Thus, we here assume that an increase in tree cover can be promoted more effectively in areas with a larger biomass gap.

Tree cover change (used as an indicator for ‘converted’ land)

This indicator was developed based on tree cover data from Hansen et al. (2013). By applying a similar methodology as in Bastin et al. (2019), we fit a predictive random forest model (Wright and Ziegler 2015) to existing tree cover data and estimate the maximum tree cover across Rwanda. We built a dataset by performing a random spatial sampling of tree cover, climatic and soil variables within protected areas (UNEP-WCMC and IUCN 2023). We assume that these areas are characterized by near-natural conditions and thus can inform on the maximum canopy cover of the unperturbed habitat. We divide the obtained data into train and test sets, and normalize all variables (Kuhn and Wickham 2020). We tuned model hyperparameters (i.e., “*mtry*”, number of predictors to sample at each split; “*min_n*” number of observations needed to keep splitting nodes) with the data partitioned into ten splits for k-fold cross-validation. We then compare model

continued on next page

Box 1. Continued

performance based on the root mean squared error (RMSE), and select the best inferential model with lowest RMSEs. Finally, we fit the final model to train data and test data (RMSE = 5.33). To obtain the gap in tree cover, we subtract the current tree cover (Hansen et al. 2013) from the potential tree cover obtained as model output. Values were re-scaled 0 to 1 based on the decile distribution (1 indicating the lowest current tree cover). Our assumption is that areas with a greater gap in tree cover have higher potential for reaping the benefits of tree planting.

Land degradation (used as an indicator for ‘converted’ land)

As a measure of land degradation, we used the Normalized Difference Vegetation Index (NDVI). The NDVI, usually estimated by satellite using red and near infrared portions of the electromagnetic spectrum, is a common surrogate for net primary productivity (Li et al. 2004) and crop productivity (Hill and Donald 2003). For our indicator, mean annual NDVI was computed from bi-weekly images sampled by MODIS (at 300 m) for the baseline period 2008 to 2012 and the comparison period 2013 to 2018. The values of mean NDVI were then reclassified based on percentile classes, and the difference in class number between the baseline and comparison time periods computed. The analysis was performed using *Trends.Earth* (Conservation International 2018), a semi-automatic plugin for the *QGIS software environment* (QGIS Development Team 2021). A map of the resulting values had pixel scores ranging from -7 to 8, where values >2 were taken to indicate locations with stable or decreased land degradation, and <-2 to indicate locations experiencing an increase in land degradation.

Market access (used as an indicator for ‘converted’ land)

The chosen indicator is an estimate of farmers’ access to local markets. It is based on global spatial data on accessibility developed by Nelson et al. (2019), where the value of each pixel is the estimated travel time in minutes to the nearest urban area (in 2015). Travel time is estimated by using a global friction surface which incorporated the best available information on transport networks and speeds, off road networks and walking speeds (Weiss et al. 2018). Of the various data layers made available by Nelson et al. (2019), we selected the layer which estimated travel times to the nearest town with a total population of ≥5,000 people for our analysis. The raster layer was re-sampled for Ethiopian planning units, and scores scaled 0 to 1 based on the quantile distribution (1 indicating the greatest town/market accessibility). Our justification for this indicator is that agroforestry adoption has been observed to be positively influenced by proximity to the nearest town (Nkamleu and Manyong 2005; Beyene et al. 2019). Specifically, access to markets has also been observed to be one of the most important variables influencing strategies of tree planting (Degrande et al. 2006) and agroforestry practice adoption (Tafero and Nigussie 2018). Market access has also been suggested by others as a key factor to consider when designing restoration projects (FAO and WRI 2021).

Erosion risk (used as an indicator for ‘unconverted’ and ‘converted’ lands)

The chosen indicator estimates potential soil loss within planning units. It is based on a global dataset of erosion risk sourced from Vågen and Winowiecki (2019). Data on soil erosion ($\text{t ha}^{-1} \text{y}^{-1}$) were re-sampled to match our planning unit grid size, and the values scaled 0 to 1 based on the quantile distribution (1 indicating the greatest soil erosion risk). Justification for this indicator is that soil erosion has multiple negative impacts, including on crop productivity (Lal and Moldenhauer 1987) and the global carbon budget (Lal 2003), while tree cover can significantly reduce soil erosion and runoff (Bennett 1940). The assumption is that tree-based restoration can have the largest benefits where erosion risk is highest. As well as using soil erosion risk for the identification of the priority areas for restoration (PARs), we used this indicator as a basis to assess the impacts of restoration (subsection 2.4).

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Box 1. Continued**Slope** (used as an indicator for ‘unconverted’ and ‘converted’ lands)

The chosen indicator is a measure of median slope gradient. It is based on a digital elevation model acquired using the R package *elevatr* (Hollister et al. 2020). The data was downloaded via the *get_elevation_raster* function, with a resolution of approximately 2.5 metres ($z = 15$). We then aggregate cells by applying a median function to homogenize the spatial resolution with remaining layers. The final layer is resampled from 0 to 1 using deciles (1 indicating higher median slope values). The justification for choosing such an indicator is that restoring canopy cover contributes to reduced risk of erosion on steep cultivated land. Thus, the assumption is that benefits of tree-based restoration practices are higher across landscapes with greater median slope gradient.

3 Priority landscapes

As mentioned in the study overview (subsection 2.1), during step six of our workflow we decided to adjust our methodology and include a comparative approach to spatial prioritization. Thus, we here present model results by dividing into national and sub-national approaches. Hereafter, we refer to the Figure 3 legend categories *top 50*, *25* and *10 percent* as “priority areas or landscapes”. Specifically, we refer to *top 50*, *25*, and *10 percent* as low, medium and high priority areas or landscapes, respectively. The category *low*, although suitable for tree planting intervention, is not considered as priority (see also subsection 2.3 above for more information on how legend categories were defined).

3.1 National approach

By applying a national approach, the resulting spatial distribution of high priority areas appears skewed towards the Southern and Western provinces, especially for the converted domain (Figure 3), whereas high priority areas for the unconverted domain are mostly found in the Northern and Western provinces. Although Eastern Province is the largest in total surface area, it contains the smallest proportion of priority areas, excluding Kigali Province. Considering that planning of restoration activities is often coordinated and implemented by local authorities, particularly by the district head, agronomist and forest officer, in Table 4 (Appendix 3) we summarize the area of priority landscapes within each district.

Ngororero, Nyabihu, Rubavu and Rutsiro are the districts with the highest densities of priority areas for both domains in Western Province. Further, for the converted domain, Huye and Muhanga are focal districts in Southern Province; while in Nyamagabe and Nyaruguru districts we observe a high density of priority areas for both domains.

In Northern Province, Burera, Gicumbi and Musanze districts show high densities of priority areas for the unconverted domain, with the latter being of importance also for the converted domain.

Finally, in Eastern Province, Kirehe and Nyagatare are the districts with higher densities of priority areas for the converted and unconverted domains, respectively.

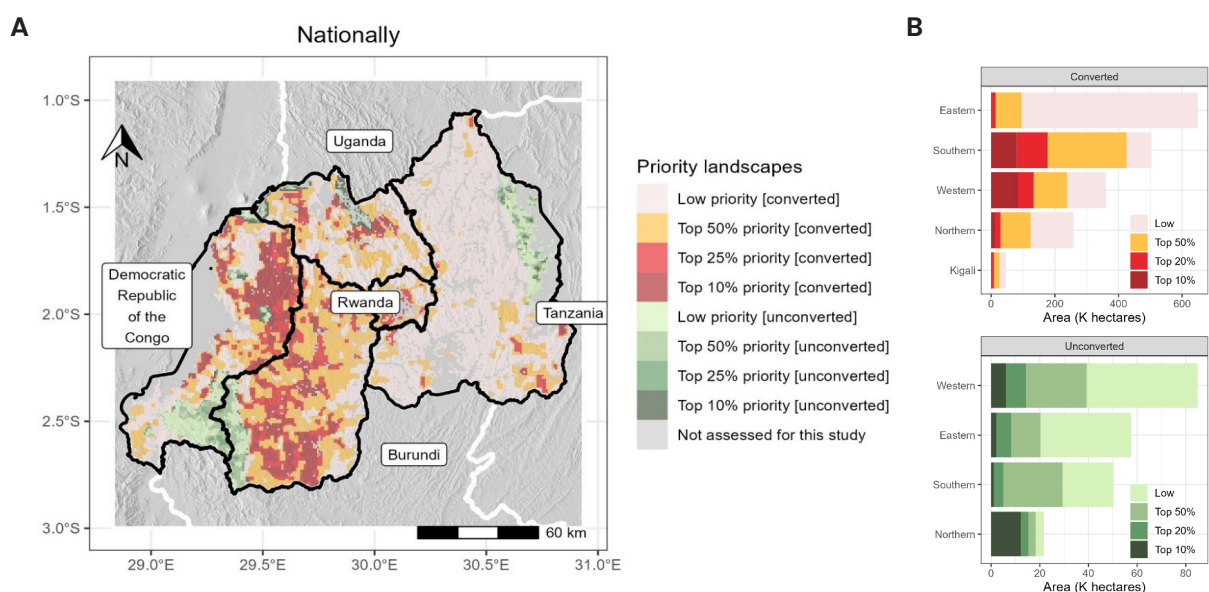


Figure 3. Priority landscapes with national approach displayed spatially (A) and summarized in their area coverage by province (B, x axis in thousands of hectares – K hectares)

3.2 Sub-national approach

By adopting a sub-national approach, we aimed at obtaining a solution which identifies a proportion of priority landscapes that is homogeneous across provinces. In other words, with this approach, we identify a given proportion of optimal landscapes characterized by the best trade-offs for the selected indicators – within each province and domain. The results are depicted in Figure 4. Overall, the sub-national approach yielded a more widespread solution that is optimal at identifying priority landscapes within each province. It is further noticeable that despite substantial differences, the two solutions (Figure 3 and Figure 4) are comparable overall in terms of the spatial distribution of key restoration hotspots, for both converted and unconverted domains.

These overlapping hotspots are located within the Gishwati-Mukura Corridor, along the Gitega Hills, around Virunga National Park and Lake Ruhondo, and a in a few areas of Eastern Province – Akagera National Park and a few areas along the southeastern border with Tanzania.

In Table 5 (Appendix 4) we break down the identified priority areas by district. Rutsiro and Ngororero are the most important districts in Western Province for both converted and unconverted domains. In Southern Province, high density of priority landscapes is found in Nyaruguru and Nyamagabe.

In Northern Province, Musanze and Burera are key districts for the restoration of converted and unconverted landscapes. Kirehe, Kayoza and Bugesera are the most important districts for the converted domain in Eastern Province. Therein, Gatsibo and Nyagatare show above average cover of priority areas for the unconverted domain.

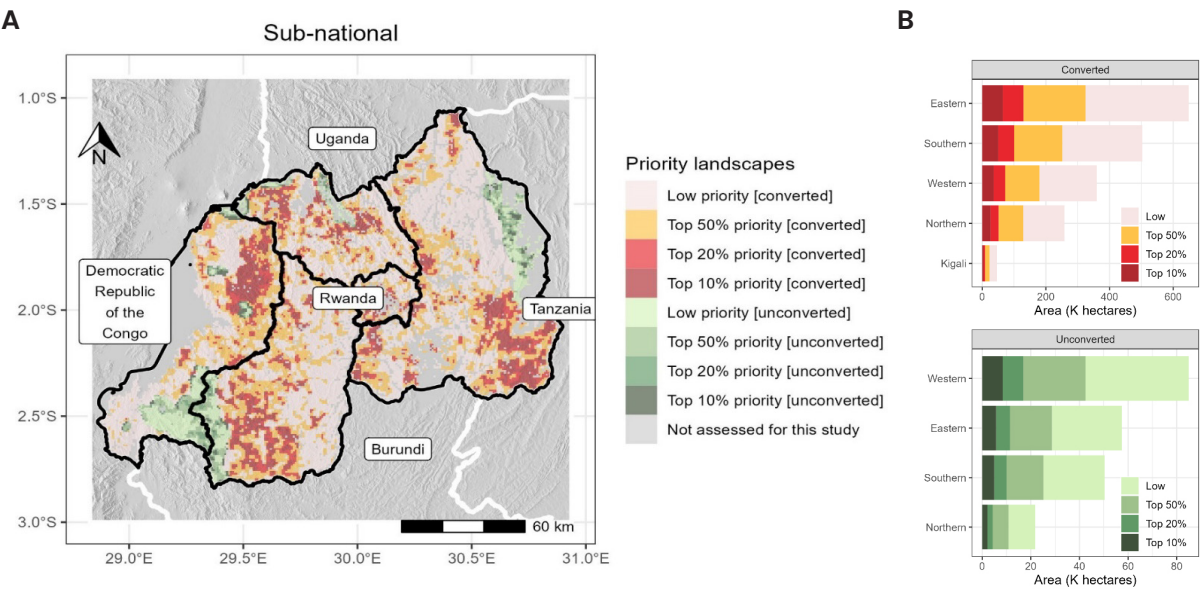


Figure 4. Priority landscapes with sub-national approach displayed spatially (A) and summarized in their area coverage by province (B, x axis in thousands of hectares – K hectares)

4 Model validation

The analysis conducted in this section aims to compare the indicators' average value and standard errors across priority landscapes identified based on two different approaches (a national approach and a sub-national approach). The objective was to assess the effectiveness of these approaches in identifying landscapes with optimal trade-offs based on the selected indicators.

To establish the validity of the chosen approaches, a null model was employed as a benchmark. In this null model, an equal number of spatial units (half of the total domain area) were randomly selected. This process was repeated 100 times, and the average values and standard errors were estimated for each iteration. The results, as shown in Figure 5, indicate that both the national and sub-national approaches, to varying degrees, maximize the expected benefits of tree planting activities in both converted (A) and unconverted (B) landscapes when compared to randomly selected landscapes. This observation suggests that the adopted indicators and the approach of prioritizing landscapes based on these indicators yield better outcomes in terms of expected benefits compared to randomly selected landscapes.

These findings support the validity of the approach used in identifying landscapes with optimal trade-offs, emphasizing the potential benefits of tree planting activities within the selected priority landscapes.

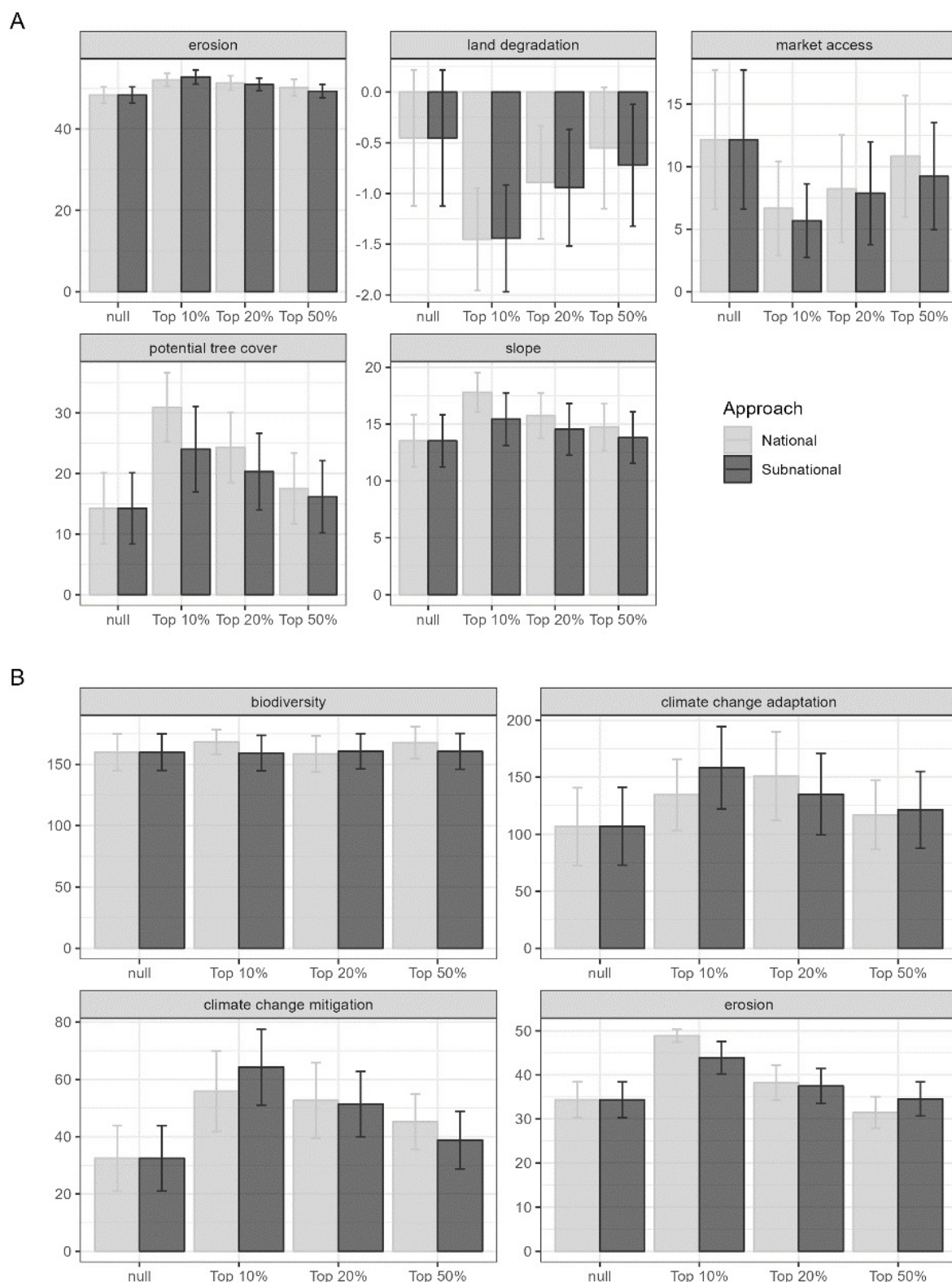


Figure 5. Bar chart showing indicators' average values and standard error across priority levels for the converted (A) and unconverted (B) domains - compared to a null model

Note: Colour coding allows us to compare model performance across the national and subnational approaches. Units are as follows: erosion (t ha⁻¹ y⁻¹); land degradation (unitless); market access (minutes to closest town); potential tree cover (percent canopy cover); slope (radians); biodiversity (number of forest-dependent species); climate change adaptation (km y⁻¹); climate change mitigation (t ha⁻¹ y⁻¹)

5 Landscape restoration options

To speculate on the most adequate interventions within the identified priority areas, it is important to analyse the current land cover (Zanaga et al. 2022), forest and plantations cover (REMA 2019; Du et al. 2022) and potential natural vegetation data (van Breugel 2015). By segregating the priority areas (in hectares) into land cover classes and potential natural vegetation types, we can compare the national and sub-national approaches for the converted and unconverted domains (Figure 6). Additionally, this analysis allows us to understand which restoration options should be in focus to restore the rural and peri-urban priority landscapes of Rwanda.

Overall, we find that the distribution of land cover classes (A) and potential natural vegetation types (B) across the priority areas of converted and unconverted domains, identified with national and sub-national approaches, are comparable. This indicates that the land cover and potential natural vegetation patterns within the priority areas are consistent, regardless of whether the prioritization analysis is conducted at a national or sub-national level, with a few exceptions that we discuss below. In the analysis, it is observed that some priority areas include built-up areas (about 30,000 hectares), even though they were initially masked from the analysis. This occurrence is attributed to the higher resolution at which the analysis is being conducted, specifically at 30 metres compared to the previous resolution of 1 kilometre.

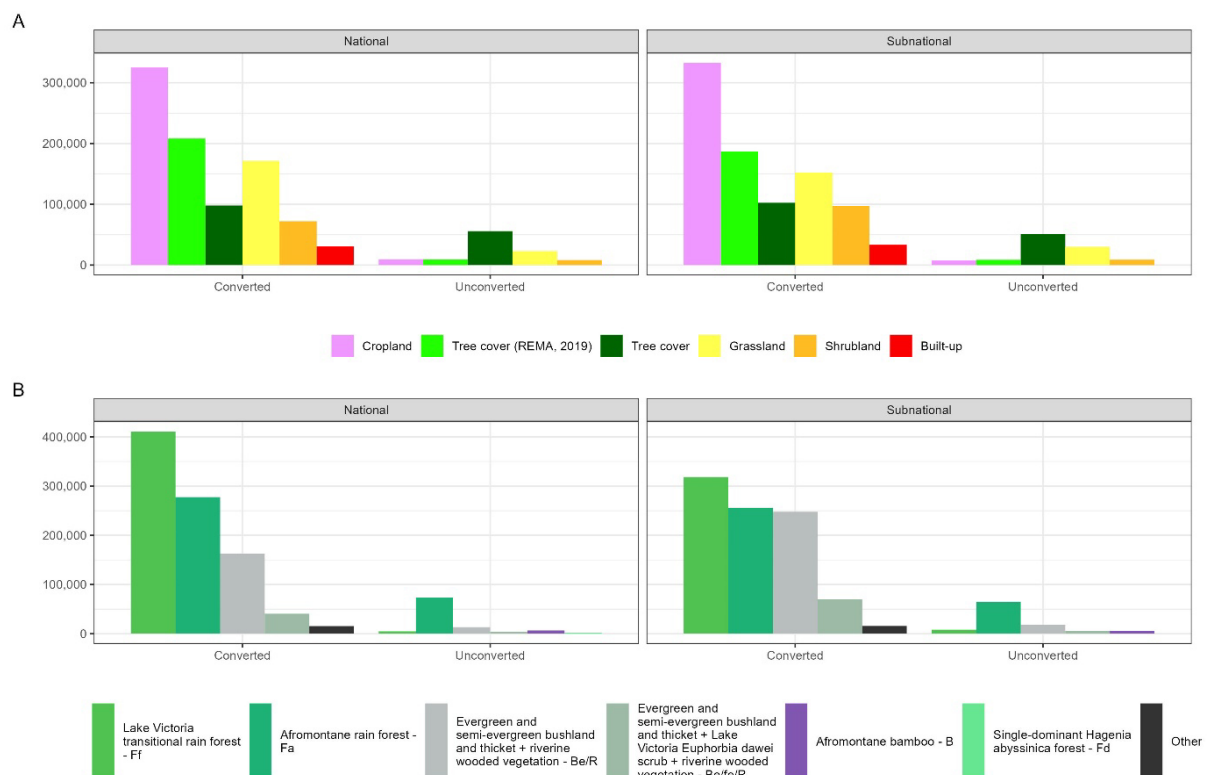


Figure 6. Priority areas (in hectares) classified into land cover classes (A) and potential natural vegetation types (B) across converted and unconverted domain identified with national and sub-national approaches

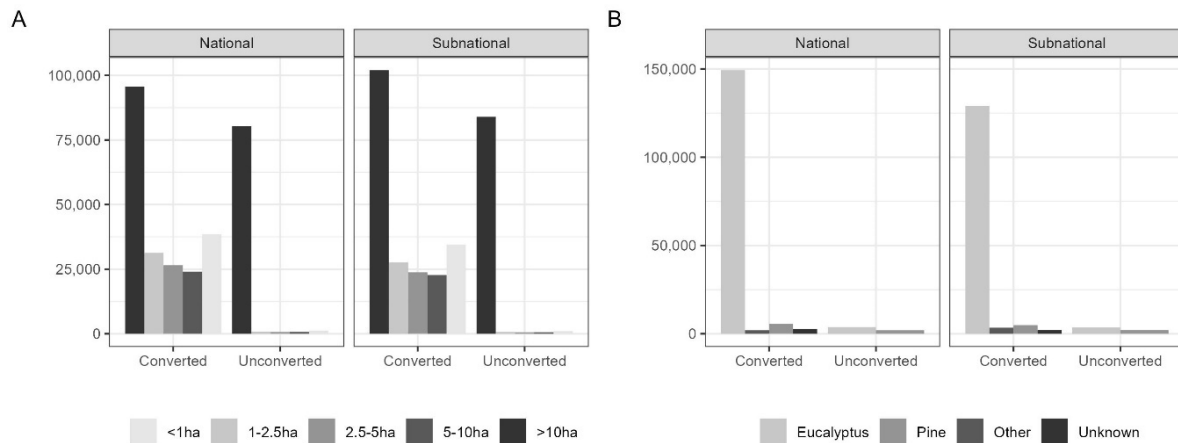


Figure 7. Areas by category for size of tree cover areas (A) and tree species in plantations (B) based on available spatial data (REMA 2019; Du et al. 2022)

In priority areas identified using the sub-national approach, there is a sharp decline in the presence of 'Lake Victoria transitional rain forest (Ff)' compared to the national approach. The decline is accompanied by an increase in 'Evergreen and semi-evergreen bushland and thicket + riverine wooded vegetation (Be/R)'. The reason for this difference is that the sub-national approach identifies a higher proportion of priority areas in Eastern Province, where the 'Evergreen and semi-evergreen bushland and thicket + riverine wooded vegetation' vegetation type is dominant (see also Figure 2B where potential natural vegetation types are spatially displayed).

In general, the priority areas in converted landscapes, are characterized by agricultural land cover classes. More than 300,000 hectares of the prioritized areas are covered by annual cropland. Furthermore, there are additional 300,000 hectares occupied by small and larger scale plantations and tree cover areas. A total of 250,000 hectares of priority landscapes are classified as shrubland and grassland which are utilized as rangeland by local communities and thus still function as productive landscapes. This indicates that a sizable portion (> 90%) of the prioritized area in the converted domain consists of farming activities, including crop cultivation, tree plantations, and livestock production.

The proportion of tree cover labelled as 'tree cover (REMA 2019)' is further described in terms of size (A) and species (B) in Figure 7. It is important to note that the area classified as 'tree cover' by Zanaga et al. (2022) does not fully overlap with areas described by REMA (2019) as forests and plantations (see Figure 10 in Appendix 5 for a visual example). According to the data extracted from REMA (2019) and Du et al. (2022), less than half of the tree cover areas within converted landscapes are larger than 10 hectares while almost one fifth (38,000 hectares) are smaller than one hectare. In contrast, tree cover patches in unconverted landscapes are entirely larger than 10 hectares – indicating a higher landscape connectivity in this domain. Additionally, the tree species composition is heavily dominated by exotics, especially by *Eucalyptus* sp. (90 percent in converted and 60 percent in unconverted landscapes) followed by *Pinus* sp. (3 percent in converted and 30 percent in unconverted landscapes).

5.1 Intervention options

Based on our analysis, there are several implications for informing the type of intervention to restore priority areas within converted landscapes. The restoration of converted landscapes heavily relies on the integration of restoration practices into existing land use. Here are some key considerations for different land cover classes within the priority areas of converted domain:

- Annual cropland (35 percent of total priority areas in converted landscapes): Agroforestry practices such as live fences, home gardens, shade trees, alley cropping and small-scale plantations can be effective options to restore annual cropland. These practices can help enhance biodiversity, soil health and ecosystem services while still allowing for agricultural production and income diversification.
- Pre-existing tree cover areas (35 percent of total priority areas in converted landscapes): For areas with pre-existing tree cover, the focus should be on diversifying species, improving plantation management through proper forest management plans (FMPs), promoting native trees, establishing mix-species forest stands and selecting species based on the specific objectives (biodiversity, production, protection). For the purpose of adaptation, options for native species should be emphasized, particularly when replacing larger-scale plantations on government-owned land (Figure 7A). Longer rotation periods can be employed for these larger plantations compared to small-scale private woodlots.
- Shrubland and grassland (25 percent of total priority areas in converted landscapes): Considerable restoration efforts are required for rangelands and pasturelands classified as shrubland and grassland. Restoration can involve planting scattered native tree species that are beneficial to the local communities or creating enclosures to protect and promote natural regeneration when remnants of natural vegetation are available. These measures can help restore biodiversity, enhance soil fertility and improve grazing conditions.
- Built-up areas (5 percent of total priority areas in converted landscapes): Focus on promoting road plantings and enhancing urban biodiversity in peri-urban areas. Planting trees along roadsides can provide benefits such as improved air quality, reduced heat island effects, and mitigation of noise pollution.

Restoring priority areas within unconverted landscapes requires careful planning and implementation to ensure the conservation and enhancement of their ecological values. The variation in land cover and potential natural vegetation area proportion across national and sub-national approaches is negligible. The pattern of potential natural vegetation types is dominated by “Afri-montane rain forest (Fa)” (Figure 6B). Based on the observed pattern of land cover classes, which includes tree cover (60,000 hectares, of which about 10,000 hectares is plantations), grassland (25,000 hectares), shrubland (8,000 hectares), and annual cropland (8,000 hectares), the following practices can be considered:

- Reforestation and enrichment planting: These practices can alleviate the negative effects of deforestation, and forest and woodland degradation. In this context, it is important to consider the specific ecological needs of local wildlife and the potential benefits for local communities. Planting of native tree species should be prioritized, especially species which provide food sources for local wildlife, and non-timber forest products for local communities. When designing the intervention, it is advisable to have a reference or pre-disturbance habitat in mind (Lillesø et al. 2023, in preparation). For example, if the priority landscapes are naturally dominated by woodland or savanna, the tree density in reforestation areas should be lower compared to degraded patches of Afri-montane rainforest.
- Buffer zone management: The encroachment of annual cropland in the buffer zones of protected areas requires careful consideration to minimize the impacts on ecological processes and biodiversity. A buffer strip with planting of native tree species can help to limit the negative effects caused by local wildlife on agricultural activities.
- Conservation of existing habitat: Besides the efforts in improving – where possible – the conservation status of degrading habitats, a key activity is to actively preserve the existing, well-conserved patches of natural forest and woodland. To do so, the involvement of local stakeholders, including local communities, NGOs and researchers, is paramount to promote sustainable management practices. Participatory approaches ensure that restoration and conservation activities align with the needs of local communities while achieving the conservation objectives.

6 Implications for the Congo-Nile Ridge

Whereas the current study has adopted a national scale to identify priority landscapes for tree-based restoration, the improved land management efforts financed through PROGREEN will primarily occur within the Congo-Nile Ridge (CNR). Thus, in this section we analyse the model results with the CNR landscape in focus, and reflect on its implications. The CNR area spans 4,130 square kilometres and is primarily located within the Western and Southern provinces of Rwanda.

Overall, based on our model results, the CNR constitutes a hotspot of priority landscapes (Figure 8) where we expect trade-offs of identified indicators to be optimal, and benefits arising from intervention to be higher than in low priority landscapes (see also Figure 5). The two approaches (national and sub-national) yielded very similar results within the CNR range; thus, we here analyse model results by focusing on the national approach.

Within this total area, 45 percent, which is equivalent to about 1,900 square kilometres, were identified as priority areas in the converted domain. These areas are dominated by agricultural landscapes, peri-urban areas and commercial plantations. In this context, the focus for restoration efforts is on active interventions aimed at restoring and enhancing the ecological and environmental aspects of these areas. Possible interventions are agroforestry, improved management of small- to large-scale plantations and silvopastoralism. The goal of these interventions is to foster an improved balance between human needs and environmental conservation by promoting sustainable land-use practices and preserving ecosystem services.

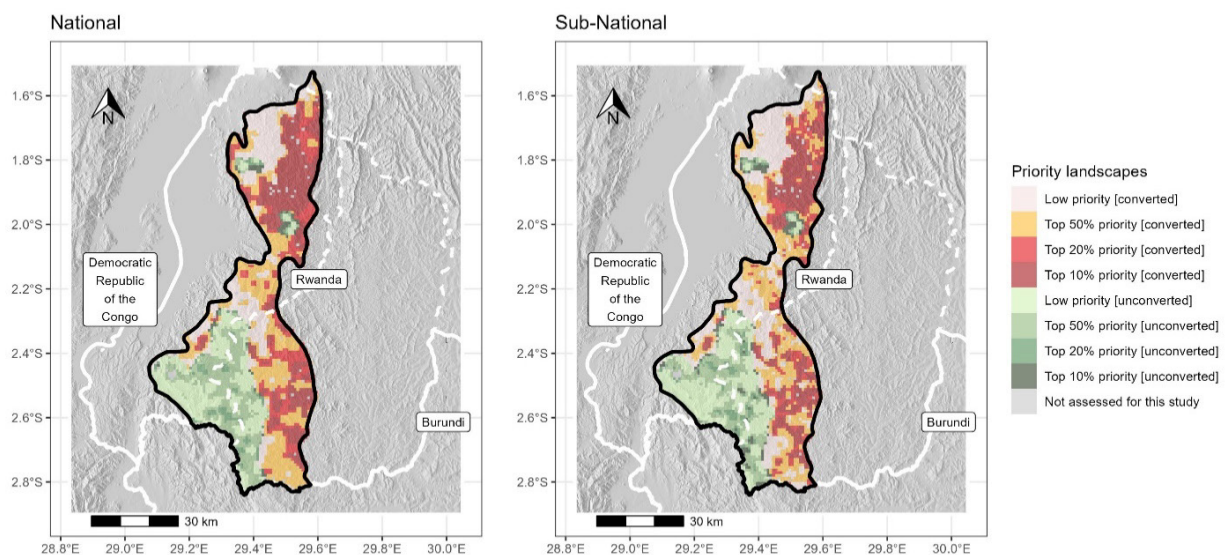


Figure 8. Distribution of priority landscapes within the Congo-Nile Ridge

Note: Provincial borders are depicted with dashed white lines

Additionally, 14 percent, which is around 600 square kilometres, were identified as priority areas in the unconverted domain. These areas are in natural or semi-natural landscapes such as forests or other untouched ecosystems (Gishwati-Mukura and Nyungwe national parks) which are showing signs of degradation and disturbance. This indicates that restoration should focus on more passive approaches such as enclosures, assisted natural regeneration and enrichment planting. The aim of promoting such interventions is to accelerate the recovery of degrading patches of natural ecosystems, while also promoting participation and sense of ownership in the conservation of protected areas within local communities.

The remaining 41 percent of the CNR area falls within the “low priority” category, either in converted or unconverted landscapes.

References

- Augustynczyk ALD, Asbeck T, Basile M, Bauhus J, Storch I, Mikusinski G, Yousefpour R, Hanewinkel M. 2019. Diversification of forest management regimes secures tree microhabitats and bird abundance under climate change. *Science of the Total Environment* 650(Pt 2): 2,717–2,730. <https://doi.org/10.1016/j.scitotenv.2018.09.366>
- Bastin J-F, Finegold Y, Garcia C, Mollicone D, Rezende M, Routh D, Zohner CM, Crowther TW. 2019. The global tree restoration potential. *Science* 365(6448): 76–79. <https://doi.org/10.1126/science.aax0848>
- Benayas JMR, Newton AC, Diaz A, Bullock JM. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: A meta-analysis. *Science* 325(5944): 1,121–1,124. <https://doi.org/10.1126/science.1172460>
- Bennett HH. 1940. Soil changes due to erosion. *Soil Science Society of America Journal* 4(C): 399–401. <https://doi.org/10.2136/sssaj1940.036159950004000c0119x>
- Beyene AD, Mekonnen A, Randall B, Deribe R. 2019. Household level determinants of agroforestry practices adoption in rural Ethiopia. *Forests, Trees and Livelihoods* 28(3): 194–213. <https://doi.org/10.1080/14728028.2019.1620137>
- Billi P, Alemu YT, Ciampalini R. 2015. Increased frequency of flash floods in Dire Dawa, Ethiopia: Change in rainfall intensity or human impact? *Natural Hazards* 76(2): 1,373–1,394. <https://doi.org/10.1007/s11069-014-1554-0>
- BirdLife International and Handbook of the Birds of the World. 2020. *Bird species distribution maps of the world*. (Version 2020.1.). Accessed from <http://datazone.birdlife.org/species/requestdis>
- Bond WJ, Stevens N, Midgley GF, Lehmann CER. 2019. The trouble with trees: Afforestation plans for Africa. *Trends in Ecology & Evolution* 34(11): 963–965. <https://doi.org/10.1016/j.tree.2019.08.003>
- Brancalion PH, Niamir A, Broadbent E, Crouzeilles R, Barros FS, Zambrano AMA, Baccini A, Aronsen J, Goetz S, Leighton Ried J, et al. 2019. Global restoration opportunities in tropical rainforest landscapes. *Science Advances* 5(7): <https://doi.org/10.1126/sciadv.aav3223>
- Brancalion PHS and Holl KD. 2020. Guidance for successful tree planting initiatives. *Journal of Applied Ecology* 57(12): 2,349–2,361. <https://doi.org/10.1111/1365-2664.13725>
- Brandon MG, Bradley CB, Andrew JM. 2018. A Simple and Effective Model-Based Variable Importance Measure. *arXiv pre-print server*. <https://arxiv.org/abs/1805.04755>
- Conservation International. 2018. *Trends.Earth*. (Version 1.0.2) <http://trends.earth>
- de Mendonca GC, Costa RCA, Parras R, de Oliveira LCM, Abdo M, Pacheco FAL, Pissarra TCT. 2022. Spatial indicator of priority areas for the implementation of agroforestry systems: An optimization strategy for agricultural landscapes restoration. *Scientific Total Environment* 839: 156185. <https://doi.org/10.1016/j.scitotenv.2022.156185>
- Degrande A, Schreckenber K, Mboosso C, Anegebeh P, Okafor V, Kanmegne J. 2006. Farmers' fruit tree-growing strategies in the humid forest zone of Cameroon and Nigeria. *Agroforestry Systems* 67(2): 159–175. <https://doi.org/10.1007/s10457-005-2649-0>
- Depicker A, Jacobs L, Mboga N, Smets B, van Rompaey A, Lennert M, Wolff E, Kervyn F, Michellier C, Dewitte O, et al. 2021. Historical dynamics of landslide risk from population and forest-cover changes in the Kivu Rift. *Nature Sustainability* 4(11): 965–974. <https://doi.org/10.1038/s41893-021-00757-9>
- Du Z, Yu L, Yang J, Xu Y, Chen B, Peng S, Zhang T, Fu H, Harris N, Gong P. 2022. A global map of planting years of plantations. *Scientific Data* 9(1): <https://doi.org/10.1038/s41597-022-01260-2>
- FAO (Food and Agriculture Organization) and WRI (World Resources Institute). 2021. *The road to restoration - A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration*. Retrieved from <http://www.fao.org/3/ca6927en/CA6927EN.pdf>

- Fick SE and Hijmans RJ. 2017. *Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas*. International Journal of Climatology **37**:4302–4315. Available from <https://rmets.onlinelibrary.wiley.com/doi/10.1002/joc.5086>.
- Fleischman F, Coleman E, Fischer H, Kashwan P, Pfeifer M, Ramprasad V, Rodriguez Solorzano C, Veldman JW. 2022. Restoration prioritization must be informed by marginalized people. *Nature* 607(7,918): E5–E6.
- Greve M, Reyers B, Mette Lykke A, Svenning J-C. 2013. Spatial optimization of carbon-stocking projects across Africa integrating stocking potential with co-benefits and feasibility. *Nature Communications* 4(1): <https://doi.org/10.1038/ncomms3975>
- Gurobi Optimization LLC. 2021. *Gurobi Optimizer Reference Manual*. <https://www.gurobi.com>
- Hamann A, Roberts DR, Barber QE, Carroll C, Nielsen SE. 2015. Velocity of climate change algorithms for guiding conservation and management. *Global Change Biology* 21(2): 997–1,004. <https://doi.org/10.1111/gcb.12736>
- Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, et al. 2013. High-resolution global maps of 21st-century forest cover change. *Science* 342(6160): 850–853. <https://doi.org/10.1126/science.1244693>
- Hanson JO. 2022. wdparr: Interface to the World Database on Protected Areas. *Journal of Open Source Software* 7(78): 4594. <https://doi.org/10.21105/joss.04594>
- Hanson JO, Schuster R, Morrell N, Strimas-Mackey M, Watts ME, Arcese P, Bennett J, Possingham HP. 2021. *prioritizr: Systematic Conservation Prioritization in R*. <https://prioritizr.net>, <https://github.com/prioritizr/prioritizr>
- Hengl T, Mendes De Jesus J, Heuvelink GBM, Ruiperez Gonzalez M, Kilibarda M, Blagotić A, Shangguan W, Wright MN, Geng X, Bauer-Marschallinger B, et al. 2017. SoilGrids250m: Global gridded soil information based on machine learning. *PLoS One* 12(2): e0169748. <https://doi.org/10.1371/journal.pone.0169748>
- Hijmans RJ. 2021. *terra: Spatial Data Analysis. R package version 1.0-7*. <https://CRAN.R-project.org/package=terra>
- Hill MJ and Donald GE. 2003. Estimating spatio-temporal patterns of agricultural productivity in fragmented landscapes using AVHRR NDVI time series. *Remote Sensing of Environment* 84(3): 367–384. [https://doi.org/10.1016/s0034-4257\(02\)00128-1](https://doi.org/10.1016/s0034-4257(02)00128-1)
- Hill SLL, Arnell A, Maney C, Butchart SHM, Hilton-Taylor C, Ciciarelli C, Davis C, Dinerstein E, Purvis A, Burgess ND. 2019. Measuring forest biodiversity status and changes globally. *Frontiers in Forests and Global Change* 2: <https://doi.org/10.3389/ffgc.2019.00070>
- Holl KD and Brancalion PH. 2020. Tree planting is not a simple solution. *Science* 368(6491): 580–581.
- Hollister J, Shah T, Robitaille A, Beck M, Johnson M. 2020. *elevatr: Access Elevation Data from Various APIs. R package version 0.3.1*. Accessed from <https://doi.org/10.5281/zenodo.4282962>
- IUCN (International Union for Conservation of Nature). 2020. *How Rwanda became a restoration leader*. Retrieved 24 April 2023 from <https://www.iucn.org/news/forests/202003/how-rwanda-became-a-restoration-leader>
- IUCN. 2021a. *Bonn Challenge: Current pledges*. International Union for Conservation of Nature (IUCN). Retrieved 20 May 2021 from <https://www.bonnchallenge.org/pledges>
- IUCN. 2021b. *The IUCN Red List of Threatened Species*. Version March 2021). Accessed from <https://www.iucnredlist.org>
- IUCN. 2021c. *Restoration Opportunities Assessment Methodology (ROAM)*. International Union for Conservation of Nature (IUCN). Retrieved May 2021 from <https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/restoration-opportunities-assessment-methodology-roam>
- Kindt R, van Breugel P, Lillesø J-PB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011a. Volume 2: Description and tree species composition for forest potential natural vegetation types. https://static-curis.ku.dk/portal/files/244325182/2_VECEA_Volume_2_Forest.pdf
- Kindt R, van Breugel P, Lillesø J-PB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011b. Volume 3: Description and tree species composition for woodland and wooded grassland potential natural vegetation types. https://static-curis.ku.dk/portal/files/36077559/VECEA_Volume3_Woodlands.pdf

- Kindt R, van Breugel P, Lillesø J-PB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011c. Volume 4: Description and tree species composition for bushland and thicket potential natural vegetation types. https://static-curis.ku.dk/portal/files/244325252/2_VECEA_Volume_4_Bushland.pdf
- Kuhn M and Wickham H. 2020. *Tidymodels: A collection of packages for modeling and machine learning using tidyverse principles*. <https://www.tidymodels.org>
- Lal R. 2003. Soil erosion and the global carbon budget. *Environment International* 29(4): 437–450. [https://doi.org/10.1016/s0160-4120\(02\)00192-7](https://doi.org/10.1016/s0160-4120(02)00192-7)
- Lal R and Moldenhauer WC. 1987. Effects of soil erosion on crop productivity. *Critical Reviews in Plant Sciences* 5(4): 303–367. <https://doi.org/10.1080/07352688709382244>
- Li J, Lewis J, Rowland J, Tappan G, Tieszen L. 2004. Evaluation of land performance in Senegal using multi-temporal NDVI and rainfall series. *Journal of Arid Environments* 59(3): 463–480.
- Lillesø J-PB, Barsotti D, Kalema J, van Breugel P, Pedercini F, Graudal L, Jamnadass R, Kindt R. 2023. (in preparation). *What constitutes a good reference map for vegetation restoration? Forests and forest types in Uganda and Kenya*.
- Loarie SR, Duffy PB, Hamilton H, Asner GP, Field CB, Ackerly DD. 2009. The velocity of climate change. *Nature* 462(7,276): 1,052–1,055. <https://doi.org/10.1038/nature08649>
- Mansourian S, Stanturf JA, Derkyi MAA, Engel VL. 2017. Forest landscape restoration: Increasing the positive impacts of forest restoration or simply the area under tree cover? *Restoration Ecology* 25(2): 178–183. <https://doi.org/10.1111/rec.12489>
- Masozera MK and Alavalapati JRR. 2004. Forest dependency and its implications for protected areas management: A case study from the Nyungwe Forest Reserve, Rwanda. *Scandinavian Journal of Forest Research* 19(sup004): 85–92. <https://doi.org/10.1080/14004080410034164>
- MINIRENA (Ministry of Natural Resources). 2014. *Forest Landscape Restoration Opportunity Assessment for Rwanda*. MINIRENA – Rwanda. IUCN and WRI.
- Ministry of Environment of Rwanda. 2019. *Rwanda Forest Cover Mapping*.
- Moguel P and Toledo VM. 1999. Biodiversity conservation in traditional coffee systems of Mexico. *Conservation Biology* 13(1): 11–21. <https://doi.org/10.1046/j.1523-1739.1999.97153.x>
- Myhre G, Alterskjær K, Stjern CW, Hodnebrog Ø, Marelle L, Samset BH, Sillmann J, Schaller N, Fischer E, Schulz M, et al. 2019. Frequency of extreme precipitation increases extensively with event rareness under global warming. *Scientific Reports* 9(1): <https://doi.org/10.1038/s41598-019-52277-4>
- Ndayambaje JD and Mohren GMJ. 2011. Fuelwood demand and supply in Rwanda and the role of agroforestry. *Agroforestry Systems* 83(3): 303–320. <https://doi.org/10.1007/s10457-011-9391-6>
- Nelson A, Weiss DJ, van Etten J, Cattaneo A, McMenomy TS, Koo J. 2019. A suite of global accessibility indicators. *Scientific Data* 6(1): <https://doi.org/10.1038/s41597-019-0265-5>
- Nkamleu GB and Manyong VM. 2005. Factors affecting the adoption of agroforestry practices by farmers in Cameroon. *Small-scale Forest Economics, Management and Policy* 4(2): 135–148. <https://doi.org/10.1007/s11842-005-0009-6>
- Noss RF. 2001. Beyond Kyoto: Forest management in a time of rapid climate change. *Conservation Biology* 15(3): 578–590. <https://doi.org/10.1046/j.1523-1739.2001.015003578.x>
- Pebesma E. 2018. Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10(1): 439–446. <https://doi.org/10.32614/RJ-2018-009>
- Pedercini F, Dawson IK, Kindt R, Tadesse W, Moestrup S, Abiyu A, Lillesø J-PB, van Schoubroeck F, McMullin S, Carsan S. 2021. Priority landscapes for tree-based restoration in Ethiopia. ICRAF Working Paper No. 320. Nairobi, Kenya: World Agroforestry. <https://doi.org/10.5716/WP21037.PDF>
- QGIS Development Team. 2021. *QGIS Geographic Information System. Open Source Geospatial Foundation Project*. (Version 3.18) <http://qgis.osgeo.org>
- R Core Team. 2020. *R: A language and environment for statistical computing*. <https://www.R-project.org/>
- REMA (Rwanda Environment Management Authority). 2019. *Rwanda Forest Cover Mapping*. Republic of Rwanda Ministry of Environment. Retrieved from https://www.environment.gov.rw/fileadmin/user_upload/Moe/Publications/Reports/Forest_cover_report_2019.pdf

- Rurangwa ML, Matthews TJ, Niyigaba P, Tobias JA, Whittaker RJ. 2021. Assessing tropical forest restoration after fire using birds as indicators: An afro-tropical case study. *Forest Ecology and Management* 483: 118765. <https://doi.org/10.1016/j.foreco.2020.118765>
- Santoro M, Cartus O, Mermoz S, Bouvet A, Le Toan T, Carvalhais N, Rozendaal D, Herold M, Avitabile V, Quegan S, et al. 2018. *GlobBiomass global above-ground biomass and growing stock volume datasets*. Accessed from <http://globbiomass.org/products/global-mapping>
- Scheffers BR, Edwards DP, Diesmos A, Williams SE, Evans TA. 2014. Microhabitats reduce animal's exposure to climate extremes. *Global Change Biology* 20(2): 495–503. <https://doi.org/10.1111/gcb.12439>
- Schuster R, Hanson JO, Strimas-Mackey M, Bennett JR. 2020. Exact integer linear programming solvers outperform simulated annealing for solving conservation planning problems. *PeerJ* 8: e9258. <https://doi.org/10.7717/peerj.9258>
- Srivathsa A, Vasudev D, Nair T, Chakrabarti S, Chanchani P, Defries R, Deomurari A, Dutta S, Ghose D, Goswami VR, et al. 2023. Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being. *Nature Sustainability*. <https://doi.org/10.1038/s41893-023-01063-2>
- Strassburg BBN, Iribarrem A, Beyer HL, Cordeiro CL, Crouzeilles R, Jakovac CC, Braga Junqueira A, Lacerda E, Latawiec AE, Balmford A, et al. 2020. Global priority areas for ecosystem restoration. *Nature* 586(7,831): 724–729. <https://doi.org/10.1038/s41586-020-2784-9>
- Sunderland TCH, Ehringhaus C, Campbell BM. 2007. Conservation and development in tropical forest landscapes: A time to face the trade-offs? *Environmental Conservation* 34(04): <https://doi.org/10.1017/s0376892908004438>
- Tafere SM and Nigussie ZA. 2018. The adoption of introduced agroforestry innovations: Determinants of a high adoption rate – a case-study from Ethiopia. *Forests, Trees and Livelihoods* 27(3): 175–194. <https://doi.org/10.1080/14728028.2018.1493954>
- Tebaldi C, Debeire K, Eyring V, Fischer E, Fyfe J, Friedlingstein P, Knutti R, Lowe J, O'Neill B, Sanderson B, et al. 2021. Climate model projections from the Scenario Model Intercomparison Project (ScenarioMIP) of CMIP6. *Earth System Dynamics* 12(1): 253–293. <https://doi.org/10.5194/esd-12-253-2021>
- Title PO and Bemmels JB. 2018. ENVIREM: An expanded set of bioclimatic and topographic variables increases flexibility and improves performance of ecological niche modeling. *Ecography* 41(2): 291–307. <https://doi.org/10.1111/ecog.02880>
- Tracewski Ł, Butchart SHM, Di Marco M, Ficetola GF, Rondinini C, Symes A, Wheatley H, Beresford AE, Buchanan GM. 2016. Toward quantification of the impact of 21st-century deforestation on the extinction risk of terrestrial vertebrates. *Conservation Biology* 30(5): 1,070–1,079. <https://doi.org/10.1111/cobi.12715>
- Trumbore S, Brando P, Hartmann H. 2015. Forest health and global change. *Science* 349(6250): 814–818. <https://doi.org/10.1126/science.aac6759>
- UNEP-WCMC and IUCN. 2023. *Protected Planet: The World Database on Protected Areas (WDPA)*. Accessed from <https://www.protectedplanet.net/en>
- University of Maryland and World Resources Institute. 2023. *Global Primary Forest Loss*. Accessed through Global Forest Watch on 25 April 2023 from www.globalforestwatch.org.
- Vågen T-G and Winowiecki LA. 2019. Predicting the spatial distribution and severity of soil erosion in the global tropics using satellite remote sensing. *Remote Sensing* 11(15): 1,800. <https://doi.org/10.3390/rs11151800>
- van Breugel P, Kindt R, Lillesø J-PB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F, et al. 2015. Potential Natural Vegetation Map of Eastern Africa (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia). Version 2.0. Forest and Landscape (Denmark) and World Agroforestry (ICRAF). <http://vegetationmap4africa.org>
- Veldman JW, Overbeck GE, Negreiros D, Mahy G, Le Stradic S, Fernandes GW, Durigan G, Buisson E, Putz FE, Bond WJ. 2015. Where tree planting and forest expansion are bad for biodiversity and ecosystem services. *BioScience* 65(10): 1,011–1,018. <https://doi.org/10.1093/biosci/biv118>
- Weiss DJ, Nelson A, Gibson HS, Temperley W, Peedell S, Lieber A, Hancher M, Poyart E, Belchior S, Fullman N, et al. 2018. A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature* 553(7,688): 333–336. <https://doi.org/10.1038/nature25181>

- Wickham H, Averick M, Bryan J, Chang W, McGowan L, François R, Grolemund G, Hayes A, Henry L, Hester J, et al. 2019. Welcome to the tidyverse. *Journal of Open Source Software* 4(43): 1,686. <https://doi.org/10.21105/joss.01686>
- World Bank. 2023. *The World Bank Data - Rwanda*. Retrieved 24 April 2023 from <https://data.worldbank.org/country/rwanda>
- WRI. 2014. *Atlas of Forest and Landscape Restoration Opportunities*. Washington, DC: World Resources Institute (WRI). Retrieved 25 April 2023 from <https://www.wri.org/data/atlas-forest-and-landscape-restoration-opportunities>
- Wright MN and Ziegler A. 2015. ranger: A fast implementation of random forests for high dimensional data in C++ and R. *arXiv preprint arXiv:1508.04409*.
- Zanaga D, van de Kerchove R, Daems D, de Keersmaecker W, Brockmann C, Kirches G, Wevers J, Cartus O, Santoro M, Fritz S, et al. 2022. *ESA WorldCover 10 m 2021 v200*. Accessed from <https://doi.org/10.5281/zenodo.7254221>
- Zheng H, Chen F, Ouyang Z, Tu N, Xu W, Wang X, Miao H, Li X, Tian Y. 2008. Impacts of reforestation approaches on runoff control in the hilly red soil region of Southern China. *Journal of Hydrology* 356(1–2): 174–184. <https://doi.org/10.1016/j.jhydrol.2008.04.007>
- Zomer RJ, Neufeldt H, Xu J, Ahrends A, Bossio D, Trabucco A, van Noordwijk M, Wang M. 2016. Global tree cover and biomass carbon on agricultural land: The contribution of agroforestry to global and national carbon budgets. *Scientific Reports* 6: 29987. <https://doi.org/10.1038/srep29987>

Appendices

Appendix 1. Potential natural vegetation reclassification approach

Table 3. List of potential natural vegetation (PNV) types found in Rwanda, with a column that specifies whether the PNV was included in the analysis – and thus whether tree (or shrub) growth is suitable in the area

CODE	PNV	Class	Included in analysis
A	Afroalpine vegetation	Other	No
B	Afromontane bamboo	Woodland	Yes
Be	Evergreen and semi-evergreen bushland and thicket	Woodland	Yes
Be/R	Evergreen and semi-evergreen bushland and thicket + riverine wooded vegetation	Woodland	Yes
E	Montane Ericaceous belt	Bushland	Yes
Fa	Afromontane rain forest	Forest	Yes
Fd	Single-dominant <i>Hagenia abyssinica</i> forest	Forest	Yes
Fd/B	Single-dominant <i>Hagenia abyssinica</i> forest and Afromontane bamboo	Forest	Yes
Ff	Lake Victoria transitional rain forest	Forest	Yes
g/P	Edaphic grassland on drainage-impaired or seasonally flooded soils and palm wooded grassland	Other	No
g/X	Edaphic grassland on drainage-impaired or seasonally flooded soils + freshwater swamp	Other	No
w	Water bodies	Other	No
X	Freshwater swamp	Other	No

Appendix 2. Reclassified spatial indicators

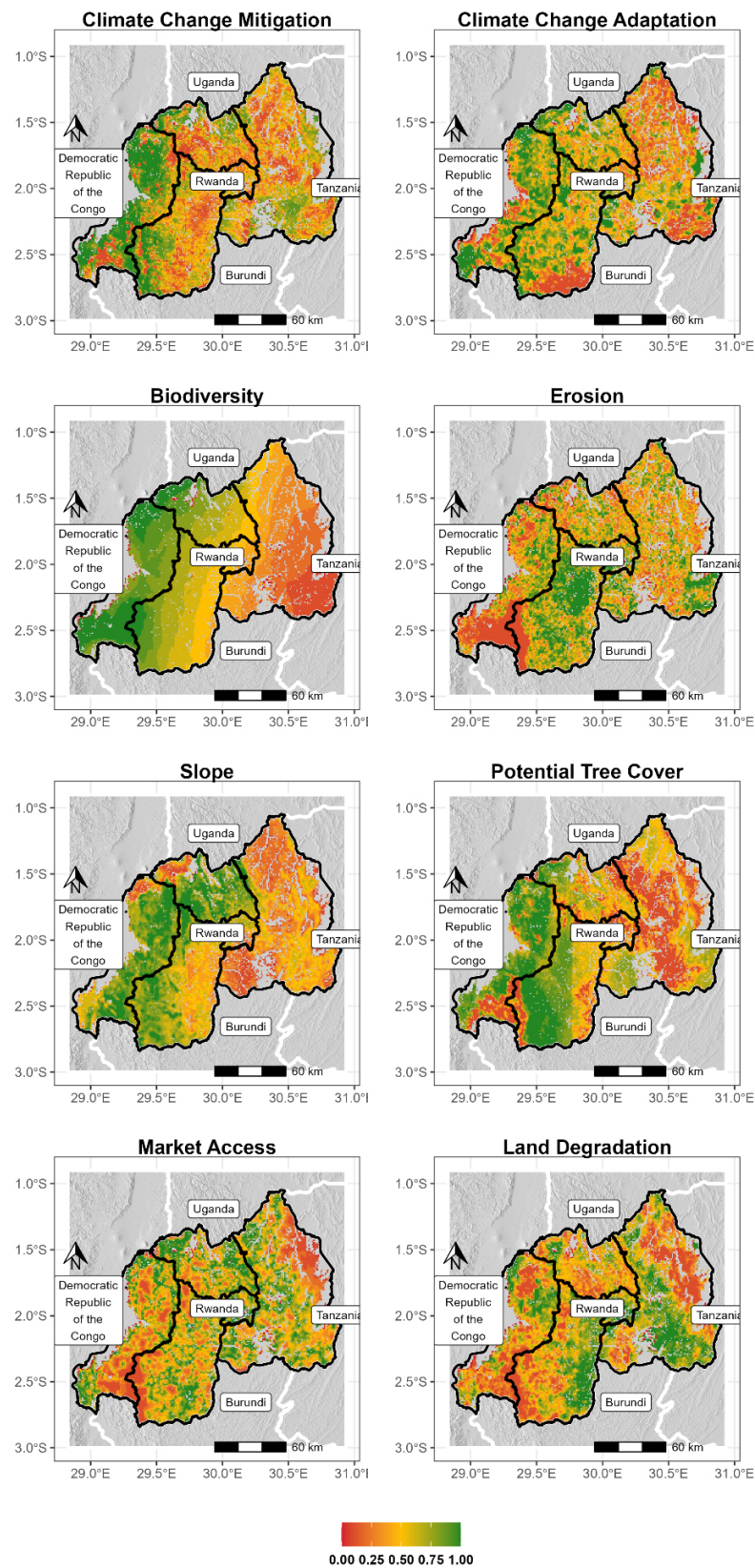


Figure 9. Spatial overview of selected criteria for landscape prioritization

Note: Values are reclassified from 0 to 1 using deciles. Higher values correspond to higher predicted benefits of implementing tree-based restoration

Appendix 3. Priority areas by district for national approach

Table 4. Breakdown of total priority areas for each domain per district when adopting a national approach to prioritization

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Eastern	Bugesera	Converted	Top 20%	2,905	3.3	88,081
		Converted	Top 50%	15,463	17.6	
		Converted	Low	69,713	79.1	
Eastern	Gatsibo	Converted	Top 20%	427	0.4	105,338
		Converted	Top 50%	6,664	6.3	
		Converted	Low	98,247	93.3	
Eastern	Gatsibo	Unconverted	Top 10%	342	2.0	17,514
		Unconverted	Top 20%	1,794	10.2	
		Unconverted	Top 50%	4,272	24.4	
		Unconverted	Low	11,106	63.4	
Eastern	Kayonza	Converted	Top 20%	342	0.3	108,072
		Converted	Top 50%	14,523	13.4	
		Converted	Low	93,207	86.2	
Eastern	Kayonza	Unconverted	Top 10%	1,281	4.1	31,524
		Unconverted	Top 20%	2,734	8.7	
		Unconverted	Top 50%	5,809	18.4	
		Unconverted	Low	21,700	68.8	
Eastern	Kirehe	Converted	Top 10%	2,221	2.4	91,669
		Converted	Top 20%	5,126	5.6	
		Converted	Top 50%	28,791	31.4	
		Converted	Low	55,531	60.6	
Eastern	Ngoma	Converted	Top 20%	1,880	3.0	61,853
		Converted	Top 50%	4,613	7.5	
		Converted	Low	55,360	89.5	
Eastern	Nyagatare	Converted	Top 20%	1,196	0.9	140,451
		Converted	Top 50%	6,407	4.6	
		Converted	Low	132,847	94.6	
Eastern	Nyagatare	Unconverted	Top 10%	513	6.1	8,372
		Unconverted	Top 20%	1,538	18.4	
		Unconverted	Top 50%	1,965	23.5	
		Unconverted	Low	4,357	52.0	
Eastern	Rwamagana	Converted	Top 20%	85	0.2	53,481
		Converted	Top 50%	4,613	8.6	
		Converted	Low	48,782	91.2	
Kigali	Gasabo	Converted	Top 10%	854	2.8	30,841
		Converted	Top 20%	3,503	11.4	
		Converted	Top 50%	9,398	30.5	
		Converted	Low	17,086	55.4	

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Table 4. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Kigali	Kicukiro	Converted	Top 10%	854	11.9	7,176
		Converted	Top 20%	1,452	20.2	
		Converted	Top 50%	2,563	35.7	
		Converted	Low	2,307	32.1	
Kigali	Nyarugenge	Converted	Top 10%	683	8.2	8,287
		Converted	Top 20%	1,623	19.6	
		Converted	Top 50%	5,724	69.1	
		Converted	Low	256	3.1	
Northern	Burera	Converted	Top 10%	1,538	4.6	33,233
		Converted	Top 20%	3,076	9.3	
		Converted	Top 50%	12,986	39.1	
		Converted	Low	15,634	47.0	
Northern	Burera	Unconverted	Top 10%	7,176	58.3	12,302
		Unconverted	Top 20%	1,794	14.6	
		Unconverted	Top 50%	1,367	11.1	
		Unconverted	Low	1,965	16.0	
Northern	Gakenke	Converted	Top 10%	171	0.3	66,381
		Converted	Top 20%	2,905	4.4	
		Converted	Top 50%	22,469	33.8	
		Converted	Low	40,837	61.5	
Northern	Gicumbi	Converted	Top 10%	5,041	6.8	73,728
		Converted	Top 20%	2,392	3.2	
		Converted	Top 50%	22,554	30.6	
		Converted	Low	43,741	59.3	
Northern	Gicumbi	Unconverted	Top 10%	940	100.0	940
Northern	Musanze	Converted	Top 10%	3,161	9.2	34,173
		Converted	Top 20%	5,297	15.5	
		Converted	Top 50%	15,805	46.2	
		Converted	Low	9,910	29.0	
Northern	Musanze	Unconverted	Top 10%	4,015	47.0	8,543
		Unconverted	Top 20%	1,367	16.0	
		Unconverted	Top 50%	1,709	20.0	
		Unconverted	Low	1,452	17.0	
Northern	Rulindo	Converted	Top 10%	2,819	5.5	50,832
		Converted	Top 20%	2,990	5.9	
		Converted	Top 50%	20,760	40.8	
		Converted	Low	24,263	47.7	
Southern	Gisagara	Converted	Top 10%	4,186	7.4	56,471
		Converted	Top 20%	6,749	12.0	
		Converted	Top 50%	25,203	44.6	
		Converted	Low	20,333	36.0	

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Table 4. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Southern	Huye	Converted	Top 10%	13,925	25.5	54,506
		Converted	Top 20%	10,252	18.8	
		Converted	Top 50%	24,092	44.2	
		Converted	Low	6,237	11.4	
Southern	Kamonyi	Converted	Top 10%	1,965	3.5	55,531
		Converted	Top 20%	7,774	14.0	
		Converted	Top 50%	36,480	65.7	
		Converted	Low	9,312	16.8	
Southern	Muhanga	Converted	Top 10%	8,031	13.1	61,169
		Converted	Top 20%	10,423	17.0	
		Converted	Top 50%	34,515	56.4	
		Converted	Low	8,201	13.4	
Southern	Nyamagabe	Converted	Top 10%	15,122	18.4	82,015
		Converted	Top 20%	23,494	28.6	
		Converted	Top 50%	32,806	40.0	
		Converted	Low	10,594	12.9	
Southern	Nyamagabe	Unconverted	Top 10%	513	2.0	25,886
		Unconverted	Top 20%	1,794	6.9	
		Unconverted	Top 50%	12,986	50.2	
		Unconverted	Low	10,594	40.9	
Southern	Nyanza	Converted	Top 10%	7,262	12.1	60,144
		Converted	Top 20%	7,262	12.1	
		Converted	Top 50%	29,560	49.1	
		Converted	Low	16,061	26.7	
Southern	Nyaruguru	Converted	Top 10%	23,836	31.7	75,266
		Converted	Top 20%	16,403	21.8	
		Converted	Top 50%	29,560	39.3	
		Converted	Low	5,468	7.3	
Southern	Nyaruguru	Unconverted	Top 10%	598	2.4	24,434
		Unconverted	Top 20%	2,136	8.7	
		Unconverted	Top 50%	11,277	46.2	
		Unconverted	Low	10,423	42.7	
Southern	Ruhango	Converted	Top 10%	5,639	9.7	58,265
		Converted	Top 20%	14,865	25.5	
		Converted	Top 50%	35,284	60.6	
		Converted	Low	2,478	4.3	
Western	Karongi	Converted	Top 10%	8,372	11.9	70,567
		Converted	Top 20%	14,523	20.6	
		Converted	Top 50%	30,243	42.9	
		Converted	Low	17,428	24.7	
Western	Karongi	Unconverted	Top 20%	256	15.0	1,709
		Unconverted	Top 50%	342	20.0	
		Unconverted	Low	1,111	65.0	

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Table 4. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Western	Ngororero	Converted	Top 10%	36,394	56.1	64,843
		Converted	Top 20%	14,780	22.8	
		Converted	Top 50%	7,945	12.3	
		Converted	Low	5,724	8.8	
Western	Ngororero	Unconverted	Top 10%	342	44.4	769
		Unconverted	Top 20%	171	22.2	
		Unconverted	Top 50%	85	11.1	
		Unconverted	Low	171	22.2	
Western	Nyabihu	Converted	Top 10%	10,935	24.3	44,937
		Converted	Top 20%	6,749	15.0	
		Converted	Top 50%	11,021	24.5	
		Converted	Low	16,232	36.1	
Western	Nyabihu	Unconverted	Top 10%	1,281	27.8	4,613
		Unconverted	Top 20%	1,025	22.2	
		Unconverted	Top 50%	598	13.0	
		Unconverted	Low	1,709	37.0	
Western	Nyamasheke	Converted	Top 10%	6,407	11.8	54,249
		Converted	Top 20%	2,136	3.9	
		Converted	Top 50%	16,659	30.7	
		Converted	Low	29,047	53.5	
Western	Nyamasheke	Unconverted	Top 10%	769	2.6	30,072
		Unconverted	Top 20%	2,478	8.2	
		Unconverted	Top 50%	10,935	36.4	
		Unconverted	Low	15,890	52.8	
Western	Rubavu	Converted	Top 10%	5,468	19.8	27,595
		Converted	Top 20%	3,844	13.9	
		Converted	Top 50%	9,483	34.4	
		Converted	Low	8,800	31.9	
Western	Rubavu	Unconverted	Top 10%	427	100.0	427
Western	Rusizi	Converted	Top 20%	85	0.2	43,570
		Converted	Top 50%	14,096	32.4	
		Converted	Low	29,389	67.5	
Western	Rusizi	Unconverted	Top 20%	2,990	7.7	38,615
		Unconverted	Top 50%	11,448	29.6	
		Unconverted	Low	24,177	62.6	
Western	Rutsiro	Converted	Top 10%	16,745	30.9	54,164
		Converted	Top 20%	7,176	13.2	
		Converted	Top 50%	14,780	27.3	
		Converted	Low	15,463	28.5	
Western	Rutsiro	Unconverted	Top 10%	3,246	37.3	8,714
		Unconverted	Top 20%	1,367	15.7	
		Unconverted	Top 50%	1,538	17.6	
		Unconverted	Low	2,563	29.4	

Appendix 4. Priority areas by district for sub-national approach

Table 5. Breakdown of total priority areas for each domain per district when adopting a sub-national approach to prioritization

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Eastern	Bugesera	Converted	Top 10%	9,568	10.9	88,081
		Converted	Top 20%	10,166	11.5	
		Converted	Top 50%	29,987	34.0	
		Converted	Low	38,359	43.5	
Eastern	Gatsibo	Converted	Top 10%	4,442	4.2	105,338
		Converted	Top 20%	6,578	6.2	
		Converted	Top 50%	30,328	28.8	
		Converted	Low	63,989	60.7	
Eastern	Gatsibo	Unconverted	Top 10%	1,965	11.2	17,514
		Unconverted	Top 20%	2,648	15.1	
		Unconverted	Top 50%	5,895	33.7	
		Unconverted	Low	7,005	40.0	
Eastern	Kayonza	Converted	Top 10%	12,644	11.7	108,072
		Converted	Top 20%	12,131	11.2	
		Converted	Top 50%	27,338	25.3	
		Converted	Low	55,958	51.8	
Eastern	Kayonza	Unconverted	Top 10%	2,734	8.7	31,524
		Unconverted	Top 20%	1,794	5.7	
		Unconverted	Top 50%	7,860	24.9	
		Unconverted	Low	19,137	60.7	
Eastern	Kirehe	Converted	Top 10%	26,484	28.9	91,669
		Converted	Top 20%	21,443	23.4	
		Converted	Top 50%	30,670	33.5	
		Converted	Low	13,071	14.3	
Eastern	Ngoma	Converted	Top 10%	4,784	7.7	61,853
		Converted	Top 20%	5,041	8.1	
		Converted	Top 50%	22,383	36.2	
		Converted	Low	29,645	47.9	
Eastern	Nyagatare	Converted	Top 10%	3,759	2.7	140,451
		Converted	Top 20%	6,237	4.4	
		Converted	Top 50%	32,635	23.2	
		Converted	Low	97,820	69.6	
Eastern	Nyagatare	Unconverted	Top 10%	1,025	12.2	8,372
		Unconverted	Top 20%	1,281	15.3	
		Unconverted	Top 50%	3,503	41.8	
		Unconverted	Low	2,563	30.6	
Eastern	Rwamagana	Converted	Top 10%	3,161	5.9	53,481
		Converted	Top 20%	3,332	6.2	
		Converted	Top 50%	21,358	39.9	
		Converted	Low	25,630	47.9	

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Table 5. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Kigali	Gasabo	Converted	Top 10%	2,050	6.6	30,841
		Converted	Top 20%	2,392	7.8	
		Converted	Top 50%	8,116	26.3	
		Converted	Low	18,282	59.3	
Kigali	Kicukiro	Converted	Top 10%	1,623	22.6	7,176
		Converted	Top 20%	769	10.7	
		Converted	Top 50%	2,221	31.0	
		Converted	Low	2,563	35.7	
Kigali	Nyarugenge	Converted	Top 10%	940	11.3	8,287
		Converted	Top 20%	1,452	17.5	
		Converted	Top 50%	3,588	43.3	
		Converted	Low	2,307	27.8	
Northern	Burera	Converted	Top 10%	3,844	11.6	33,233
		Converted	Top 20%	4,784	14.4	
		Converted	Top 50%	12,046	36.2	
		Converted	Low	12,559	37.8	
Northern	Burera	Unconverted	Top 10%	854	6.9	12,302
		Unconverted	Top 20%	1,623	13.2	
		Unconverted	Top 50%	3,332	27.1	
		Unconverted	Low	6,493	52.8	
Northern	Gakenke	Converted	Top 10%	2,734	4.1	66,381
		Converted	Top 20%	6,407	9.7	
		Converted	Top 50%	18,710	28.2	
		Converted	Low	38,530	58.0	
Northern	Gicumbi	Converted	Top 10%	6,749	9.2	73,728
		Converted	Top 20%	4,528	6.1	
		Converted	Top 50%	17,086	23.2	
		Converted	Low	45,365	61.5	
Northern	Gicumbi	Unconverted	Top 20%	171	18.2	940
		Unconverted	Top 50%	513	54.5	
		Unconverted	Low	256	27.3	
Northern	Musanze	Converted	Top 10%	8,629	25.2	34,173
		Converted	Top 20%	5,297	15.5	
		Converted	Top 50%	13,157	38.5	
		Converted	Low	7,091	20.8	
Northern	Musanze	Unconverted	Top 10%	1,281	15.0	8,543
		Unconverted	Top 20%	427	5.0	
		Unconverted	Top 50%	2,648	31.0	
		Unconverted	Low	4,186	49.0	
Northern	Rulindo	Converted	Top 10%	3,844	7.6	50,832
		Converted	Top 20%	4,784	9.4	
		Converted	Top 50%	16,574	32.6	
		Converted	Low	25,630	50.4	

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Table 5. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Southern	Gisagara	Converted	Top 10%	1,196	2.1	56,471
		Converted	Top 20%	2,136	3.8	
		Converted	Top 50%	9,568	16.9	
		Converted	Low	43,570	77.2	
Southern	Huye	Converted	Top 10%	7,689	14.1	54,506
		Converted	Top 20%	5,980	11.0	
		Converted	Top 50%	14,011	25.7	
		Converted	Low	26,826	49.2	
Southern	Kamonyi	Converted	Top 10%	683	1.2	55,531
		Converted	Top 20%	2,221	4.0	
		Converted	Top 50%	13,327	24.0	
		Converted	Low	39,299	70.8	
Southern	Muhanga	Converted	Top 10%	5,297	8.7	61,169
		Converted	Top 20%	6,237	10.2	
		Converted	Top 50%	19,393	31.7	
		Converted	Low	30,243	49.4	
Southern	Nyamagabe	Converted	Top 10%	15,292	18.6	82,015
		Converted	Top 20%	13,157	16.0	
		Converted	Top 50%	30,243	36.9	
		Converted	Low	23,323	28.4	
Southern	Nyamagabe	Unconverted	Top 10%	1,794	6.9	25,886
		Unconverted	Top 20%	3,076	11.9	
		Unconverted	Top 50%	7,603	29.4	
		Unconverted	Low	13,413	51.8	
Southern	Nyanza	Converted	Top 10%	1,965	3.3	60,144
		Converted	Top 20%	2,905	4.8	
		Converted	Top 50%	14,951	24.9	
		Converted	Low	40,324	67.0	
Southern	Nyaruguru	Converted	Top 10%	16,659	22.1	75,266
		Converted	Top 20%	14,267	19.0	
		Converted	Top 50%	27,765	36.9	
		Converted	Low	16,574	22.0	
Southern	Nyaruguru	Unconverted	Top 10%	3,161	12.9	24,434
		Unconverted	Top 20%	1,965	8.0	
		Unconverted	Top 50%	7,518	30.8	
		Unconverted	Low	11,790	48.3	
Southern	Ruhango	Converted	Top 10%	1,538	2.6	58,265
		Converted	Top 20%	3,417	5.9	
		Converted	Top 50%	21,785	37.4	
		Converted	Low	31,524	54.1	

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Table 5. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Western	Karongi	Converted	Top 10%	769	1.1	70,567
		Converted	Top 20%	4,955	7.0	
		Converted	Top 50%	32,721	46.4	
		Converted	Low	32,123	45.5	
Western	Karongi	Unconverted	Top 10%	85	5.0	1,709
		Unconverted	Top 20%	342	20.0	
		Unconverted	Top 50%	171	10.0	
		Unconverted	Low	1,111	65.0	
Western	Ngororero	Converted	Top 10%	19,991	30.8	64,843
		Converted	Top 20%	11,448	17.7	
		Converted	Top 50%	20,760	32.0	
		Converted	Low	12,644	19.5	
Western	Ngororero	Unconverted	Top 10%	342	44.4	769
		Unconverted	Top 20%	85	11.1	
		Unconverted	Top 50%	171	22.2	
		Unconverted	Low	171	22.2	
Western	Nyabihu	Converted	Top 10%	6,237	13.9	44,937
		Converted	Top 20%	6,322	14.1	
		Converted	Top 50%	11,533	25.7	
		Converted	Low	20,845	46.4	
Western	Nyabihu	Unconverted	Top 10%	1,623	35.2	4,613
		Unconverted	Top 20%	683	14.8	
		Unconverted	Top 50%	1,623	35.2	
		Unconverted	Low	683	14.8	
Western	Nyamasheke	Converted	Top 10%	2,648	4.9	54,249
		Converted	Top 20%	1,880	3.5	
		Converted	Top 50%	11,790	21.7	
		Converted	Low	37,932	69.9	
Western	Nyamasheke	Unconverted	Top 10%	1,880	6.2	30,072
		Unconverted	Top 20%	2,563	8.5	
		Unconverted	Top 50%	12,046	40.1	
		Unconverted	Low	13,584	45.2	
Western	Rubavu	Converted	Top 20%	3,246	11.8	27,595
		Converted	Top 50%	11,704	42.4	
		Converted	Low	12,644	45.8	
Western	Rubavu	Unconverted	Top 10%	427	100.0	427
Western	Rusizi	Converted	Top 20%	85	0.2	43,570
		Converted	Top 50%	2,734	6.3	
		Converted	Low	40,751	93.5	
Western	Rusizi	Unconverted	Top 10%	513	1.3	38,615
		Unconverted	Top 20%	3,076	8.0	
		Unconverted	Top 50%	10,252	26.5	
		Unconverted	Low	24,775	64.2	

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Table 5. Continued

Province	District	Domain	Priority level	Priority area (ha)	% of DA	Total area (ha)
Western	Rutsiro	Converted	Top 10%	6,322	11.7	54,164
		Converted	Top 20%	8,031	14.8	
		Converted	Top 50%	16,745	30.9	
		Converted	Low	23,067	42.6	
Western	Rutsiro	Unconverted	Top 10%	3,588	41.2	8,714
		Unconverted	Top 20%	1,709	19.6	
		Unconverted	Top 50%	1,281	14.7	
		Unconverted	Low	2,136	24.5	

Appendix 5. Comparison of forest map and tree cover areas

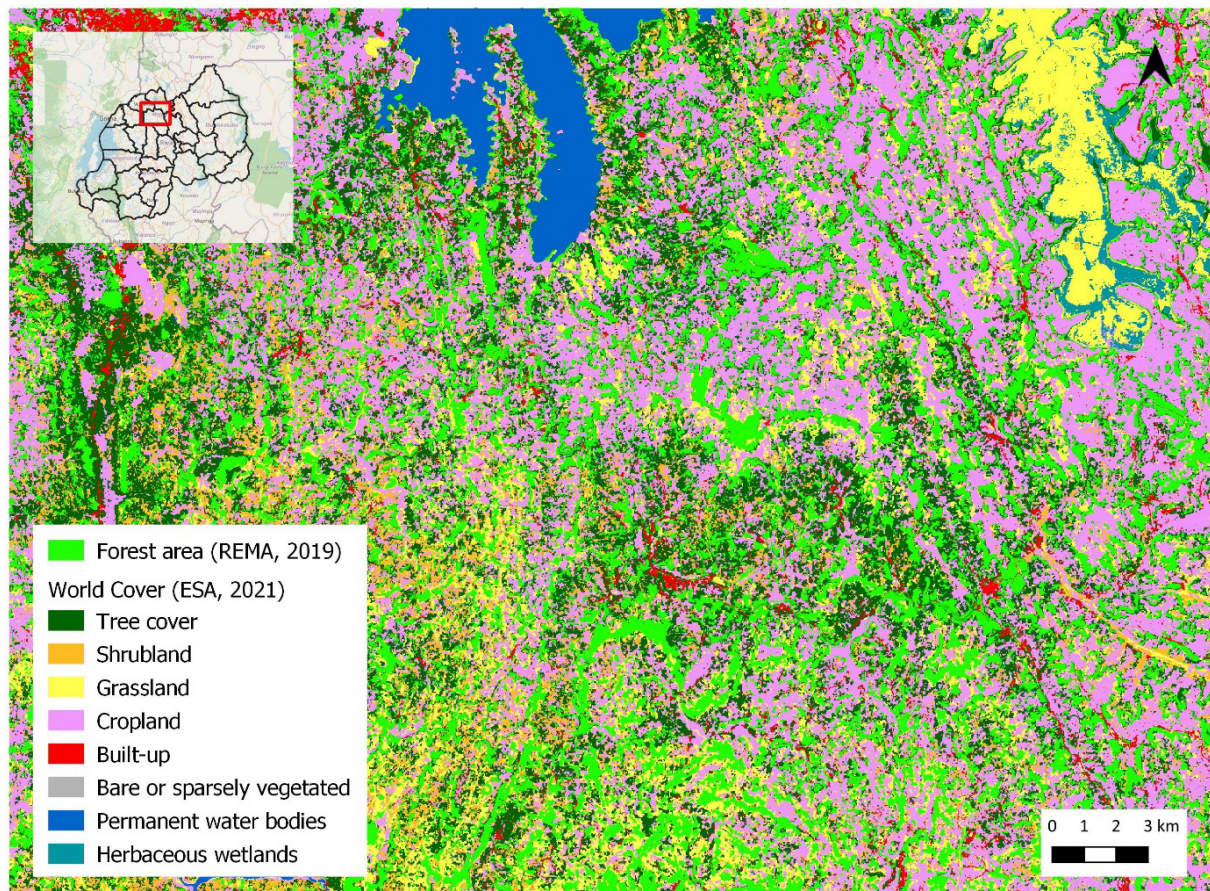


Figure 10. Overlay of land cover map (ESA 2021) and forest map (REMA 2019) which depicts the differences in classification

See also text above Figure 7 for more context.

Part 2.

Selection of a master list of priority tree species, including some potential seed sources for tree improvement in Rwanda

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Contents

1	Introduction	69
2	Data sources	70
3	Species ranking based on number of data sources	72
4	Attributes of the highest-ranked species	76
4.1	Attributes from ‘Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda’	76
4.2	Attributes from an online species selection tool for Rwanda	84
4.3	Attributes from a global list of priority tree species for planting in the tropics and subtropics	87
5	Species available from existing seed sources in Rwanda	90
6	A subset of species for humid areas	95
	References	100
	Appendices	102
1	Full list of species and their presence in information sources	102
2	Full list of species with taxonomic details	114

List of figures and tables

Figures

1	Location of seed sources for prioritized species.	94
2	Country and provincial boundaries for Rwanda sourced from the GADM database	95
3	Overlay of the Climatic Moisture Index (CMI) onto the map shown in Figure 2	96
4	Overlay of elevation zones (obtained from WorldClim 2.1) onto the map shown in Figure 2	96

Tables

1	Sources consulted to compile a comprehensive list of tree species	70
2	Ranking of prioritized species based on the number of sources in which these were listed	73
3	Information on geography and ecology of prioritized tree species	76
4	Information on products and ecological services of prioritized tree species	84
5	Global ranking of tree species with databases where information is available	88
6	Sources consulted to compile a comprehensive list of national seed sources	90
7	Prioritized species with available information on existing seed sources (S refers to the information source in Table 6).	90
8	Occurrence of the priority species list in different zones defined by the Climatic Moisture Index (CMI) as documented in the Tree Globally Observed Environmental Ranges database	97

1 Introduction

This report documents a list of priority tree species that are candidates to be included in the action plans for improved genetic material of native and exotic species, which aims to improve overall productivity, promote utilization and adoption, as well as increase distribution of high quality tree genetic material. This objective is part of an overarching programme that strives to improve landscape management in the Congo-Nile Ridge (CNR) landscape in Western Province of Rwanda. Establishment of partnerships and green climate financing to implement such improved landscape management will ultimately be supported by the PROGREEN grant.

This report is an output of a study for the World Bank to provide Technical Assistance in Forestry and Rural Development in Rwanda under PROGREEN (https://www.progreen.info/about_page).

The report has been provided as part of Task 1 of this study: analytical work and development of action plans for improved genetic material (native and exotic species), their productivity, promotion and distribution. This study takes a national perspective to make it relevant to other ongoing restoration projects and broader tree-based interventions.

The report provides a master list of 90 priority tree species (from a total of 458 species) for possible improvement (section 2) and the baseline tree seed source register including 32 species (section 5). Attributes of the priority species are described from different sources of information (section 4) and the suitability of the priority species for climate zones in the western region is tabled (section 5).

We first propose a method to consolidate a master list of priority species by gathering existing priority lists proposed by Rwanda Forestry Authority, external forestry consultants and researchers. Subsequently, we map existing seed sources, seed stands and tree improvement trials to establish a basis and a gap analysis for reliable seed collection of priority-listed tree species. The information here contributes to the design of the proposed research and development programme for tree improvement in Rwanda (see synthesis).

For establishment of breeding orchards, mother blocks and seed production stands (as part of the tree improvement programme) priority species should be identified on a yearly basis. This should take place in consultation with relevant stakeholders. In this process, the planting zones (deployment zones) should be considered to ensure adequate species and seed source-site matching, where relevant subsets of species will depend on environmental factors and their expected development with climate change.

2 Data sources

We compiled species lists from different ‘sources’ that we deemed relevant for the project. Several of these sources were shared with us from Rwandan partners and experts in response to our requests for results of previous priority setting exercises for trees, especially for Western Province. Table 1 gives an overview of the final set of sources used in this report. The order by which sources are listed in Table 1 and elsewhere in the report is arbitrary and mainly reflects the sequence by which these sources were compiled.

Mainly as a sensitivity analysis, we gave different weights to the sources to increase probabilities that species listed in certain sources would be selected, with some sources being considered more relevant (higher weight, see next section).

An additional list of priority species that should be taken into consideration when moving ahead with further prioritisation is the Ministerial Order Establishing a List of Protected Trees (2015) with a list of 84 protected tree species in state, district or private forests, and isolated species of trees (RoR 2015).

Table 1. Sources consulted to compile a comprehensive list of tree species

Source	Explanation	Reference and comments	Weight
Catalogue	Species listed in the 2020 Tree Seed Catalogue of the Rwanda Tree Seed Centre. The catalogue lists 128 taxa. ¹	RFA (2020); PDF document available from the Rwanda Forestry Authority.	1
Nursery	Indigenous trees listed in the Rwanda Wildlife Conservation Association (RWCA). The list includes 38 taxa. ²	RWCA (2025); PDF document available from the RWCA	1
Book	Trees and shrubs listed in the book ‘Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda’. The book includes 222 taxa.	Nduwayezu et al. (2009)	2
SuitableApp	Species listed in an online species selection tool developed for Bugesera and Gishwati. The tool describes 111 taxa.	Kuria (2017)	1
COMBIO	Species covered by the COMBIO project. 20 species were listed.	MoE (2025) Email correspondence with Jacques Peeters (Enabel).	1
Mukuralinda	Priority tree species shared by Athanase. 74 species were listed.	Mukuralinda (2022) Available from the author.	2
RTSC	Seed sales at the RFA Tree Seed Centre in the period 2016–2019 ranked by quantity (kg) and income (RWF). 52 species were listed.	Pedersen (2019) Shared by Jacques Peeters, Enabel.	2

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1 During the standardization of names, various synonyms were encountered including those of *Afrocarpus falcatus* and *Podocarpus falcatus*; *Dombeya goetzenii* and *Dombeya torrida*; and *Pinus oocarpa* var. *ochoteranae* and *Pinus patula* var. *tecunamanii*.

2 There is no entry #16 in this catalogue. *Markhamia lutea* and *Markhamia platycalyx* are synonyms.

Table 1. Continued

Source	Explanation	Reference and comments	Weight
Regreening	Species planted in the Eastern Savanna Region through the Regreening Africa project as captured in the baseline report and final report. 22 species were listed.	Regreening Africa (2022) Email communication with Sammy Carsan, 31 January 2023.	1
LakeKivu	Inventory of Kivu island biodiversity and socioeconomic values, particularly in Karongi District. A total of seven islands were surveyed to study birds, plants, invertebrates, small mammals, reptiles, amphibians and socioeconomics.	REMA (2012)	2
GMNPmp	Ten-year management plan and three-year action plan for Gishwati-Mukura National Park (GMNP). The document includes management programmes for several components: ecological, community, tourism and management, as well as security and operation.	RDB & REMA (2017) Available from the author.	2
GMNPbdv	Biodiversity survey of GMNP commissioned by the Rwanda Environment Management Authority (REMA) and carried out by a team of researchers. The study focuses on plants, mammals, birds, amphibians and reptiles.	BIOCEM-RD Ltd (2018) Available from the author.	2
LAFREC ₀₀₃	Issue that targets the promotion of a more sustainable and eco-friendly mining business within the Gishwati-Mukura landscape. They include a priority list of native species for planting on degraded sites.	LAFREC (2018) LAFREC Mag. 2016. Gishwati-Mukura: Setting ground for eco-friendly mining sector. Issue 003 [April–June 2016].s LINK	3
GMNPGui	Informative guidebook that targets tourists and distributes general information with regard to the GMNP. In the flora section, key tree species from a touristic and ornamental perspective are mentioned.	RDB et al. Rwanda Development Board (RDB). n.d. Gishwati-Mukura National Park Guidebook. See also LINK	2
RFA5	The Rwanda Forestry Authority (RFA) selected five tree species with high economic value to boost the wood industry as the country planned to plant 30 million tree seedlings in the 2022/23 fiscal year.	KME Ltd (2021) Rwanda Forest Authority (RFA). 2021. Selection of 5 Tree Species With High Economic Value Likely to Boost the Wood Industry in Rwanda. <i>Final report</i> . See also LINK. Full document available from the author.	3

3 Species ranking based on number of data sources

Having compiled lists of species³ for different sources, we standardized species names to World Flora Online⁴ via the WorldFlora (Kindt, 2020) R package (different versions of the package were used, most recently version 1.13-2). Afterwards we cross-tabulated the species with the different information sources. The full cross-tabulation is available from Appendix 1, with Appendix 2 giving taxonomic details for all species.

Species were ranked by two different scores; one representing the count of sources by which they were listed ('Top-C'), and a second one representing a weighted count calculated by weighting counts ('Top-W'). The weighting process gave highest weights (3) to species prioritized by LAFREC and RFA for the CNR. Medium weights (2) were given to sources that still target the CNR and Western and Southern provinces of Rwanda, but without a specific focus on restoration and improvement (national park lists, biodiversity surveys, etc.). Finally, lowest weights (1) were given to sources which are targeting the national level, or other provinces of Rwanda. The reason to include such sources is that, while focusing on Western and Southern provinces, we wish to develop a tree breeding programme with a national and regional perspective.

Species were sorted by their scores and given the following rankings: A for species listed among the top-34+ (Top-C: 34 species listed in a minimum of five sources; Top-W: 36 species with a minimum score of 8); and B for species listed among the top-91+ (Top-C: 102 species listed in a minimum of three sources; Top-W: 91 species with a minimum score of five). Ranking C was given for species encountered among the sources, but not with rankings A or B. Ranking D was given to species encountered among the vegetation assemblages of the vegetationmap4Africa (Kindt et al., 2011a; Kindt et al., 2011b, 2011c) which were not mentioned by any sources.

Selecting species that were given rankings of A or B in the two ranking processes resulted in 90 species being prioritized. These are shown in Table 2 with relative information on species nativity to Rwanda⁵ (Govaerts et al., 2021). In the remainder of the document, these species will be referred to as top-ranking or prioritized species.

³ Although some sources listed trees at infraspecific levels, we did not resolve rankings to the species level. For simplicity reasons, we refer to all taxa as 'species' in most of this report.

⁴ Note that World Flora Online also provides information from different flora.

⁵ Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants

Table 2. Ranking of prioritized species based on the number of sources in which these were listed

Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red. Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants.

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukurilinda	RTSC	Regreening	Lakekivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNpgui	RFA5	Sources	Sources weighted
<i>Polyscias fulva</i> (n)	A	A	1	1	1	1	1	1	1	1	0	1	1	1	1	0	12	20
<i>Prunus africana</i> (n)	A	A	1	1	1	0	0	1	0	0	0	1	1	1	1	1	9	18
<i>Entandrophragma excelsum</i> (n)	A	A	1	1	1	0	0	0	1	0	0	0	1	1	1	1	8	16
<i>Symphonia globulifera</i> (n)	A	A	1	1	1	0	0	0	0	0	0	1	1	1	1	1	8	16
<i>Hagenia abyssinica</i> (n)	A	A	1	1	1	1	0	1	0	0	0	0	1	1	1	0	8	14
<i>Markhamia lutea</i> (n)	A	A	1	1	1	1	1	0	1	0	0	0	1	0	0	1	8	13
<i>Erythrina abyssinica</i> (n)	A	A	1	1	1	1	1	1	0	0	1	0	1	0	0	0	8	12
<i>Carapa grandiflora</i> (n)	A	A	0	1	0	0	0	1	1	0	0	1	1	1	1	0	7	14
<i>Acacia melanoxylon</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	1	7	13
<i>Grevillea robusta</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	1	7	13
<i>Maesopsis eminii</i> (e)	A	A	1	1	1	0	1	1	1	0	0	0	0	0	0	1	7	12
<i>Afrocarpus falcatus</i> (e)	A	A	1	1	1	0	0	0	1	0	0	0	0	1	0	1	6	12
<i>Pinus patula</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	1	6	11
<i>Maesa lanceolata</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	1	0	0	6	11
<i>Myrianthus holstii</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	1	0	0	6	11
<i>Acacia mearnsii</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	0	6	10
<i>Croton megalocarpus</i> (n)	A	A	1	1	1	1	0	0	1	0	0	0	0	1	0	0	6	10
<i>Dombeya torrida</i> (n)	A	A	1	1	1	1	0	0	0	0	0	0	1	1	0	0	6	10
<i>Parinari excelsa</i> (n)	A	A	1	0	1	0	0	1	0	0	0	0	1	1	0	0	5	10
<i>Persea americana</i> (e)	A	A	0	0	1	1	0	1	1	0	0	0	1	0	0	0	5	9
<i>Cupressus lusitanica</i> (e)	A	A	1	0	1	1	0	1	0	0	0	0	0	0	0	1	5	9
<i>Eucalyptus globulus subsp. maidenii</i> (e)	A	A	1	0	0	1	0	1	1	0	0	0	0	0	0	1	5	9
<i>Faurea saligna</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	0	1	0	0	5	9
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Casuarina equisetifolia</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Eucalyptus saligna</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Bersama abyssinica</i> (n)	A	A	0	0	1	1	0	1	0	1	0	0	1	0	0	0	5	8
<i>Syzygium guineense</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	0	0	0	5	8
<i>Neoboutonia macrocalyx</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	0	0	0	5	8
<i>Syzygium parvifolium</i> (n)	A	A	1	1	0	1	0	1	0	0	0	0	0	1	0	0	5	8
<i>Pterygota mildbraedii</i> (n)	A	A	1	1	1	1	0	0	0	0	0	0	0	0	0	1	5	8
<i>Ficus thonningii</i> (n)	A	B	0	1	1	1	1	1	0	0	0	0	0	0	0	0	5	7
<i>Senegalia polyacantha</i> (n)	A	B	1	1	1	0	1	0	1	0	0	0	0	0	0	0	5	7
<i>Entada abyssinica</i> (n)	A	B	1	1	1	0	1	0	0	0	1	0	0	0	0	0	5	7
<i>Pinus caribaea</i> (e)	B	A	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4	8
<i>Eucalyptus grandis</i> (e)	B	A	1	0	0	0	0	1	1	0	0	0	0	0	0	1	4	8
<i>Eucalyptus microcorys</i> (e)	B	A	1	0	0	0	0	1	1	0	0	0	0	0	0	1	4	8

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Table 2. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	Lakeivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Ficalhoa laurifolia</i> (n)	B	A	1	0	1	0	0	0	0	0	0	0	1	0	0	1	4	8
<i>Kuloa usambarensis</i> (n)	B	A	1	0	1	0	0	0	0	0	0	0	1	0	0	1	4	8
<i>Artocarpus heterophyllus</i> (e)	B	B	0	0	1	1	0	1	1	0	0	0	0	0	0	0	4	7
<i>Tephrosia vogelii</i> (n)	B	B	1	0	1	0	0	1	1	0	0	0	0	0	0	0	4	7
<i>Psidium guajava</i> (e)	B	B	0	0	1	1	0	1	0	0	1	0	0	0	0	0	4	7
<i>Mitragyna rubrostipulata</i> (n)	B	B	0	0	0	1	1	1	0	0	0	0	0	1	0	0	4	7
<i>Harungana montana</i> (n)	B	B	0	1	0	0	0	1	0	0	0	1	0	0	1	0	4	7
<i>Macaranga kilimandscharica</i> (n)	B	B	1	0	0	0	0	1	0	0	0	1	0	0	1	0	4	7
<i>Gambeya gorungosana</i> (n)	B	B	1	1	0	0	0	0	0	0	0	0	1	1	0	0	4	7
<i>Gymnanthemum amygdalinum</i> (e)	B	B	1	0	1	1	0	1	0	0	0	0	0	0	0	0	4	6
<i>Alnus acuminata</i> (e)	B	B	1	0	0	1	0	1	1	0	0	0	0	0	0	0	4	6
<i>Gliricidia sepium</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Acaciella angustissima</i> (e)	B	B	1	0	0	1	0	1	1	0	0	0	0	0	0	0	4	6
<i>Jacaranda mimosifolia</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Leucaena diversifolia</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Senna spectabilis</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Sesbania sesban</i> (n)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Cajanus cajan</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Leucaena leucocephala</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Senna siamea</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Spathodea campanulata</i> (n)	B	B	1	1	1	0	0	0	1	0	0	0	0	0	0	0	4	6
<i>Vachellia sieberiana</i> (n)	B	B	1	1	1	0	0	0	1	0	0	0	0	0	0	0	4	6
<i>Solanecio mannii</i> (n)	B	B	0	0	0	1	0	1	0	1	1	0	0	0	0	0	4	6
<i>Vachellia hockii</i> (n)	B	B	1	0	1	1	0	0	0	0	1	0	0	0	0	0	4	6
<i>Vepris nobilis</i> (n)	B	B	0	0	1	1	1	0	0	0	1	0	0	0	0	0	4	6
<i>Phoenix reclinata</i> (n)	B	B	1	0	1	0	0	0	0	1	1	0	0	0	0	0	4	6
<i>Newtonia buchananii</i> (n)	B	B	1	1	1	0	0	0	0	0	0	0	1	0	0	0	4	6
<i>Strombosia scheffleri</i> (n)	B	B	1	1	1	0	0	0	0	0	0	0	1	0	0	0	4	6
<i>Combretum molle</i> (n)	B	B	0	1	1	1	1	0	0	0	0	0	0	0	0	0	4	5
<i>Acokanthera schimperi</i> (n)	B	B	0	0	1	1	1	0	0	1	0	0	0	0	0	0	4	5
<i>Solanum betaceum</i> (e)	B	B	0	0	1	0	0	1	1	0	0	0	0	0	0	0	3	6
<i>Searsia natalensis</i> (e)	B	B	0	0	1	0	0	1	0	0	1	0	0	0	0	0	3	6
<i>Cornus volkensii</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Dracaena steudneri</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Ilex mitis</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Myrsine melanophloeos</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Xymalos monospora</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Ximenia caffra</i> (n)	B	B	0	0	1	0	0	0	0	1	0	0	0	1	0	0	3	6

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Table 2. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	Lakekivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Toona sinensis</i> (e)	B	B	0	0	0	1	0	1	1	0	0	0	0	0	0	0	3	5
<i>Euphorbia tirucalli</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Psydrax schimperianus</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Ficus laurifolia</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Morus nigra</i> (e)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Carica papaya</i> (e)	B	B	0	0	1	1	0	0	1	0	0	0	0	0	0	0	3	5
<i>Trema orientalis</i> (n)	B	B	0	0	1	0	1	1	0	0	0	0	0	0	0	0	3	5
<i>Eucalyptus tereticornis</i> (e)	B	B	1	0	0	0	0	1	1	0	0	0	0	0	0	0	3	5
<i>Mimosa scabrella</i> (e)	B	B	1	0	0	0	0	1	1	0	0	0	0	0	0	0	3	5
<i>Acrocarpus fraxinifolius</i> (e)	B	B	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	5
<i>Biancaea decapetala</i> (e)	B	B	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	5
<i>Dracaena afromontana</i> (n)	B	B	0	0	0	1	0	1	0	0	0	0	0	0	1	0	3	5
<i>Alnus glutinosa</i> (e)	B	B	0	0	1	1	0	0	0	0	0	0	1	0	0	0	3	5
<i>Euclea racemosa</i> (n)	B	B	0	0	1	1	0	0	0	0	1	0	0	0	0	0	3	5
<i>Macaranga capensis</i> (e)	B	B	0	1	1	0	0	0	0	0	0	0	1	0	0	0	3	5

4 Attributes of the highest-ranked species

The ranking of species given in the previous section is meant to be relative. When selecting species for particular activities in the project, it would be perfectly acceptable to compose a list that has some species with C or D status based on some other criteria besides the number of sources available – e.g., the preference of key local partners (Rwanda Forestry Authority, Rwanda Agriculture and Animal Resources Development Board). We thus strongly recommend that any final choices of species are cross-checked with national stakeholders and local experts. In this section, we provide some descriptors for the prioritized species that may aid in compiling final subsets of species.

4.1 Attributes from ‘Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda’

Table 3 provides information on geography and ecology of the prioritized species. The information was compiled from the *Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda* book (Nduwayezu et al., 2009). This information was also included in a Rwanda Tree Finder shinyapp that was developed for Rwanda based on the vegetationmap4africa (van Breugel, 2015). From this book, other information can be obtained about the prioritized species, such as their local names, uses and botanical descriptions. This book features among sources used to select priority tree species (Table 1).

Table 3. Information on geography and ecology of prioritized tree species

Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red. Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants.

Species	Geography and ecology
<i>Polyscias fulva</i> (n)	<i>P. fulva</i> is widely spread from Guinea Republic eastwards to Ethiopia and southwards through East and Central Africa south to Angola. It grows in upland grassland, and upland, riverine and lowland rainforests, at 1,180–2,160 m. In Rwanda, this species is found in Nyungwe and Volcano national parks, Cyamudongo, Busaga and Gishwati natural forest reserves, Ruhande Arboretum, Rubona and Buhanga historical site, at 1,650–2,400 m. The rainfall in these areas ranges from 435–1,969 mm.
<i>Prunus africana</i> (n)	<i>P. africana</i> is widespread from West Africa through Eastern and Central Africa, south to South Africa and Madagascar. It grows in upland rainforest, dry montane and riverine forests or on termite mounds in <i>Brachystegia</i> woodland, from 800–3,000 m. In Rwanda, the species has been recorded in Nyungwe National Park, and Cyamudongo and Mukura natural forest reserves, at 2,000–2,300 m. Rainfall in these areas ranges from 489–2,008 mm.
<i>Entandrophragma excelsum</i> (n)	<i>E. excelsum</i> is distributed from the Democratic Republic of the Congo eastwards to Uganda, Tanzania and Malawi. It grows in montane and midaltitude rainforests, sometimes in riverine forests at lower altitudes from 1,280–2,150 m. In Rwanda, this species has been recorded in Nyungwe National Park and in Cyamudongo Natural Forest Reserve, also planted in Ruhande Arboretum, from 1,740–1,800 m where rainfall ranges from 435–1,969 mm.
<i>Symphonia globulifera</i> (n)	<i>S. globulifera</i> is widespread in West, Central and East Africa, south to Zambia. It grows in montane and upper montane rainforests, at 840–2,550 m. In Rwanda, this species has been recorded in Nyungwe National Park, and Gishwati and Cyamudongo natural forest reserves, from 1,600–2,400 m where rainfall ranges from 489–1,969 mm.

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Table 3. Continued

Species	Geography and ecology
<i>Hagenia abyssinica</i> (n)	<i>H. abyssinica</i> is a tree extending from Ethiopia, Sudan, through East and Central Africa south to Malawi and Zambia. It is found in montane rainforest, upland evergreen bushland, often above moist bamboo-thickets, from 2,400–3,600 m. In Rwanda, this species has been recorded in Nyungwe and Volcano national parks and Mukura Forest Reserve, from 2,150–2,750 m where rainfall ranges from 549–2,130 mm.
<i>Markhamia lutea</i> (n)	<i>M. lutea</i> is a widespread tree found in tropical Africa, from Ivory Coast to Tanzania and North to Ethiopia. It grows in high-rainfall areas, on forest edges, forest gallery and in river valleys to 2,000 m. In Rwanda, this species is common in most areas of the country.
<i>Erythrina abyssinica</i> (n)	<i>E. abyssinica</i> is widespread from Ethiopia southwards through East and Central Africa to Zimbabwe and South Africa. It grows in grassland, open woodland, Zambezian miombo woodland, bushland and forest edges, especially on rocky places at 200–2,100 m. In Rwanda, the species is common in Bugarama, Huye, Nyanza, Muhanga, Gasabo, Bugesera, Umutara and Rwinkwavu from 950–2,000 m within areas receiving total rainfall ranging from 214–1,634 mm.
<i>Carapa grandiflora</i> (n)	(not available)
<i>Acacia melanoxylon</i> (e)	<i>A. melanoxylon</i> originates from Australia and has been introduced in different areas of Rwanda as a timber and shade tree, especially in highlands. It is commonly found in Mukura and Gishwati forest reserves, Nyungwe and Volcano national parks and Gasabo at 1,400–2,600 m where total rainfall ranges from 363–2,130 mm.
<i>Grevillea robusta</i> (e)	<i>G. robusta</i> originates from Southern and Eastern Australia from sea level to 1,500 m. This species is now widely planted as an agroforestry tree in Africa and grows well in medium and high altitude areas. In Rwanda, the species has been planted as timber, shade and agroforestry species in many areas including Huye, Muhanga, Kamonyi, Musanze, Karongi, Bugesera, Umutara, Bugarama and Nyamasheke, from 1,500–2,000 m where rainfall ranges from 214–2,705 mm.
<i>Maesopsis eminii</i> (e)	<i>M. eminii</i> is a large tree, indigenous to West, Central and East Africa where it grows in lowland, montane and riverine forests. In Rwanda, this species grows in riverine forest in Rusumo. It is also widely planted in gardens, farms and on roadsides in many towns where it has spread into fallows and wastelands. This species has been recorded in Huye, Kigali, Gabiro and Rwamagana, from 1,300–1,600 m where rainfall ranges from 435–1,634 mm.
<i>Afrocarpus falcatus</i> (e)	<i>A. falcatus</i> occurs in Northeastern, Central and Southern Africa. It grows in montane forest at 1,500–2,400 m. In Rwanda, this species has been recorded in Nyungwe National Park, Huye and Gasabo, at 1,800–3,000 m where total rainfall ranges from 363–1,960 mm.
<i>Pinus patula</i> (e)	<i>P. patula</i> is an introduced tree from tropical America which is one of the most widely planted in tropical Africa. It is tolerant to most soils and will grow even in grassland. It grows best with good water supplies, but can also tolerate adverse conditions. In Rwanda, this species is planted in medium and high altitude areas including Gasabo, Muhanga, Huye, in buffer zones of Nyungwe National Park, and Mukura and Gishwati forest reserves, from 1,450–2,600 m where rainfall ranges from 363–2,008 mm.
<i>Maesa lanceolata</i> (n)	<i>M. lanceolata</i> is a tree of tropical and southern Africa, Madagascar and the Arabian Peninsula. It is widespread but usually common in secondary and riverine forests, forest edges, thickets and bushlands, and is a pioneer in forest margins, from 260–2,550 m. In Rwanda, this species has been recorded in Nyungwe and Volcano national parks, Cyamudongo, Gishwati, Mukura and Busaga forest reserves, and Buhanga historical site, from 1,600–2,750 m where rainfall ranges from 489–2,130 mm.
<i>Myrianthus holstii</i> (n)	<i>M. holstii</i> is a widespread tree occurring from Nigeria and Cameroon through Central and East Africa, south to eastern Zimbabwe. It is common in sub-montane and montane forests, sometimes at edges or in secondary vegetation and along rivers, from 900–2,100 m. In Rwanda, this species is found in montane forest, particularly on forest edges and watercourses in Nyungwe National Park, and Cyamudongo, Busaga and Gishwati forest reserves, from 2,000–2,300 m. The rainfall in these areas ranges from 489–1,969 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Acacia mearnsii</i> (e)	<i>A. mearnsii</i> is native to Australia and grows well from hot Queensland to cool Tasmania, and has been introduced in many parts of Africa for commercial purposes. In Rwanda, this species has been recorded in many highland areas including Busaga, Mukura and Gishwati forest reserves, and Huye and Burera, at 1,600–2,600 m where rainfall ranges from 435–2,008 mm.
<i>Croton megalocarpus</i> (n)	<i>C. megalocarpus</i> is found in East and Central Africa. It grows in dry and moist upland forests, from 1,200–2,400 m. In Rwanda, this species has been recorded in Nyungwe National Park, Cyamudongo and Gishwati natural forest reserves, Nyagatare and Huye (Ruhande Arboretum and Rubona ISAR), at 1,600–2,000 m where rainfall ranges from 435–1,960 mm.
<i>Dombeya torrida</i> (n)	<i>D. torrida</i> is found in secondary or open montane, dry montane and upper montane forests at altitudes of 1,800–2,700 m. It is often associated with Hagenia, Cassipourea and Cornus, and its distribution includes north central, northeastern and eastern tropical Africa. In Rwanda, this species is found in Nyungwe and Volcano national parks, and Busaga, Gishwati and Cyamudongo natural forest reserves, at 2,000–2,700 m in areas receiving total rainfall ranging from 488–2,130 mm.
<i>Parinari excelsa</i> (n)	<i>P. excelsa</i> is widespread from Senegal, through East and Central Africa, south to Zambia, Zimbabwe and Botswana. It grows in lowland, riverine, sub-montane and montane forests, at 1,000–2,100 m. In Rwanda, this species has been recorded in Nyungwe National Park, and Cyamudongo and Mukura forest reserves, from 1,900–2,400 m where rainfall ranges from 489–2,008 mm.
<i>Persea americana</i> (e)	<i>P. americana</i> is an introduced fruit tree from Mexico south to Venezuela, and is now common in many tropical countries. It grows well in deep and fertile sandy loam soils, but can grow also in a wide range of soils provided they have good drainage and high rainfall, at altitudes from 1–2,200 m. In Rwanda, this species is widely planted from medium to high altitude areas, especially in Huye, Gisagara, Ruhango, Kamonyi, Muhanga, Gasabo, Karongi and Musanze districts, from 1,400–2,200 m where rainfall ranges from 435–1,965 mm.
<i>Cupressus lusitanica</i> (e)	<i>C. lusitanica</i> is an introduced tree from moist mountains of Central America. It is now planted in most parts of tropical and subtropical Africa at medium and high altitudes in areas with fertile soil and good rainfall. In Rwanda, this species has been planted as a timber tree in many localities including Huye, Ndiza mountain, Gisakura, Bugesera, Rutsiro and Musanze, Gishwati natural forest reserve and Volcano National Park, at 1,600–2,600 m where rainfall ranges from 214–2,130 mm.
<i>Eucalyptus globulus</i> subsp. <i>maidenii</i> (e)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdf/lib/Eucalyptus_globulus_UGA.pdf)
<i>Faurea saligna</i> (n)	<i>F. saligna</i> is found from low to high altitude forest and bushland from West and North Africa through eastern and Central Africa to South Africa. In Rwanda, this species grows in wooded grasslands and montane forests, at altitudes of 1,800–2,400 m. It has been recorded in Nyungwe National Park, and Mukura and Cyamudongo forest reserves where rainfall ranges from 489–1,969 mm.
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	This is one of the <i>Calliandra</i> species native to Central America that have been introduced in the tropics and become popular in highland areas. In Rwanda, this species is found in many areas including Huye, Kigali, Bugesera, Musanze and Karongi at medium and higher altitudes between 1,500–2,100 m. Rainfall in these areas ranges from 214–1,978 mm.
<i>Casuarina equisetifolia</i> (e)	<i>C. equisetifolia</i> is native to coastal areas of the Pacific and Indian Oceans, including Sri Lanka, Malaysia and Indonesia. It is now widespread in many parts of tropical Africa. In Rwanda, this species is commonly planted for avenue and ornamental purposes in many towns including Butare, Kigali, Gitarama, Nyamata, Nyagatare and Ruhengeri, and at altitudes of 1,000–2,000 m where rainfall ranges from 214–1,965 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Eucalyptus saligna</i> (e)	<i>E. saligna</i> is native to Australia, and is now widely planted in highland areas of tropical and subtropical countries. In Rwanda, the species has been planted mainly as a timber and fuel species in most of the highlands, including the buffer zone of Nyungwe National Park, and Ruhande Arboretum at 1,700–2,300 m where rainfall ranges from 435–1,960 mm.
<i>Bersama abyssinica</i> (n)	<i>B. abyssinica</i> is common from East to South Africa, occurring along banks in wooded river valleys, at the edges of evergreen forests, open woodland, highland and lowland forests, at 1,140–2,550 m. In Rwanda, this species is found in Nyungwe and Volcano national parks, and in Cyamudongo, Gishwati and Busaga forest reserves, at 1,800–2,500 m, where total rainfall ranges from 489–2,130 mm.
<i>Syzygium guineense</i> (n)	<i>S. guineense</i> is a widespread tree from Eastern and Central Africa, south to South Africa. It grows in sub-montane, montane, upper montane, dry montane and riverine forests, from 1–2,100 m. In Rwanda, this species occurs in Nyungwe National Park, Cyamudongo, Gishwati, Mukura and Busaga natural forests reserves, at 1,500–2,600 m. The rainfall in these areas ranges from 489–2,130 mm.
<i>Neoboutonia macrocalyx</i> (n)	<i>N. macrocalyx</i> is naturally found in eastern and Central Africa. It is a pioneer species in upland forest, mostly on edges and in clearings, from 1,100–2,700 m. In Rwanda, this species is found in Cyamudongo and Gishwati natural forest reserves, and Nyungwe and Volcano national parks, from 1,900–2,450 m where rainfall ranges from 489–2,130 mm.
<i>Syzygium parvifolium</i> (n)	(not available)
<i>Pterygota mildbraedii</i> (n)	<i>P. mildbraedii</i> grows naturally in Cameroon, Democratic Republic of the Congo, Burundi, Zambia, Uganda and Tanzania. It prefers warm and humid conditions with fertile alluvial soils in riverine, lowland, ground water and sub-montane forests, at 750–1,550 m. In Rwanda, the species has been recorded in Ngoma, Rusumo and Bugesera, from 1,250–1,500 m where rainfall ranges from 214–1,319 mm.
<i>Ficus thonningii</i> (n)	<i>F. thonningii</i> is very widespread in tropical Africa at altitudes from 300–2,500 m. In Rwanda, this species is well distributed in upland and riverine forests and in open grasslands. It is usually left standing in cropland and near homes in Musanze, Kigali, Bugesera and Rwinkwavu, at altitudes of 1,000–2,500 m where rainfall ranges from 214–1,965 mm.
<i>Senegalia polyacantha</i> (n)	<i>A. polyacantha</i> is widespread in tropical and southern Africa. It grows in wooded grassland, riverine woodland, near riverbanks and in swampy valleys, at 200–1,800 m. In Rwanda, this species is found in riverine forest and wooded grassland. It has been recorded in Bugarama, Gasabo, Kicukiro and Kayanza, and in Akagera National Park, at altitudes of 1,000–1,800 m where rainfall ranges from 363–1,519 mm.
<i>Entada abyssinica</i> (n)	<i>E. abyssinica</i> grows in wooded grassland, riverine forests and wet forest edges. It is widespread from East and Central Africa south to Angola, at 450–2,250 m. In Rwanda, this species has been recorded in Bugarama, Umutara (Nyagatare), Akagera National Park, Nyanza, Bugesera and Huye, from 1,100–1,700m where rainfall ranges from 214–1,634 mm.
<i>Pinus caribaea</i> (e)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdflib/Pinus_caribaea_UGA.pdf)
<i>Eucalyptus grandis</i> (e)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdflib/Eucalyptus_grandis_UGA.pdf)
<i>Eucalyptus microcorys</i> (e)	(not available)
<i>Ficalhoa laurifolia</i> (n)	<i>F. laurifolia</i> grows in montane and riverine forests in Tanzania, Uganda and Democratic Republic of the Congo south to Angola. In Rwanda, this species has been recorded in Nyungwe and Volcano national parks, and in Cyamudongo, Gishwati and Mukura forest reserves, from 1,600–2,500 m where rainfall ranges from 489–2,130 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Kuloa usambarensis</i> (n)	<i>O. usambarensis</i> is widely distributed throughout Central and East Africa to Malawi and Zambia. It is common in the wetter montane and sub-montane forests at altitudes of 900–2,600 m, and prefers deep fertile soils with good drainage. In Rwanda, the species has been recorded in Nyungwe National Park, at 2,430 m where rainfall ranges from 1,394–1,960 mm.
<i>Artocarpus heterophyllus</i> (e)	<i>A. heterophyllus</i> originates from Asia but is currently widespread in other parts of warm and humid tropical countries at altitudes from 1–1,500 m. In Rwanda, this species has been introduced as a fruit tree in many areas, including Butare, Gatsibo, Kigali and Kamembe.
<i>Tephrosia vogelii</i> (n)	<i>T. vogelii</i> is widespread in Africa, from West Africa, eastwards to Ethiopia and southwards through eastern and Central Africa to Zimbabwe and Angola. It grows in grassland and forest margins, from 1–2100 m with rainfall ranging from 800–1,100 mm. In Rwanda, this species is common in waste ground, old cultivations and marshlands. It has been recorded in Nyungwe National Park, and Muhanga, Huye and Ngoma districts, at 1,400–2,400 m where rainfall ranges from 383–2,130 mm.
<i>Psidium guajava</i> (e)	<i>P. guajava</i> originates from southern America. It is now grown throughout the tropics and warmer subtropics, including the African continent south of the Sahara. It grows at most altitudes from 1–2,000 m in a variety of soils and is drought resistant, but cannot tolerate waterlogging. In Rwanda, this species is commonly planted in many home gardens for its fruits, at altitudes ranging from 1,000–2,000 m
<i>Mitragyna rubrostipulata</i> (n)	(not available)
<i>Harungana montana</i> (n)	(not available)
<i>Macaranga kilimandscharica</i> (n)	(not available; but see https://apps.worldagroforestry.org/usefultrees/pdf/lib/Macaranga_kilimandscharica_UGA.pdf)
<i>Gambeya gorungosana</i> (n)	(not available)
<i>Gymnanthemum amygdalinum</i> (e)	<i>V. amygdalina</i> is widespread in sub-Saharan Africa, from West to East Africa and in Yemen. It grows in sub-humid wooded savanna or wetter highlands, gallery forest and fallow land, at 900–1,500 m. In Rwanda, this species has been recorded in Nyungwe and Akagera national parks, Gishwati Natural Forest Reserve, and Bugarama, Huye, Nyanza, Muhanga, Kamonyi, Gasabo, Karongi, Mayaga, Kayonza and Umutara at altitudes of 1,000–2,150 m. Rainfall in these areas ranges from 363–2,130 mm.
<i>Alnus acuminata</i> (e)	(not available)
<i>Gliricidia sepium</i> (e)	<i>G. sepium</i> is an introduced species from tropical America that is now widely planted in the tropics for agroforestry purposes at elevations of 1–1,600 m. In Rwanda, this species is commonly planted by farmers in lower and medium altitudes for fodder and fuelwood. It has been recorded in Bugarama, Umutara, Bugesera, Huye and Kigali, at altitudes of 1,000–1,700 m. Rainfall in these areas ranges from 214–1,634 mm.
<i>Acaciella angustissima</i> (e)	(not available)
<i>Jacaranda mimosifolia</i> (e)	<i>J. mimosifolia</i> is a very popular tree which is widely grown as an ornamental species throughout the high and lowland tropics. It prefers highland areas, but can also grow at low and medium altitudes up to 2,200 m. In Rwanda, this species is planted in medium and highland areas, particularly Butare, Kigali, Gitarama, Rwamagana and Ruhengeri, from 1,300–2,100 m where rainfall ranges from 435–1,965 mm.
<i>Leucaena diversifolia</i> (e)	<i>L. diversifolia</i> originates from the highlands of Central America, usually as an understorey tree in pine forests. It is one of the most widely cultivated of all <i>leucaena</i> species in tropical highlands. In Rwanda, this species has been introduced as an agroforestry tree and used in soil conservation and improvement. It is commonly found in Huye, Muhanga, Nyanza, Musanze and Gasabo, from 1,500–1,700 m where rainfall ranges from 363–1,965 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Senna spectabilis</i> (e)	<i>S. spectabilis</i> is native to central and northern South America and has been introduced in Africa as an ornamental tree. It grows well on deep, moist sandy loam and tolerates cool conditions (15–25°C), up to 2,000 m. In Rwanda, this species is widely planted as an ornamental or boundary marker in many parts of the country at altitudes of 1,000–1,700 m.
<i>Sesbania sesban</i> (n)	<i>S. sesban</i> is widespread from Senegal to Somalia and southwards through Central and East Africa to South Africa. It grows in riverine forest, near streams, freshwater lakes, seasonal ponds and springs, at 100–2,200 m. In Rwanda, <i>S. sesban</i> has been recorded in Akagera National Park, and Bugesera, Umutara (Nyagatare), Huye, Nyanza, Gasabo and Nyaruguru, from 1,350–1,900 m where rainfall ranges from 214–1,634 mm.
<i>Cajanus cajan</i> (e)	<i>C. cajan</i> is cultivated on different soil types in most tropical African countries as a food plant. In Rwanda, this plant is commonly found in many farmlands in Nyagatare, Bugarama, Bugesera and Huye, from 1,000–1,800 m. Rainfall in these areas ranges from 214–1,634 mm.
<i>Leucaena leucocephala</i> (e)	<i>L. leucocephala</i> is native of Central America. This species has been widely introduced in the tropics over the last 100 years, reaching Africa in 1950. It grows in areas with full sunlight and well-drained neutral or calcareous soils at altitudes from 1–1,600 m. In Rwanda, farmers plant this species for fodder, but it has already shown signs of escaping from farms to other areas, including home gardens, fallows and roadsides at altitudes of 1,000–1,700 m.
<i>Senna siamea</i> (e)	<i>S. siamea</i> is an introduced tree from Southeast Asia which is now widely cultivated in many tropical and subtropical countries. Growing at elevations of 1–1,800 m, it prefers warm and humid conditions, but may also tolerate extended drought. In Rwanda, <i>S. siamea</i> is commonly planted as woodlots and avenues in most parts of the country, including Bugarama, Kayonza, Gasabo, Bugesera and Musanze, at 1,100–1,800 m where rainfall ranges from 214–1,965 mm.
<i>Spathodea campanulata</i> (n)	<i>S. campanulata</i> is widespread in tropical Africa from Ghana south to East and Central Africa. It grows in forest edges and in riverine forest, at 1–2,000 m. It is also a common ornamental tree widely planted from Ethiopia south to Zambia and Angola. In Rwanda, this species is planted as an ornamental and shade tree in many towns including Huye, Kigali, Muhanga, Karongi, Gicumbi, Bugarama, Kayonza and Musanze, from 1,400–1,900 m. Rainfall in these areas ranges from 454–1,965 mm.
<i>Vachellia sieberiana</i> (n)	<i>A. sieberiana</i> is widespread in tropical and southern Africa. It grows in wooded grassland, bushed grassland and riverine forest, at 950–1,950 m. In Rwanda, the species has been recorded in Huye, Gasabo, Umutara (Nyagatare) and Kayonza, and in Akagera National Park, at 1,000–1,800 m where rainfall ranges from 363–1,519 mm.
<i>Solanecio mannii</i> (n)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdf/lib/Solanecio_mannii_UGA.pdf)
<i>Vachellia hockii</i> (n)	<i>A. hockii</i> is widespread in Africa and occurs in wooded grassland and bushland, especially in areas where people have been living. In Rwanda, this species is found in Bugesera, Gasabo, Umutara (Nyagatare) and Akagera National Park, at 1,350–1,800 m. The total rainfall in these areas ranges from 214–1,519 mm.
<i>Vepris nobilis</i> (n)	<i>V. nobilis</i> is widely distributed from Ethiopia, through eastern and Central Africa, southwards to Malawi and Zimbabwe. It grows in woodland, evergreen and riverine forests, at 900–2,600 m. In Rwanda, this species has been recorded in Akagera National Park, and in Bugesera, Nyagatare, Rwigyavu and Rusumo at altitudes of 1,300–1,500 m. Rainfall in these areas ranges from 214–1,519 mm.
<i>Phoenix reclinata</i> (n)	<i>P. reclinata</i> is a widespread species throughout tropical Africa, South Africa and Madagascar. It grows in dry lowland, montane and riverine forests and thickets, at 1–3,000 m. In Rwanda, this species has been recorded in Akagera National Park, and in Rubavu (Kivu lakeside), Karongi, Rusizi, Gasabo and Huye, from 1,250–1,750 m where rainfall ranges from 363–2,165 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Newtonia buchananii</i> (n)	<i>N. buchananii</i> is widespread in tropical Africa, from East and Central Africa south to South Africa. It grows in lowland and upland rainforests, riverine and swamp forests, from 600–2,400 m. In Rwanda, this species is found in Nyungwe National Park, Cyamudongo forest reserve, Rujambala forest and Rusumo, from 1,300–2,400 m where rainfall ranges from 383–1,969 mm.
<i>Strombosia scheffleri</i> (n)	<i>S. scheffleri</i> is widespread from Nigeria southwards through East and Central Africa to Angola and Mozambique. It grows in moist forest at altitudes of 800–2,500 m. In Rwanda, this species is found in Nyungwe National Park, and Cyamudongo and Mukura natural forest reserves, at 1,400–2,000 m where rainfall ranges from 489–2,130 mm.
<i>Combretum molle</i> (n)	<i>C. molle</i> is widespread in East, Central and South Africa, and is also found in Yemen. It grows in wooded grassland and bushland, often on stony hills and termite mounds, at elevations of 30–2,300 m. In Rwanda, this species has been found in Bugarama, Bugesera and Umutara, and in Akagera National Park, from 1,000–1,700 m where rainfall ranges from 214–1,633 mm.
<i>Acokanthera schimperi</i> (n)	<i>A. schimperi</i> is widespread in Central and East Africa. It is also found in Eritrea, Ethiopia, Djibouti, Somalia and Yemen. It grows in dry woodland, grassland, wooded grassland, rocky bushland and dry forest or forest margins, at 250–2,200 m. In Rwanda, the species is found in Bugesera and Akagera National Park, at 1,300–1,700 m. Total rainfall in these areas ranges from 213–1,519 mm.
<i>Solanum betaceum</i> (e)	<i>C. betacea</i> is an introduced tree from tropical America. Now widespread in the tropics, it grows in highlands with fertile and well drained soils, at altitudes of 1,000–2,000 m. The species is one of the most common fruit trees in Rwanda where it is being grown in most home gardens in many areas between 1,200–1,800 m.
<i>Searsia natalensis</i> (e)	<i>R. natalensis</i> is widespread in tropical Asia, and also found in Africa from Guinea to Somalia, Eastern and Central Africa, south to South Africa. It grows in wooded savannas, forest edges and riverine forest, from 1–3,000 m. In Rwanda, this species is found in low and medium altitude areas including Akagera National Park, Bugesera, Umutara, Rusumo and Mayaga, at 1,300–1,700 m. Rainfall in these areas ranges from 214–1,519 mm.
<i>Cornus volkensii</i> (n)	<i>C. volkensii</i> is found in eastern, Central and southern tropical Africa. It grows in montane forest, at 1,200–3,200 m. In Rwanda, this species has been recorded in Nyungwe and Volcano national parks, and Mukura Natural Forest Reserve, at 1,900–3,000 m where rainfall ranges from 549–2,130 mm.
<i>Dracaena steudneri</i> (n)	<i>D. steudneri</i> is widespread from East and Central Africa, south to Zimbabwe. It is found in moist and dry montane forests, sometimes in lowland rainforest especially in gaps, near swamps, along stream and river banks, and in gallery forests from 1–2,100 m. In Rwanda, this species grows naturally in both Nyungwe and Volcano national parks, Gishwati and Cyamudongo natural forest reserves and Buhanga historical site. It has been commonly planted as an ornamental plant in many towns in Rwanda, including Butare, Kigali, Karongi, Gitarama, Gicumbi and Ruhengeri, at 1,450–2,300 m. Rainfall in these areas ranges from 435–1,965 mm.
<i>Ilex mitis</i> (n)	<i>I. mitis</i> is widespread from Ethiopia to South Africa. It grows in montane, dry montane, upper montane and riverine forests at 1,000–3,000 m. In Rwanda, this species is found in montane forests from 1,700–2,600 m where rainfall ranges from 435–2,130 mm, including in Nyungwe and Volcano national parks, and Mukura and Gishwati natural forest reserves. It has also been planted in Ruhande Arboretum.
<i>Myrsine melanophloeos</i> (n)	<i>M. melanophloeos</i> is widespread in tropical East and Central Africa, south to South Africa and Madagascar. It grows in montane, upper montane, dry montane, riverine and swamp forests, open woodland, thickets, upland grassland and occasionally in dry lowland. It prefers white sandy, peaty or volcanic soils, at 5–3,750 m. In Rwanda, this species has been recorded in Nyungwe and Volcano national parks, and Cyamudongo and Mukura natural forest reserves, from 1,400–3,300 m where rainfall ranges from 489–2,130 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Xymalos monospora</i> (n)	<i>X. monospora</i> is widespread in East, Central and South Africa, and is also found in Cameroon and Equatorial Guinea. It grows in lowland, sub-montane, montane and upper montane forests, at elevations of 900–2,700 m. In Rwanda, it has been recorded in Volcano National Park, and Cyamudongo, Gishwati, Mukura and Busaga natural forest reserves, from 2,017–2,616 m, where rainfall ranges from 489–2,130 mm.
<i>Ximenia caffra</i> (n)	<i>X. caffra</i> is widespread in East and Central Africa, southwards to Malawi, Mozambique and South Africa. It grows in dry woodland and wooded grassland, especially on rocky hillsides and termite mounds, at altitudes of 1–2,000 m. In Rwanda, this species is found in Akagera National Park, Bugesera, Huye and Nyagatare, from 1,300–1,700 m where rainfall ranges from 214–1,634 mm.
<i>Toona sinensis</i> (e)	(not available)
<i>Euphorbia tirucalli</i> (n)	<i>E. tirucalli</i> is believed to have been introduced from India, but is now naturalized throughout tropical Africa. The species is frequently planted as a live fence around fields and cattle bomas, and is much associated with human habitation. In Rwanda, this species is commonly found in the drier areas of Umutara, Akagera National Park, Bugesera, Kigali and Bugarama, from 950–1,700 m where rainfall ranges from 214–1,633 mm.
<i>Psydrax schimperianus</i> (n)	<i>P. schimperiana</i> is widespread in Central and eastern tropical Africa, and is also found in Yemen. It grows in dry forest, evergreen bushland, thickets and wooded grassland in rocky sites, at 15–2,500 m. In Rwanda, this species has been recorded in Akagera National Park, Bugesera, Mayaga, Umutara and Kayonza (Rwinkwavu), from 1,000–1,650 m where rainfall ranges from 214–1,519 mm.
<i>Ficus laurifolia</i> (n)	<i>F. ovata</i> is found in deciduous woodlands, riverine forests, wooded grasslands and lakesides from Senegal to Ethiopia through eastern and Central Africa south to Mozambique and Angola. In Rwanda, this species has been recorded in Akagera National Park, Bugarama and Rusumo. It is also planted as a shade tree in Kigali, Musanze, Huye, Nyamagabe and Ngoma from 1,000–2,100 m where rainfall ranges from 383–1,965 mm.
<i>Morus nigra</i> (e)	<i>M. nigra</i> is native to warm temperate Asia. This species is widely cultivated in the Middle East and warm parts of Europe. It is also common in many parts of Africa up to 2,000 m. In Rwanda, the species is planted for hedge and live fence in most areas including Bugarama, Gasabo, Nyagatare and Karongi, from 1,000–1,700 m where rainfall ranges from 363–1,633 mm.
<i>Carica papaya</i> (e)	<i>C. papaya</i> is widespread throughout tropical and subtropical countries in Africa, Australia and North America. It favours warm and humid areas with fertile soils below 1,500 m. In Rwanda, the species is mainly grown in Bugarama, Bugesera, Umutara, Muhanga, Huye and Ngoma, at 900–1,500 m where rainfall ranges from 350–1,500 mm.
<i>Trema orientalis</i> (n)	<i>T. orientalis</i> is widely distributed in Africa, from Senegal and Sudan, through East and Central Africa to South Africa and Madagascar. It grows in higher-rainfall areas in riverine forest or forest margins, woodland and wooded grassland, usually, as a pioneer species in open gaps and clearings, from 1–2,200 m. In Rwanda, <i>T. orientalis</i> has been recorded in Nyungwe National Park, Bugarama, Bugesera and Rusumo, from 1,100–2,350 m where rainfall ranges from 214–2,130 mm.
<i>Eucalyptus tereticornis</i> (e)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdflib/Eucalyptus_tereticornis_TZA.pdf)
<i>Mimosa scabrella</i> (e)	(not available, but see https://apps.worldagroforestry.org/usefultrees/pdflib/Mimosa_scabrella_UGA.pdf)
<i>Acrocarpus fraxinifolius</i> (e)	This Asian tree is widely planted in East and Central Africa. In Rwanda, the species has been introduced as an avenue, garden and arboretum tree. It has been recorded in Huye, Bugarama and Karongi, at 1,300–2,000 m where rainfall ranges from 435–1,657 mm.

continued on next page

Table 3. Continued

Species	Geography and ecology
<i>Biancaea decapetala</i> (e)	<i>C. decapetala</i> is widely cultivated and has been naturalized in medium and high rainfall areas of Africa where altitudes range from 800–2,100 m. Although this species is widespread in Rwanda, it is more common in Gicumbi, Bugesera, Huye and Muhanga, at 1,400–2,000 m. Rainfall in these areas ranges from 214 to 1,978 mm.
<i>Dracaena afromontana</i> (n)	(not available)
<i>Alnus glutinosa</i> (e)	(not available)
<i>Euclea racemosa</i> (n)	<i>E. racemosa</i> is found in wooded grasslands, thickets, dry montane and dry lowland forests of East, Central and South Africa. In Rwanda, the species occurs in forest galleries and dry thickets in Mayaga, Bugesera, Umutara and Akagera National Park, from 1,300–1,500 m where rainfall ranges from 214–1,519 mm.
<i>Macaranga capensis</i> (e)	<i>M. capensis</i> is a tree of montane and upland montane forests of Eastern and Central tropical Africa, often abundant in forest edges, from 1,500–3,000 m. In Rwanda, the species is commonly found in Volcano and Nyungwe national parks, and Cyamudongo, Busaga, Mukura and Gishwati forest reserves, from 1,700–2,650 m where rainfall ranges from 489–2,130 mm.

4.2 Attributes from an online species selection tool for Rwanda

Table 4, showing products and ecological services, was compiled from an online tool for tree species selection in Rwanda, or more precisely for the Bugesera and Gishwati locations (Kuria, 2017). Only species for which there was information were included.

Table 4. Information on products and ecological services of prioritized tree species

Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red. Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants.

Species	Location ⁶	Products	Ecological services
<i>Polyscias fulva</i> (n)	G	Fuelwood, timber for furniture, farm tools, bee forage, bean stakes	Ornamental
<i>Markhamia lutea</i> (n)	BG	Fuelwood, charcoal, timber for construction, medicine, bee forage, bean stakes	Ornamental, shade, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves
<i>Pinus patula</i> (e)	G	Fuelwood, charcoal, timber for furniture, timber for construction, medicine, gums/resins	Ornamental, shade, soil erosion control, wind break
<i>Erythrina abyssinica</i> (n)	BG	Fuelwood, timber for construction, medicine, fodder, bee forage, bean stakes	Ornamental, live fence, soil erosion control, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves, riverbank stabilization
<i>Croton megalocarpus</i> (n)	G	Fuelwood, charcoal, timber for furniture, timber for construction, medicine, bee forage	Ornamental, shade
<i>Ficus thonningii</i> (n)	BG	Fuelwood, medicine, fodder, bean stakes, gums/resins, Fibre	Ornamental, live fence, shade, soil erosion control

continued on next page

⁶ B = Bugesera; G = Gishwati

Table 4. Continued

Species	Location ⁶	Products	Ecological services
<i>Acacia mearnsii</i> (e)	G	Fuelwood, timber for construction, fodder, bee forage, tannins/dyestuff	Ornamental, shade, soil erosion control, soil fertility improvement through nitrogen-fixing
<i>Acacia melanoxylon</i> (e)		Fuelwood, timber for construction, fodder	Ornamental, shade, soil erosion control, soil fertility improvement through nitrogen-fixing, wind break
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	B	Fuelwood, timber for construction, fodder, bee forage	Ornamental, shade, soil erosion control, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves, wind break
<i>Casuarina equisetifolia</i> (e)	BG	Fuelwood, charcoal, timber for construction, farm tools, fodder, tannins/dyestuff	Ornamental, shade, soil erosion control, soil fertility improvement through nitrogen-fixing, wind break
<i>Cupressus lusitanica</i> (e)	BG	Fuelwood, charcoal, timber for furniture, timber for construction, bean stakes	Ornamental, live fence, shade, wind break
<i>Grevillea robusta</i> (e)	BG	Fuelwood, charcoal, timber for construction, farm tools, fodder, bee forage, bean stakes	Ornamental, live fence, shade, soil fertility improvement through mulch/leaves, wind break
<i>Combretum molle</i> (n)	B	Fuelwood, charcoal, farm tools, bee forage	Shade, soil fertility improvement through mulch/leaves
<i>Gymnanthemum amygdalinum</i> (e)	BG	Fuelwood, medicine, fodder, bee forage	Ornamental, live fence, soil fertility improvement through mulch/leaves
<i>Artocarpus heterophyllus</i> (e)	B	Fruits, other foods, fuelwood, timber for furniture, timber for construction, medicine, fodder, tannins/dyestuff, gums/resins	Shade
<i>Persea americana</i> (e)	BG	Fruits, fuelwood, charcoal, timber for construction, fodder	Shade, soil erosion control, wind break
<i>Alnus acuminata</i> (e)	G	Fuelwood, timber for construction, farm tools, medicine, fodder, bee forage, bean stakes	Soil erosion control, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves, wind break
<i>Jacaranda mimosifolia</i> (e)	B	Fuelwood, timber for construction, farm tools, bee forage	Ornamental, live fence, soil fertility improvement through mulch/leaves
<i>Leucaena diversifolia</i> (e)	B	Fuelwood, timber for construction, fodder, gums/resins	Soil erosion control, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves, wind break
<i>Moringa oleifera</i> (e)	B	Other foods, medicine, fodder, bee forage	Shade, soil erosion control, wind break
<i>Senna spectabilis</i> (e)	B	Fuelwood, charcoal, timber for construction, farm tools, bee forage	Ornamental, shade, wind break
<i>Eucalyptus saligna</i> (e)	BG	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, bean stakes	Wind break
<i>Sesbania sesban</i> (n)	B	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, gums/resins	Live fence, shade, soil fertility improvement through mulch/leaves, wind break
<i>Vachellia hockii</i> (n)	B	Fuelwood, charcoal, bee forage, Fibre	Ornamental, Dead fence

continued on next page

Table 4. Continued

Species	Location ⁶	Products	Ecological services
<i>Carica papaya</i> (e)	BG	Fruits, medicine	
<i>Toona sinensis</i> (e)	B		
<i>Acokanthera schimperi</i> (n)	B	Fruits, medicine	Ornamental, shade
<i>Gliricidia sepium</i> (e)	B	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, bean stakes	Ornamental, shade, soil erosion control, soil fertility improvement through nitrogen-fixing
<i>Euphorbia tirucalli</i> (n)	B	Fuelwood, charcoal, timber for furniture, timber for construction, gums/resins	Live fence, soil erosion control
<i>Lannea schimperi</i> (n)	B	Fruits, other foods, fuelwood, charcoal, timber for furniture, farm tools, medicine	Ornamental, shade, soil fertility improvement through mulch/leaves
<i>Psidium guajava</i> (e)	BG	Fruits, fuelwood, farm tools	Shade, soil fertility improvement through nitrogen-fixing
<i>Dombeya torrida</i> (n)	BG	Fuelwood, charcoal, timber for construction, farm tools, medicine, bee forage, Fibre	Shade, soil fertility improvement through mulch/leaves
<i>Hagenia abyssinica</i> (n)	G		
<i>Pterygota mildbraedii</i> (n)	B	Fuelwood, charcoal	Shade
<i>Acaciella angustissima</i> (e)	G	Medicine, fodder, bean stakes	Soil fertility improvement through nitrogen-fixing
<i>Cajanus cajan</i> (e)	B	Other Foods, fuelwood, charcoal, timber for construction, medicine, fodder, bee forage	Shade, soil erosion control, soil fertility improvement through nitrogen-fixing, wind break
<i>Corymbia maculata</i> (e)	BG	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, bean stakes	Wind break
<i>Eucalyptus globulus subsp. Maidenii</i> (e)	B	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, bean stakes	Wind break
<i>Grewia similis</i> (n)	B	Fruits, other foods, fuelwood, timber for construction, farm tools, fodder	
<i>Leucaena leucocephala</i> (e)	B		
<i>Mitragyna rubrostipulata</i> (n)	BG	Fuelwood, timber for construction, medicine	
<i>Psydrax schimperianus</i> (n)		Fruits, fuelwood, timber for construction, farm tools, medicine, fodder	Shade
<i>Senna siamea</i> (e)	B	Fuelwood, charcoal, timber for furniture, timber for construction, medicine, bee forage	Ornamental, shade, soil erosion control, wind break
<i>Solanecio mannii</i> (n)	B	Fuelwood, medicine, bean stakes, tannins/dyestuff	Ornamental
<i>Vepris nobilis</i> (n)	B	Fuelwood, charcoal, timber for construction, farm tools, medicine	
<i>Bersama abyssinica</i> (n)	G	Fuelwood, charcoal, timber for construction, medicine	Ornamental, shade
<i>Markhamia obtusifolia</i> (n)	B	Fuelwood, timber for furniture, timber for construction, medicine, fodder	Ornamental
<i>Euphorbia candelabrum</i> (e)	G	Fuelwood, timber for construction, medicine	Dead fence

continued on next page

Table 4. Continued

Species	Location ⁶	Products	Ecological services
<i>Syzygium parvifolium</i> (n)	G	Fruits, fuelwood, charcoal, timber for furniture, timber for construction, farm tools, medicine, fodder, tannins/dyestuff	Shade
<i>Albizia versicolor</i> (n)	B	Fuelwood, charcoal, timber for construction, farm tools, medicine	Soil fertility improvement through nitrogen-fixing
<i>Faidherbia albida</i> (e)	B	Other foods, fuelwood, charcoal, timber for construction, fodder	Shade, soil erosion control, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves
<i>Ficus laurifolia</i> (n)	B	Fruits, fuelwood, medicine, fodder	Ornamental
<i>Leucaena trichandra</i> (e)	B	Other Foods, fuelwood, timber for construction, fodder	Live fence, soil fertility improvement through nitrogen-fixing, soil fertility improvement through mulch/leaves
<i>Mangifera indica</i> (e)	B	Fruits, fuelwood, fodder, bee forage, tannins/dyestuff	Ornamental, shade, soil erosion control, wind break
<i>Morus nigra</i> (e)	B	Fruits, fuelwood, medicine, fodder, bee forage	Ornamental, live fence
<i>Pappea capensis</i> (n)	B	Fruits, other foods, fuelwood, charcoal, timber for furniture, timber for construction, farm tools, medicine, fodder, bee forage, tannins/dyestuff	Ornamental, shade
<i>Zanthoxylum chalybeum</i> (n)	B	Other foods, fuelwood, timber for furniture, timber for construction, medicine	
<i>Ricinus communis</i> (e)	BG	Fuelwood, medicine	
<i>Terminalia mantaly</i> (e)	B	Fuelwood, medicine, fodder, bee forage, tannins/dyestuff	Ornamental, shade
<i>Tetradenia riparia</i> (e)	B	medicine	
<i>Eucalyptus globulus</i> (e)	BG	Fuelwood, charcoal, timber for construction, medicine, fodder, bee forage, bean stakes	Wind break
<i>Dracaena afromontana</i> (n)	BG	Medicine, fodder	Live fence, soil fertility improvement through nitrogen-fixing
<i>Alnus glutinosa</i> (e)	G	Fuelwood, timber for construction, bee forage, bean stakes	Shade, soil erosion control, soil fertility improvement through nitrogen-fixing, wind break
<i>Euclea racemosa</i> (n)	B	Fruits, fuelwood, farm tools	Ornamental, live fence

4.3 Attributes from a global list of priority tree species for planting in the tropics and subtropics

Kindt et al. (2021) provide a global ranking of the top-100 and top-830 tree species for planting in the tropics and subtropics. Table 5 shows which of the prioritized species feature among the global priority species. At the same time, the table lists databases where more information can be gathered from a particular species. Note also that the Agroforestry Species Switchboard provides most of this information (Kindt et al., 2025), and that this online database also has a more recent update than the version used for compiling the top-100 and top-830 lists.

The 'Presence' column lists the databases that formed the basis of selecting the global species. Global databases included were coded as: C = Commercial Timber Tree Species; E = Ecocrop; e = GRIN World Economic Plants; D = Feedipedia; F = Selection of Forages for the Tropics; G = Global Species Matrix; H = Species Files in Tropical Forestry, available from the Tropical Forestry Handbook; L = Seed Leaflets; N = Crop Index of NewCROP Database; T = Agroforestree Database; U = USDA Food Composition Databases; u = Useful Tropical Plants; W = The Wood Database; Y = FAO Crop Stats.

Regional databases included (separated from global databases by a hyphen) were coded as: A = Plant Resources of Tropical Africa online database; X = Useful Tree Species for Africa map; I = Useful Tree Species for India; B = Árboles de Centroamérica; M = MAPFORGEN; R = Especies para restauración; P = Species Profiles for Pacific Island Agroforestry; S = Plant Resources of South East Asia; Z = Useful Tree Species for South East Asia

Attribute databases included were coded as: c = Invasive Species Compendium (ISC); i = Global Invasive Species Database (GISD); j = Global Register of Introduced and Invasive Species (GRIIS); o = OECD Scheme for the Certification of Forest Reproductive Material (OECD); s = First report on The State of the World's Forest Genetic Resources (SoWFGR); z = Global Agro-ecological Zones (GAEZ).

Table 5. Global ranking of tree species with databases where information is available

Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red. Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants.

Species	Global top	Presence
<i>Acacia mearnsii</i> (e)	100	CEeHLNTuW-ASZ-cigos
<i>Aleurites moluccanus</i> (e)	100	CEeGNTu-APSZ-cig
<i>Alnus acuminata</i> (e)	100	EeGHLTu-ABR-cos
<i>Artocarpus heterophyllus</i> (e)	100	EeDGTUu-AIPSZ-cgs
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	100	EeDFGHLNTu-ARSZ-os
<i>Carica papaya</i> (e)	100	EeDNTUuY-AISZ-cgs
<i>Casuarina equisetifolia</i> (e)	100	CEeGHLNTu-AIPSZ-cios
<i>Ceiba pentandra</i> (e)	100	CEeDGHLNTuY-AXIBRZ-cgs
<i>Cupressus lusitanica</i> (e)	100	CEeHTuW-ABM-cos
<i>Eucalyptus globulus</i> (e)	100	CEeGHNTuW-A-cos
<i>Eucalyptus grandis</i> (e)	100	CEeGHNTuW-AZ-cgos
<i>Eucalyptus tereticornis</i> (e)	100	CEeGHNTu-AISZ-cgos
<i>Euphorbia tirucalli</i> (n)	100	EeGHNTu-AXS-cg
<i>Faidherbia albida</i> (e)	100	EeDGHLNTu-AXS-gs
<i>Gliricidia sepium</i> (e)	100	EeDFGHLNTu-IBMRPSZ-cgos
<i>Grevillea robusta</i> (e)	100	CEeHLTu-ISZ-cigos
<i>Leucaena leucocephala</i> (e)	100	EeDFGHNTu-IRSZ-cigs
<i>Mangifera indica</i> (e)	100	CEeDNTUuWY-IPSZ-cgs
<i>Moringa oleifera</i> (e)	100	CEeDGLNTUu-IRZ-cgos
<i>Persea americana</i> (e)	100	EeGNTUuY-BMRSZ-cgs
<i>Pinus caribaea</i> (e)	100	CEeGHLTu-BMZ-cios
<i>Psidium guajava</i> (e)	100	CEeDHNTUuY-IBSZ-cigs
<i>Senegalia senegal</i> (n)	100	EeDGHLNTu-AX-os
<i>Senna siamea</i> (e)	100	CEeDGHLTuW-ISZ-cgos
<i>Acacia melanoxylon</i> (e)	1,000	CEeHTuW-AX-cigos
<i>Acaciella angustissima</i> (e)	1,000	EeFGTu-AB-c

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Table 5. Continued

Species	Global top	Presence
<i>Acokanthera schimperi</i> (n)	1,000	Eeu-AX-c
<i>Acrocarpus fraxinifolius</i> (e)	1,000	CEeHTu-A-cgos
<i>Afrocarpus falcatus</i> (e)	1,000	CEeLTu-A-gos
<i>Albizia gummifera</i> (n)	1,000	CeTu-AX-go
<i>Albizia versicolor</i> (n)	1,000	CeTu-A-cs
<i>Alnus glutinosa</i> (e)	1,000	CEeGNW-A-cios
<i>Cajanus cajan</i> (e)	1,000	EeDFGNTUuY-ARSZ-cgoz
<i>Combretum molle</i> (n)	1,000	ETu-AX-
<i>Corymbia maculata</i> (e)	1,000	CEeHTu-A-cgo
<i>Croton megalocarpus</i> (n)	1,000	CeTu-A-o
<i>Dovyalis caffra</i> (e)	1,000	EeLNTu-AS-cg
<i>Entada abyssinica</i> (n)	1,000	ETu-AX-g
<i>Erythrina abyssinica</i> (n)	1,000	EeTu-AX-c
<i>Eucalyptus microcorys</i> (e)	1,000	EeHu-A-cgo
<i>Eucalyptus saligna</i> (e)	1,000	EeDHNTu-A-cgos
<i>Faurea saligna</i> (n)	1,000	ETu-AX-s
<i>Ficus thonningii</i> (n)	1,000	EeTu-A-
<i>Harungana madagascariensis</i> (n)	1,000	CEeTu-X-gos
<i>Ilex mitis</i> (n)	1,000	CTuW-X-
<i>Jacaranda mimosifolia</i> (e)	1,000	CEeHTu--cgo
<i>Kigelia africana</i> (n)	1,000	CEeDLTu-X-c
<i>Leucaena diversifolia</i> (e)	1,000	EeFGTu-SZ-cgo
<i>Leucaena trichandra</i> (e)	1,000	EFTu-B-
<i>Maesopsis eminii</i> (e)	1,000	CEeHLTu-SZ-cgo
<i>Markhamia lutea</i> (n)	1,000	EeLTu-X-cgo
<i>Mimosa scabrella</i> (e)	1,000	EeNTu--o
<i>Morus nigra</i> (e)	1,000	CEeDTUu-S-cgs
<i>Newtonia buchananii</i> (n)	1,000	CGTu-X-
<i>Ocotea usambarensis</i> (n)	1,000	CEeTu-X-s
<i>Parinari curatellifolia</i> (n)	1,000	CEeDGLTu-X-g
<i>Phoenix reclinata</i> (n)	1,000	EeTu-X-cg
<i>Pinus patula</i> (e)	1,000	CEeHLTu-M-cos
<i>Prunus africana</i> (n)	1,000	CEeLTu-X-s
<i>Ricinus communis</i> (e)	1,000	EeDGNuY-R-cig
<i>Senegalia polyacantha</i> (n)	1,000	EeT-AXZ-
<i>Senna spectabilis</i> (e)	1,000	EeTu-R-cos
<i>Sesbania sesban</i> (n)	1,000	EeDFGTu-XS-co
<i>Solanum betaceum</i> (e)	1,000	EeNTu-AS-cg
<i>Spathodea campanulata</i> (n)	1,000	CEeHTu-XI-cigos
<i>Symphonia globulifera</i> (n)	1,000	Ceu-XBR-
<i>Tephrosia vogelii</i> (n)	1,000	EeGTu-SZ-cgo
<i>Terminalia superba</i> (e)	1,000	CEeHTuW--gos
<i>Trema orientalis</i> (n)	1,000	CEeGTu-XSZ-g

5 Species available from existing seed sources in Rwanda

A list of available sources of tree seed stands was gathered as part of the assignment. The sources of information are listed in Table 6. Based on the information gathered, a baseline tree seed source register was compiled. Although we believe this is the most complete register currently compiled, existing information needs to be updated and verified. In Table 7 we list the available sources for prioritized species. The sources which we were able to georeference (mostly by approximating geolocation) are displayed in Figure 1. Overall, it is noticeable that previous efforts to describe existing sources of tree seed have been heavily focusing on exotic species.

We wish to stress the preliminary nature of the gathered data, and the need for verifying and updating. For instance, some seed sources may be coded differently in two of the below sources and thus appear as two different sources in our data, although in reality there is only one existing source. Despite seed sources being listed in the table below, some may not be viable anymore due to harvesting, senescence, degradation, etc. A verification exercise will be part of the tree improvement programme.

Table 6. Sources consulted to compile a comprehensive list of national seed sources

Source	Explanation	Reference and comment
Pelgas et al. 2016 (A)	Technical report with detailed information about different sites visited from 8–12 February 2016 in five districts for identification and selection of good quality seed sources.	Pelgas et al. (2016) PDF document available from Jean Damascène Ndayambaje.
Pedersen A. 2019 (B)	Final technical report by international consultant engaged by Enabel to work with RFA on the seed sources management, establishment, and identification.	Pedersen (2019) PDF document available from Jacques Peeters (Enabel).
Pedersen A. 2018 (C)	Interim technical report by international consultant working with RFA for inputs on seed source identification, recording, demarcation, assessment, and registration in the period from 15 May to 8 June 2018.	Pedersen (2018) PDF document available from Jacques Peeters (Enabel).
Rwanda Forestry Authority (RFA). 2023 (D)	Latest updated data sheet of described seed sources at the Tree Seed Centre in Huye under the Rwanda Forestry Authority (RFA).	RFA (2023) Excel and word file available from Lambert Uwizeyimana (RFA).

Table 7. Prioritized species with available information on existing seed sources (S refers to the information source in Table 6).

The table is sorted by species, with intended placing of the species name for species with more than one seed source.

Species	Origin	Alt. (m)	Province	District	Site	S
<i>Acacia melanoxylon</i>	Exotic			Karongi	Ryabicinyiro	A
	Exotic			Nyamagabe	Mazimeru	A
	Exotic	2,357	Southern	Nyaruguru	Mironzi	A
<i>Afrocarpus falcatus</i>	Exotic	1,668	Southern	Nyamagabe	Gakomeye	C

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Table 7. Continued

Species	Origin	Alt. (m)	Province	District	Site	S
<i>Alnus acuminata</i>	Exotic	1,990	Northern	Gicumbi	Kagamba	A
	Exotic	2,118	Western	Burera	Kalima (RAB-Rwerere)	A
	Exotic	1,891	Northern	Musanze	Ruhondo	A
	Exotic	2,476	Western	Nyabihu	Ngamba	A
	Exotic			Nyabihu	Cyinka	A
	Exotic	1,662	Western	Rubavu	Akanyange	A
	Exotic	2,333	Western	Burera	Ngonya	B
	Exotic	1,737	Northern	Musanze	Ruhondo	B
	Exotic	2,057	Northern	Burera	Ngonya	D
<i>Casuarina equisetifolia</i>	Exotic	1,663	Southern	Nyanza		C
<i>Corymbia maculata</i>	Exotic	1,668	Southern	Nyamagabe	Gakomeye	B
	Exotic	1,668	Southern	Nyamagabe	Gakomeye	C
<i>Croton megalocarpus</i>	Native	1,663	Southern	Nyanza		C
<i>Cupressus lusitanica</i>	Exotic	1,735	Western	Ngoma	Gahororo	A
	Exotic	1,695	Southern	Gicumbi	Arboretum of Giti	A
	Exotic	1,663	Southern	Nyanza		C
	Exotic	1,724	Southern	Huye	Ruhande Arboretum	D
<i>Eucalyptus globulus subsp. maidenii</i>	Exotic	2,612	Northern	Gakenke	Kabuye mountain	A
	Exotic	1,670	Northern	Musanze	Mugara	A
	Exotic	2,281	Northern	Musanze	Musonga	A
	Exotic	2,072	Western	Rubavu	Bisesero	A
	Exotic	2,033	Western	Rutsiro	Kagugu	A
	Exotic	2,750	Western	Ngororero	Butimba	A
	Exotic			Karongi	Mutiti	A
	Exotic			Karongi	Ryabicinyiro	A
	Exotic	1,633	Southern	Huye	A Sahera	B
	Exotic	2,283	Western	Nyabihu	Ruhongore	B
	Exotic	1,945	Northern	Musanze	Cyabararika	B
	Exotic	2,524	Western	Ngororero	Butimba	B
	Exotic	1,913	Southern	Nyamagabe	Uruganda	B
	Exotic	1,945	Southern	Nyamagabe	Buhoro	B
	Exotic	1,909	Southern	Nyamagabe	Ryarubondo	B
	Exotic	1,903	Southern	Nyamagabe	Gisanze	B
	Exotic	2,273	Western	Rubavu	Bisesero	B
	Exotic	2,659	Western	Rubavu	Musumba	B
	Exotic	2,326	Southern	Nyamagabe	Remera mountain	C
	Exotic	1,680	Southern	Huye		C
	Exotic	1,633	Southern	Huye	Sahera	C
	Exotic	2,524	Western	Ngororero	Butimba	D
	Exotic	1,702	Southern	Huye	Sahera	D
	Exotic	2,056	Southern	Nyamagabe	Kuruganda rw'amazi	D
	Exotic	1,909	Southern	Nyamagabe	Ryarubondo	D

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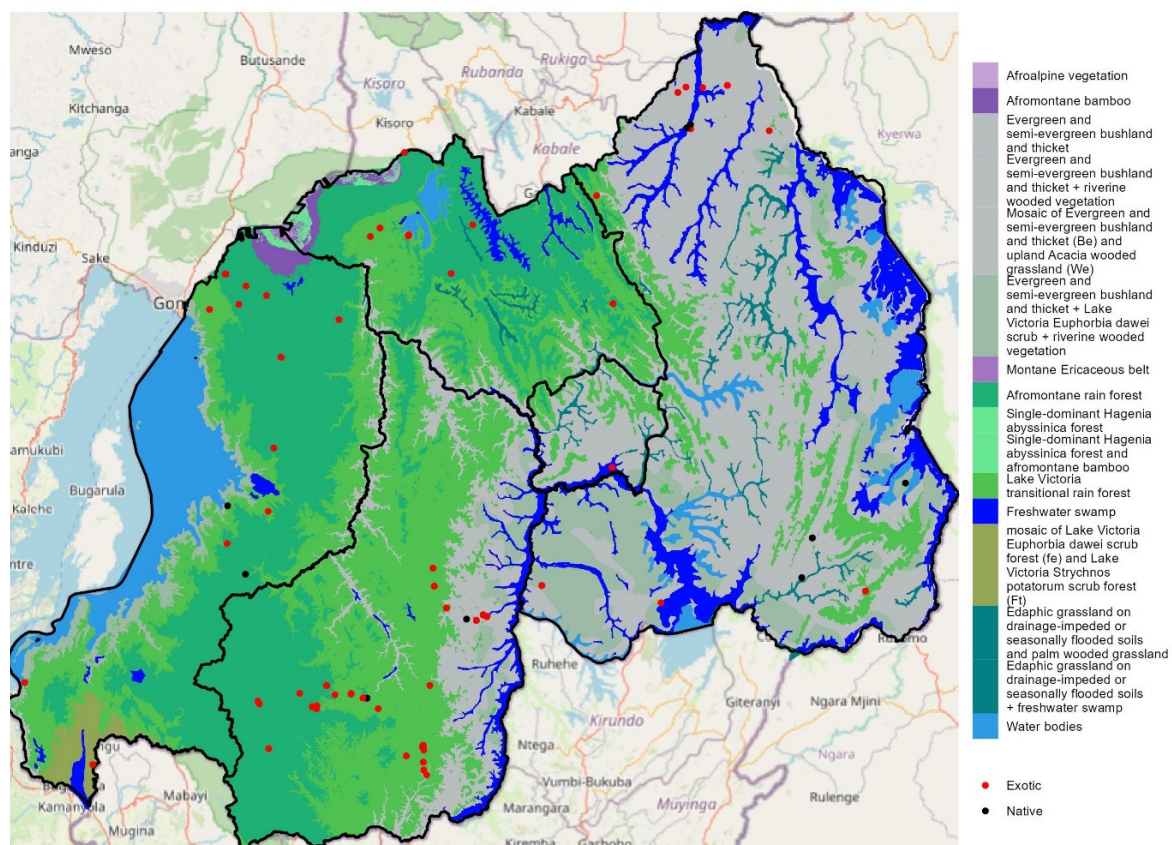
Table 7. Continued

Species	Origin	Alt. (m)	Province	District	Site	S
<i>Eucalyptus grandis</i>	Exotic	1,650	Eastern	Gicumbi	Cyondo	A
	Exotic	2,373	Southern	Nyamagabe	Remera mountain	C
<i>Eucalyptus microcorys</i>	Exotic	1,695	Southern	Gicumbi	Arboretum of Giti	A
	Exotic	1,695	Southern	Gicumbi	Arboretum of Giti	A
	Exotic	1,615	Southern	Ruhango	Ryabonyinka	B
	Exotic	1,775	Southern	Ruhango	Muyange	B
	Exotic	1,668	Southern	Nyamagabe	Gakomeye	C
	Exotic	1,640	Southern	Huye	Mirego	C
	Exotic	1,664	Southern	Nyanza	Gashuru	C
	Exotic	1,663	Southern	Nyanza		C
	Exotic	1,468	Southern	Nyanza	Mugari	C
	Exotic	1,502	Southern	Nyanza	Jali	C
	Exotic	1,775	Southern	Ruhango	Muyange	D
<i>Eucalyptus saligna</i>	Exotic	1,631	Southern	Huye	Mirego	C
<i>Eucalyptus tereticornis</i>	Exotic	1,656	Southern	Huye		C
<i>Eucalyptus microcorys</i>	Exotic	1,664	Southern	Nyanza	Gashuru	C
	Exotic	1,502	Southern	Nyanza	Jali	C
<i>Faurea saligna</i>	Native	1,724	Southern	Huye	Ruhande Arboretum	D
<i>Gliricidia sepium</i>	Exotic	1,340	Kigali	Bugesera	Karama	A
	Exotic	1,341	Eastern	Nyagatare	Nyagatare	A
	Exotic	1,368	Eastern	Nyagatare	Rwempasha	A
	Exotic	1,419	Eastern	Nyagatare	Nyendo	A
	Exotic	1,442	Eastern	Nyagatare	Nyendo	B
	Exotic	1,442	Eastern	Nyagatare	Nyendo	D
	Exotic	1,442	Eastern	Nyagatare	Cyamunyana	D
<i>Grevillea robusta</i>	Exotic	1,340	Kigali	Bugesera	Karama	A
	Exotic	1,350	Eastern	Nyagatare	Nyagatare Health Center	A
	Exotic	1,695	Southern	Gicumbi	Arboretum of Giti	A
	Exotic	1,990	Northern	Gicumbi	Kagamba	A
	Exotic			Rusizi	Cyijuru	A
	Exotic	1,718	Southern	Huye	Mpare	A
	Exotic	1,373	Eastern	Bugesera	Batima	B
	Exotic	1,663	Southern	Nyanza		C
<i>Maesopsis eminii</i>	Exotic			Rusizi	Rumaranyota	A
	Exotic	1,901	Western	Rusizi	Rumaranyota	B
	Exotic	1,668	Southern	Nyamagabe	Gakomeye	C
	Exotic	1,631	Southern	Huye	Mirego	C
<i>Markhamia lutea</i>	Native	1,349	Southern	Nyanza	Nyarubogo	A
	Native	1,436	Southern	Nyanza	Nyarubogo	B
<i>Milicia excelsa</i>	Exotic	1,640	Southern	Huye	RAB, Rubona station	C
<i>Pinus caribaea</i>	Exotic	1,459	Eastern	Bugesera	Shyara	A
	Exotic	1,597	Eastern	Kirehe	Nyarushunzi	A
	Exotic	1,597	Eastern	Kirehe	Nyarushunzi	A
	Exotic	1,533	Eastern	Bugesera	Shyara	B

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Table 7. Continued

Species	Origin	Alt. (m)	Province	District	Site	S
<i>Pinus caribaea</i>	Exotic	1,559	Western	Rusizi	Ntemabiti	B
	Exotic	1,468	Southern	Nyanza	Mugari	C
	Exotic	1,597	Eastern	Kirehe	Nyarushunzi	D
<i>Pinus patula</i>	Exotic			Muhanga	Nyabihanga	A
<i>Polyscias fulva</i>	Native	1,668	Southern	Nyamagabe	Gakomeye	C
	Native	1,631	Southern	Huye	Mirego	C
<i>Pterygota mildbraedii</i>	Native	1,527	Eastern	Ngoma	Rurama	A
	Native	1,336	Eastern	Ngoma	Rurama	B
	Native	1,468	Southern	Nyanza	Mugari	C
	Native	1,502	Eastern	Ngoma	Rurama	D
	Native	1,336	Eastern	Ngoma	Rurama	D
<i>Senegalia polyacantha</i>	Native	1,307	Eastern	Kirehe	Nyawerall	B
<i>Senna spectabilis</i>	Exotic	1,419	Eastern	Nyagatare	Nyendo	A
	Exotic	1,442	Eastern	Nyagatare	Nyendo	B
<i>Syzygium guineense</i>	Native	1,468	Southern	Nyanza	Mugari	C
<i>Pterygota mildbraedii</i>	Native	1,465	Western	Karongi	Gatare	A
	Native	2,442	Western	Karongi	Gakuta	B
<i>Toona sinensis</i>	Exotic	1,349	Southern	Nyanza	Nyarubogo	A
	Exotic	1,468	Southern	Nyanza	Mugari	C
<i>Vachellia kirkii</i>	Native	1,351	Eastern	Nyagatare	Nyagatare	B
	Native	1,351	Eastern	Nyagatare	Nyagatare	D



6 A subset of species for humid areas

When investigating the distribution of the moisture index in Rwanda, the characteristic zone in western Rwanda is the humid zone, characterized by a climatic moisture index above -0.35 (Figure 2 and Figure 3; note also that Rwanda does not include semi-arid or arid zones according to this classification).⁷ Zones where the CMI was above 0 (equivalent to zones where the precipitation was above the Potential Evapotranspiration) correspond mainly to areas where the elevation was above 2,000 m, especially in the west of the country (Figure 4).

We checked whether the prioritized species could be suitable based on a new global database with environmental ranges for a large subset of known tree species (TreeGOER; (Kindt, 2023a, 2023b)). The results are shown in Table 8 for the priority species using a zonation system that was developed for the TreeGOER database.



Figure 2. Country and provincial boundaries for Rwanda sourced from the GADM database

Note: Map generated in QGIS (version 3.22.11).

Source: Basemap obtained from OpenStreetMap (OSM Humanitarian Data Model)

⁷ High resolution maps with the global distribution of CMI zones are available from the TreeGOER Global Zones atlas (Kindt, 2023a)

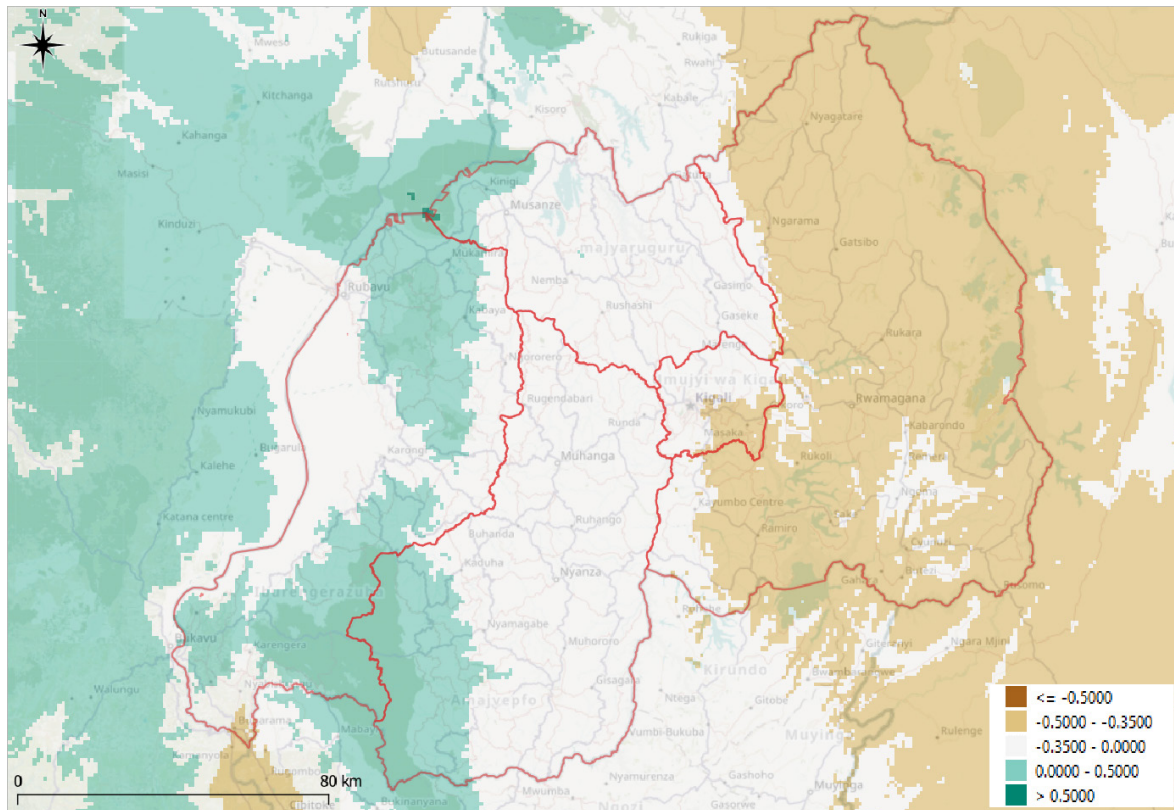


Figure 3. Overlay of the Climatic Moisture Index (CMI) onto the map shown in Figure 2

Note: Humid zones have a CMI > -0.35 (see Kindt 2023a). Map generated in QGIS (version 3.22.11).

Source: Basemap obtained from OpenStreetMap (OSM Humanitarian Data Model)

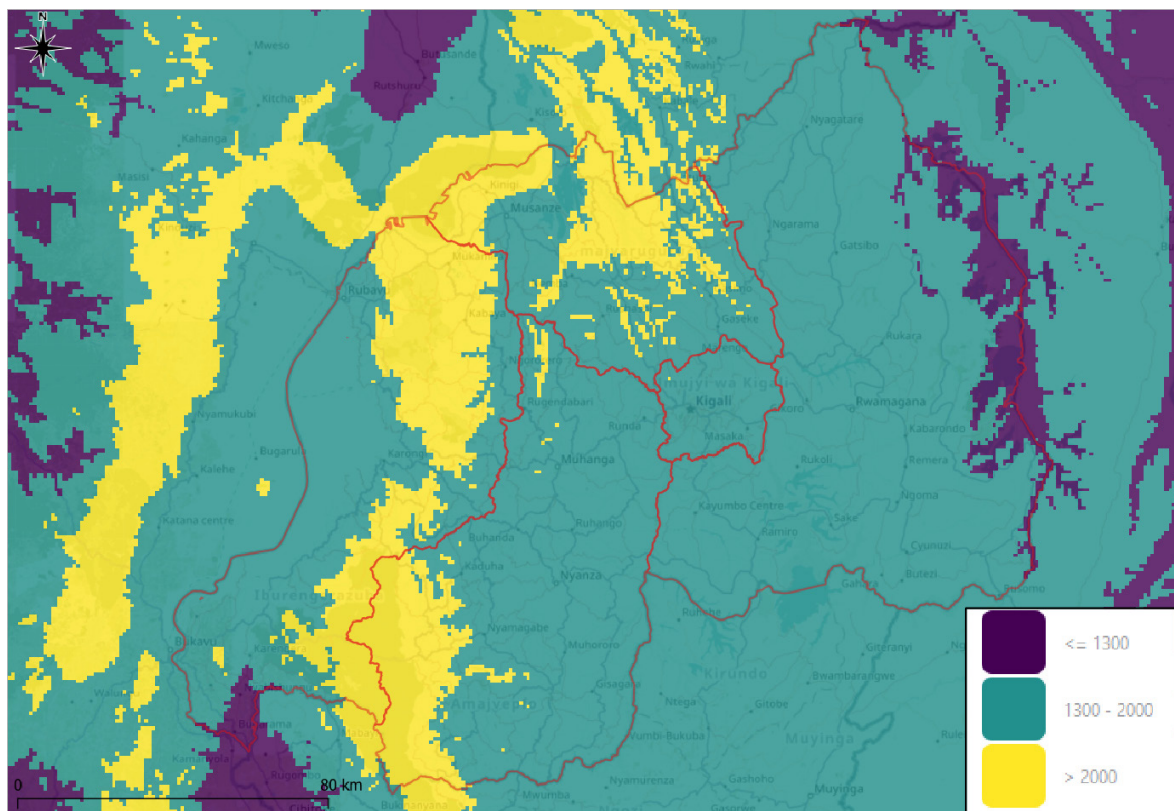


Figure 4. Overlay of elevation zones (obtained from WorldClim 2.1) onto the map shown in Figure 2

Note: Map generated in QGIS (version 3.22.11).

Source: Basemap obtained from OpenStreetMap (OSM Humanitarian Data Model)

Table 8. Occurrence of the priority species list in different zones defined by the Climatic Moisture Index (CMI) as documented in the Tree Globally Observed Environmental Ranges database

For taxa encountered at infraspecific level, data was compiled from the species listed in TreeGOER. Codes used for the CMI zones are: 1 = species only occurs in this zone; u = species reaches its upper distribution limits in this zone; M = the zone is entirely included in the species range; I = the species reaches its lower distribution limits in this zone. n = number of cleaned records where outliers were removed. DS = Dry sub-humid drylands zone. The colour scheme reflects colours used in Figure 3. Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red. Native and introduced wild distributions of accepted taxa are gathered from the World Checklist of Vascular Plants.

Species	n	Q05	Q95	CMI ≥ 0.5	0 ≤ CMI < 0.5	-0.35 ≤ CMI < 0	-0.5 ≤ CMI < -0.35 (= DS)
<i>Polyscias fulva</i> (n)	146	-0.29	0.47	u	u	I	
<i>Prunus africana</i> (n)	290	-0.55	0.43		u	M	M
<i>Entandrophragma excelsum</i> (n)	29	-0.27	0.31		u	I	
<i>Symphonia globulifera</i> (n)	1614	-0.18	0.63		M	I	
<i>Hagenia abyssinica</i> (n)	95	-0.38	0.3		u	M	I
<i>Markhamia lutea</i> (n)	150	-0.5	0.49		u	M	M
<i>Erythrina abyssinica</i> (n)	247	-0.59	0.07		u	M	M
<i>Carapa grandiflora</i> (n)	(not available)			u			
<i>Acacia melanoxylon</i> (e)	25420	-0.45	0.44		u	M	I
<i>Grevillea robusta</i> (e)	4036	-0.62	0.25		u	M	M
<i>Maesopsis eminii</i> (e)	170	-0.28	0.54		M	I	
<i>Afrocarpus falcatus</i> (e)	314	-0.64	0.2		u	M	M
<i>Pinus patula</i> (e)	928	-0.54	0.39		u	M	M
<i>Maesa lanceolata</i> (n)	632	-0.5	0.41		u	M	M
<i>Myrianthus holstii</i> (n)	68	-0.34	0.3		u	I	
<i>Acacia mearnsii</i> (e)	11375	-0.51	0.09		u	M	M
<i>Croton megalocarpus</i> (n)	69	-0.66	0.19		u	M	M
<i>Dombeya torrida</i> (n)	80	-0.52	0.31		u	M	M
<i>Parinari excelsa</i> (n)	577	-0.36	0.47		u	M	I
<i>Persea americana</i> (e)	2953	-0.71	0.5		M	M	M
<i>Cupressus lusitanica</i> (e)	1364	-0.65	0.45		u	M	M
<i>Eucalyptus globulus subsp. Maidenii</i> (e)	7973	-0.6	0.37		u	M	M
<i>Faurea saligna</i> (n)	226	-0.63	0.04		u	M	M
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	2376	-0.59	0.44		u	M	M
<i>Casuarina equisetifolia</i> (e)	1415	-0.74	0.52		M	M	M
<i>Eucalyptus saligna</i> (e)	3204	-0.27	0.33		u	I	
<i>Bersama abyssinica</i> (n)	348	-0.38	0.47		u	M	I
<i>Syzygium guineense</i> (n)	1476	-0.61	0.29		u	M	M
<i>Neoboutonia macrocalyx</i> (n)	61	-0.33	0.37		u	I	
<i>Syzygium parvifolium</i> (n)	12	0	0.46		u		
<i>Pterygota mildbraedii</i> (n)	17	-0.4	0.43		u	M	I
<i>Ficus thonningii</i> (n)	849	-0.7	0.21		u	M	M
<i>Senegalia polyacantha</i> (n)	851	-0.74	-0.18			u	M

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Table 8. Continued

Species	n	Q05	Q95	CMI ≥ 0.5	0 ≤ CMI < 0.5	-0.35 ≤ CMI < 0	-0.5 ≤ CMI < -0.35 (= DS)
<i>Entada abyssinica</i> (n)	692	-0.51	0.07		u	M	M
<i>Pinus caribaea</i> (e)	293	-0.34	0.52	u	M	I	
<i>Eucalyptus grandis</i> (e)	1387	-0.18	0.36		u	I	
<i>Eucalyptus microcorys</i> (e)	4251	-0.2	0.34		u	I	
<i>Ficalhoa laurifolia</i> (n)	64	-0.35	0.29		u	M	
<i>Ocotea usambarensis</i> (= <i>Kuloa usambarensis</i>) (n)	61	-0.39	0.29		u	M	I
<i>Artocarpus heterophyllus</i> (e)	1248	-0.48	0.57	u	M	M	I
<i>Tephrosia vogelii</i> (n)	244	-0.45	0.49		u	M	I
<i>Psidium guajava</i> (e)	7160	-0.65	0.5		M	M	M
<i>Mitragyna rubrostipulata</i> (n)	12	-0.12	0.35		u	I	
<i>Harungana montana</i> (n)	14	0.02	0.4		1		
<i>Macaranga kilimandscharica</i> (n)	(not available)						
<i>Gambeya gorungosana</i> (n)	55	-0.31	0.39		u	I	
<i>Gymnanthemum amygdalinum</i> (e)	603	-0.65	0.45		u	M	M
<i>Alnus acuminata</i> (e)	1667	-0.6	0.5		M	M	M
<i>Gliricidia sepium</i> (e)	1773	-0.55	0.48		u	M	M
<i>Acaciella angustissima</i> (e)	1486	-0.73	0.35		u	M	M
<i>Jacaranda mimosifolia</i> (e)	4916	-0.73	0.19		u	M	M
<i>Leucaena diversifolia</i> (e)	348	-0.62	0.42		u	M	M
<i>Senna spectabilis</i> (e)	1859	-0.63	0.34		u	M	M
<i>Sesbania sesban</i> (n)	723	-0.86	0.52	u	M	M	M
<i>Cajanus cajan</i> (e)	(not available)						
<i>Leucaena leucocephala</i> (e)	6933	-0.71	0.57	u	M	M	M
<i>Senna siamea</i> (e)	2842	-0.63	0.15		u	M	M
<i>Spathodea campanulata</i> (n)	1675	-0.59	0.52	u	M	M	M
<i>Vachellia sieberiana</i> (n)	1481	-0.82	-0.33			u	M
<i>Solanecio mannii</i> (n)	102	-0.39	0.59	u	M	M	I
<i>Vachellia hockii</i> (n)	579	-0.63	-0.15			u	M
<i>Vepris nobilis</i> (n)	148	-0.64	0.19		u	M	M
<i>Phoenix reclinata</i> (n)	774	-0.65	0.29		u	M	M
<i>Newtonia buchananii</i> (n)	100	-0.41	0.24		u	M	I
<i>Strombosia scheffleri</i> (n)	148	-0.28	0.53	u	M	I	
<i>Combretum molle</i> (n)	1741	-0.67	-0.09			u	M
<i>Acokanthera schimperi</i> (n)	56	-0.93	-0.13			u	M
<i>Solanum betaceum</i> (e)	549	-0.55	0.54	u	M	M	M
<i>Searsia natalensis</i> (e)	322	-0.63	0.01		u	M	M
<i>Cornus volkensii</i> (n)	40	-0.24	0.42		u	I	
<i>Dracaena steudneri</i> (n)	69	-0.38	0.17		u	M	I
<i>Ilex mitis</i> (n)	518	-0.57	0.35		u	M	M
<i>Myrsine melanophloeos</i> (n)	378	-0.66	0.23		u	M	M

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Table 8. Continued

Species	n	Q05	Q95	CMI ≥ 0.5	0 ≤ CMI < 0.5	-0.35 ≤ CMI < 0	-0.5 ≤ CMI < -0.35 (= DS)
<i>Xymalos monospora</i> (n)	321	-0.47	0.44		u	M	I
<i>Ximenia caffra</i> (n)	339	-0.74	-0.04			u	M
<i>Toona sinensis</i> (e)	155	-0.44	0.61	u	M	M	I
<i>Euphorbia tirucalli</i> (n)	1840	-0.69	0.2		u	M	M
<i>Psydrax schimperianus</i> (n)	83	-0.73	-0.06			u	M
<i>Ficus laurifolia</i> (n)	1	-0.21	-0.21			1	
<i>Morus nigra</i> (e)	1041	-0.71	0.33		u	M	M
<i>Carica papaya</i> (e)	7893	-0.66	0.51	u	M	M	M
<i>Trema orientalis</i> (n)	1835	-0.49	0.63	u	M	M	I
<i>Eucalyptus tereticornis</i> (e)	6523	-0.55	0.19		u	M	M
<i>Mimosa scabrella</i> (e)	193	-0.09	0.45		u	I	
<i>Acrocarpus fraxinifolius</i> (e)	53	-0.53	0.27		u	M	M
<i>Biancaea decapetala</i> (e)	(not available)						
<i>Dracaena afromontana</i> (n)	101	-0.49	0.32		u	M	I
<i>Alnus glutinosa</i> (e)	154253	-0.2	0.48		u	I	
<i>Euclea racemosa</i> (n)	408	-0.91	-0.13			u	M
<i>Macaranga capensis</i> (e)	76	-0.45	0.2		u	M	I

Source: TreeGOER; Kindt (2023a); Kindt (2023b)

References

- BIOCEM-RD Ltd. 2018. *Biodiversity Survey of Gishwati-Mukura National Park*. Rwanda Environment Management Authority (REMA) & Rwanda Development Board (RDB).
- Govaerts R, Nic Lughadha E, Black N, Turner R, Paton A. .2021. The World Checklist of Vascular Plants, a continuously updated resource for exploring global plant diversity. *Scientific Data*, 8(1). <https://doi.org/10.1038/s41597-021-00997-6>
- Kindt R. 2020. WorldFlora: An R package for exact and fuzzy matching of plant names against the World Flora Online taxonomic backbone data. *Applications in Plant Sciences*, 8(9), e11388. <https://doi.org/10.1002/aps3.11388>
- Kindt R. 2023a. *TreeGOER Global Zones: Global atlas for the Climatic Moisture Index (CMI), Maximum Climatological Water Deficit (MCWD) and the number of months with average temperature > 10 degrees C (Tmo10)*. Version [2023.10]. <https://doi.org/10.5281/zenodo.8252756>
- Kindt R. 2023b. TreeGOER: A database with globally observed environmental ranges for 48,129 tree species. *Global Change Biology*, 29(22), 6303-6318. <https://doi.org/10.1111/gcb.16914>
- Kindt R, Dawson IK, Lillesø J-P B, Muchugi A, Pedercini F, Roshetko J, van Noordwijk M, Graudal L, Jamnadass R. 2021. The one hundred tree species prioritized for planting in the tropics and subtropics as indicated by database mining. *World Agroforestry*.
- Kindt R, Siddique I, Dawson I, John I, Pedercini F, Lillesø J-P, Graudal L. 2025. The Agroforestry Species Switchboard, a global resource to explore information for 107,269 plant species. *bioRxiv*, 2025.2003. 2009.642182.
- Kindt R, van Breugel P, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011a. Volume 2: Description and Tree Species Composition for Forest Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/244325182/2_VECEA_Volume_2_Forest.pdf
- Kindt R, van Breugel P, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011b. Volume 3: Description and Tree Species Composition for Woodland and Wooded Grassland Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/36077559/VECEA_Volume3_Woodlands.pdf
- Kindt R, van Breugel P, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011c. Volume 4: Description and Tree Species Composition for Bushland and Thicket Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/244325252/2_VECEA_Volume_4_Bushland.pdf
- KME Ltd. 2021. *Selection of 5 Tree Species with High Economic Value Likely to Boost the Wood Industry in Rwanda* [Final Report]. Rwanda Forestry Authority (RFA). <https://www.rfa.rw/index.php?eID=dumpFile&t=f&f=35539&token=258a88ea4a54eff3ade70646a1edb2e53dbddcfff>
- Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kindt R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T, Sinclair F. 2017. *Suitable tree species selection and management tool for Rwanda [Database]*. World Agroforestry Centre (ICRAF). <https://apps.worldagroforestry.org/suitable-tree/rwanda>
- LAFREC. 2018. Gishwati-Mukura Setting ground for eco-friendly mining sector. *Landscape Approach to Forest Restoration and Conservation (LAFREC) Project*. LAFREC PROJECT MAGAZINE, Issue 003.
- MoE. 2025. *Reducing vulnerability to climate change through enhanced community-based biodiversity conservation in the Eastern Province of Rwanda (COMBIO)*. Ministry of Environment (MoE), Republic of Rwanda. <https://www.environment.gov.rw/1-1/muhazi-dyke>
- Mukuralinda A. 2022. *Community led planning and management for biodiversity protection and resilient communities in Southern Rwanda. Technical Progress Report*. World Agroforestry Centre (ICRAF).
- Nduwayezu JB, Ruffo C., Minani V, Munyaneza E, Nshutiayesu S. 2009. *Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda*. Pallotti Press.
- BIOCEM-RD Ltd. 2018. *Biodiversity Survey of Gishwati-Mukura National Park*. Rwanda Environment Management Authority (REMA) & Rwanda Development Board (RDB).

- Govaerts, R., Nic Lughadha, E., Black, N., Turner, R., & Paton, A. (2021). The World Checklist of Vascular Plants, a continuously updated resource for exploring global plant diversity. *Scientific Data*, 8(1). <https://doi.org/10.1038/s41597-021-00997-6>
- Kindt R. 2020. WorldFlora: An R package for exact and fuzzy matching of plant names against the World Flora Online taxonomic backbone data. *Applications in Plant Sciences*, 8(9), e11388. <https://doi.org/10.1002/aps3.11388>
- Kindt R. 2023a. *TreeGOER Global Zones: Global atlas for the Climatic Moisture Index (CMI), Maximum Climatological Water Deficit (MCWD) and the number of months with average temperature > 10 degrees C (Tmo10)*. Version [2023.10]. <https://doi.org/10.5281/zenodo.8252756>
- Kindt R. 2023b. TreeGOER: A database with globally observed environmental ranges for 48,129 tree species. *Global Change Biology*, 29(22), 6303-6318. <https://doi.org/10.1111/gcb.16914>
- Kindt R, Dawson IK, Lillesø J-P B, Muchugi A, Pedercini F, Roshetko J, van Noordwijk M, Graudal L, Jamnadass R. 2021. The one hundred tree species prioritized for planting in the tropics and subtropics as indicated by database mining. *World Agroforestry*.
- Kindt R, Siddique I, Dawson I, John I, Pedercini F, Lillesø J-P, Graudal L. 2025. The Agroforestry Species Switchboard, a global resource to explore information for 107,269 plant species. *bioRxiv*, 2025.2003.2009.642182.
- Kindt R, van Breugel P, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011a. Volume 2: Description and Tree Species Composition for Forest Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/244325182/2_VECEA_Volume_2_Forest.pdf
- Kindt R, van Breugel, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011b. Volume 3: Description and Tree Species Composition for Woodland and Wooded Grassland Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/36077559/VECEA_Volume3_Woodlands.pdf
- Kindt R, van Breugel P, Lillesø J-P B, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F. 2011c. Volume 4: Description and Tree Species Composition for Bushland and Thicket Potential Natural Vegetation Types. https://static-curis.ku.dk/portal/files/244325252/2_VECEA_Volume_4_Bushland.pdf
- KME Ltd. 2021. *Selection of 5 Tree Species with High Economic Value Likely to Boost the Wood Industry in Rwanda* [Final Report]. Rwanda Forestry Authority (RFA). <https://www.rfa.rw/index.php?eID=dumpFile&t=f&f=35539&token=258a88ea4a54eff3ade70646a1edb2e53dbddcfc>
- Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kindt R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T, Sinclair F. 2017. *Suitable tree species selection and management tool for Rwanda [Database]*. World Agroforestry Centre (ICRAF). <https://apps.worldagroforestry.org/suitable-tree/rwanda>
- LAFREC. 2018. Gishwati-Mukura Setting ground for eco-friendly mining sector. *Landscape Approach to Forest Restoration and Conservation (LAFREC) Project*. LAFREC PROJECT MAGAZINE, Issue 003.
- MoE. 2025. *Reducing vulnerability to climate change through enhanced community-based biodiversity conservation in the Eastern Province of Rwanda (COMBIO)*. Ministry of Environment (MoE), Republic of Rwanda. <https://www.environment.gov.rw/1-1/muhazi-dyke>
- Mukuralinda A. 2022. *Community led planning and management for biodiversity protection and resilient communities in Southern Rwanda. Technical Progress Report*. World Agroforestry Centre (ICRAF).
- Nduwayezu JB, Ruffo C., Minani V, Munyaneza E, Nshutiyayesu S. 2009. *Know Some Useful Trees and Shrubs for Agricultural and Pastoral Communities of Rwanda*. Pallotti Press.

Appendices

Appendix 1. Full list of species and their presence in information sources

See Table 2 for details. Note that species of rank D include species that are not trees as they were encountered among vegetation assemblages of the vegetationmap4africa.

Native species are marked with (n) and displayed in green, exotic species are marked with (e) and displayed in red.

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNpgui	RFA5	Sources	Sources weighted
<i>Polyscias fulva</i> (n)	A	A	1	1	1	1	1	1	1	1	0	1	1	1	1	0	12	20
<i>Prunus africana</i> (n)	A	A	1	1	1	0	0	1	0	0	0	1	1	1	1	1	9	18
<i>Entandrophragma excelsum</i> (n)	A	A	1	1	1	0	0	0	1	0	0	0	1	1	1	1	8	16
<i>Symphonia globulifera</i> (n)	A	A	1	1	1	0	0	0	0	0	0	1	1	1	1	1	8	16
<i>Hagenia abyssinica</i> (n)	A	A	1	1	1	1	0	1	0	0	0	0	1	1	1	0	8	14
<i>Markhamia lutea</i> (n)	A	A	1	1	1	1	1	0	1	0	0	0	1	0	0	1	8	13
<i>Erythrina abyssinica</i> (n)	A	A	1	1	1	1	1	1	0	0	1	0	1	0	0	0	8	12
<i>Carapa grandiflora</i> (n)	A	A	0	1	0	0	0	1	1	0	0	1	1	1	1	0	7	14
<i>Acacia melanoxylon</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	1	7	13
<i>Grevillea robusta</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	1	7	13
<i>Maesopsis eminii</i> (e)	A	A	1	1	1	0	1	1	1	0	0	0	0	0	0	1	7	12
<i>Afrocarpus falcatus</i> (e)	A	A	1	1	1	0	0	0	1	0	0	0	0	1	0	1	6	12
<i>Pinus patula</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	1	6	11
<i>Maesa lanceolata</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	1	0	0	6	11
<i>Myrianthus holstii</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	1	0	0	6	11
<i>Acacia mearnsii</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	1	0	0	0	6	10
<i>Croton megalocarpus</i> (n)	A	A	1	1	1	1	0	0	1	0	0	0	0	1	0	0	6	10
<i>Dombeya torrida</i> (n)	A	A	1	1	1	1	0	0	0	0	0	0	1	1	0	0	6	10
<i>Parinari excelsa</i> (n)	A	A	1	0	1	0	0	1	0	0	0	0	1	1	0	0	5	10
<i>Persea americana</i> (e)	A	A	0	0	1	1	0	1	1	0	0	0	1	0	0	0	5	9
<i>Cupressus lusitanica</i> (e)	A	A	1	0	1	1	0	1	0	0	0	0	0	0	0	1	5	9
<i>Eucalyptus globulus subsp. maidenii</i> (e)	A	A	1	0	0	1	0	1	1	0	0	0	0	0	0	1	5	9
<i>Faurea saligna</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	0	1	0	0	5	9
<i>Calliandra houstoniana</i> var. <i>calothyrsus</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Casuarina equisetifolia</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Eucalyptus saligna</i> (e)	A	A	1	0	1	1	0	1	1	0	0	0	0	0	0	0	5	8
<i>Bersama abyssinica</i> (n)	A	A	0	0	1	1	0	1	0	1	0	0	1	0	0	0	5	8
<i>Syzygium guineense</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	0	0	0	5	8

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Neoboutonia macrocalyx</i> (n)	A	A	1	1	1	0	0	1	0	0	0	0	1	0	0	0	5	8
<i>Syzygium parvifolium</i> (n)	A	A	1	1	0	1	0	1	0	0	0	0	0	1	0	0	5	8
<i>Pterygota mildbraedii</i> (n)	A	A	1	1	1	1	0	0	0	0	0	0	0	0	0	1	5	8
<i>Ficus thonningii</i> (n)	A	B	0	1	1	1	1	1	0	0	0	0	0	0	0	0	5	7
<i>Senegalia polyacantha</i> (n)	A	B	1	1	1	0	1	0	1	0	0	0	0	0	0	0	5	7
<i>Entada abyssinica</i> (n)	A	B	1	1	1	0	1	0	0	0	1	0	0	0	0	0	5	7
<i>Pinus caribaea</i> (e)	B	A	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4	8
<i>Eucalyptus grandis</i> (e)	B	A	1	0	0	0	0	1	1	0	0	0	0	0	0	1	4	8
<i>Eucalyptus microcorys</i> (e)	B	A	1	0	0	0	0	1	1	0	0	0	0	0	0	1	4	8
<i>Ficalhoa laurifolia</i> (n)	B	A	1	0	1	0	0	0	0	0	0	0	1	0	0	1	4	8
<i>Kuloo usambarensis</i> (n)	B	A	1	0	1	0	0	0	0	0	0	0	1	0	0	1	4	8
<i>Artocarpus heterophyllus</i> (e)	B	B	0	0	1	1	0	1	1	0	0	0	0	0	0	0	4	7
<i>Tephrosia vogelii</i> (n)	B	B	1	0	1	0	0	1	1	0	0	0	0	0	0	0	4	7
<i>Psidium guajava</i> (e)	B	B	0	0	1	1	0	1	0	0	1	0	0	0	0	0	4	7
<i>Mitragyna rubrostipulata</i> (n)	B	B	0	0	0	1	1	1	0	0	0	0	0	1	0	0	4	7
<i>Harungana montana</i> (n)	B	B	0	1	0	0	0	1	0	0	0	1	0	0	1	0	4	7
<i>Macaranga kilimandscharica</i> (n)	B	B	1	0	0	0	0	1	0	0	0	1	0	0	1	0	4	7
<i>Gambeya gorungosana</i> (n)	B	B	1	1	0	0	0	0	0	0	0	0	1	1	0	0	4	7
<i>Gymnanthemum amygdalinum</i> (e)	B	B	1	0	1	1	0	1	0	0	0	0	0	0	0	0	4	6
<i>Alnus acuminata</i> (e)	B	B	1	0	0	1	0	1	1	0	0	0	0	0	0	0	4	6
<i>Gliricidia sepium</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Acaciella angustissima</i> (e)	B	B	1	0	0	1	0	1	1	0	0	0	0	0	0	0	4	6
<i>Jacaranda mimosifolia</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Leucaena diversifolia</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Senna spectabilis</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Sesbania sesban</i> (n)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Cajanus cajan</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Leucaena leucocephala</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Senna siamea</i> (e)	B	B	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4	6
<i>Spathodea campanulata</i> (n)	B	B	1	1	1	0	0	0	1	0	0	0	0	0	0	0	4	6
<i>Vachellia sieberiana</i> (n)	B	B	1	1	1	0	0	0	1	0	0	0	0	0	0	0	4	6
<i>Solanecio mannii</i> (n)	B	B	0	0	0	1	0	1	0	1	1	0	0	0	0	0	4	6
<i>Vachellia hockii</i> (n)	B	B	1	0	1	1	0	0	0	0	1	0	0	0	0	0	4	6
<i>Vepris nobilis</i> (n)	B	B	0	0	1	1	1	0	0	0	1	0	0	0	0	0	4	6
<i>Phoenix reclinata</i> (n)	B	B	1	0	1	0	0	0	0	1	1	0	0	0	0	0	4	6
<i>Newtonia buchananii</i> (n)	B	B	1	1	1	0	0	0	0	0	0	0	1	0	0	0	4	6
<i>Strombosia scheffleri</i> (n)	B	B	1	1	1	0	0	0	0	0	0	0	1	0	0	0	4	6
<i>Combretum molle</i> (n)	B	B	0	1	1	1	1	0	0	0	0	0	0	0	0	0	4	5
<i>Acokanthera schimperi</i> (n)	B	B	0	0	1	1	1	0	0	1	0	0	0	0	0	0	4	5

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Solanum betaceum</i> (e)	B	B	0	0	1	0	0	1	1	0	0	0	0	0	0	0	3	6
<i>Searsia natalensis</i> (e)	B	B	0	0	1	0	0	1	0	0	1	0	0	0	0	0	3	6
<i>Cornus volkensii</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Dracaena steudneri</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Ilex mitis</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Myrsine melanophloeos</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Xymalos monospora</i> (n)	B	B	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	6
<i>Ximenia caffra</i> (n)	B	B	0	0	1	0	0	0	0	1	0	0	0	1	0	0	3	6
<i>Toona sinensis</i> (e)	B	B	0	0	0	1	0	1	1	0	0	0	0	0	0	0	3	5
<i>Euphorbia tirucalli</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Psydrax schimperianus</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Ficus laurifolia</i> (n)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Morus nigra</i> (e)	B	B	0	0	1	1	0	1	0	0	0	0	0	0	0	0	3	5
<i>Carica papaya</i> (e)	B	B	0	0	1	1	0	0	1	0	0	0	0	0	0	0	3	5
<i>Trema orientalis</i> (n)	B	B	0	0	1	0	1	1	0	0	0	0	0	0	0	0	3	5
<i>Eucalyptus tereticornis</i> (e)	B	B	1	0	0	0	0	1	1	0	0	0	0	0	0	0	3	5
<i>Mimosa scabrella</i> (e)	B	B	1	0	0	0	0	1	1	0	0	0	0	0	0	0	3	5
<i>Acrocarpus fraxinifolius</i> (e)	B	B	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	5
<i>Biancaea decapetala</i> (e)	B	B	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	5
<i>Dracaena afromontana</i> (n)	B	B	0	0	0	1	0	1	0	0	0	0	0	0	1	0	3	5
<i>Alnus glutinosa</i> (e)	B	B	0	0	1	1	0	0	0	0	0	0	1	0	0	0	3	5
<i>Euclea racemosa</i> (n)	B	B	0	0	1	1	0	0	0	0	1	0	0	0	0	0	3	5
<i>Macaranga capensis</i> (e)	B	B	0	1	1	0	0	0	0	0	0	0	1	0	0	0	3	5
<i>Corymbia maculata</i> (e)	B	C	1	0	0	1	0	1	0	0	0	0	0	0	0	0	3	4
<i>Tetradenia riparia</i> (e)	B	C	1	0	0	1	0	1	0	0	0	0	0	0	0	0	3	4
<i>Moringa oleifera</i> (e)	B	C	1	0	1	1	0	0	0	0	0	0	0	0	0	0	3	4
<i>Grewia similis</i> (n)	B	C	0	0	1	1	1	0	0	0	0	0	0	0	0	0	3	4
<i>Markhamia obtusifolia</i> (n)	B	C	0	0	1	1	0	0	0	1	0	0	0	0	0	0	3	4
<i>Faidherbia albida</i> (e)	B	C	1	0	0	1	0	0	1	0	0	0	0	0	0	0	3	4
<i>Leucaena trichandra</i> (e)	B	C	1	0	0	1	0	0	1	0	0	0	0	0	0	0	3	4
<i>Albizia gummifera</i> (n)	B	C	1	1	1	0	0	0	0	0	0	0	0	0	0	0	3	4
<i>Ricinus communis</i> (e)	B	C	0	0	1	1	0	0	0	1	0	0	0	0	0	0	3	4
<i>Terminalia mantaly</i> (e)	B	C	0	0	1	1	0	0	0	1	0	0	0	0	0	0	3	4
<i>Vachellia kirkii</i> (n)	B	C	1	0	1	0	1	0	0	0	0	0	0	0	0	0	3	4
<i>Dovyalis caffra</i> (e)	B	C	1	1	1	0	0	0	0	0	0	0	0	0	0	0	3	4
<i>Milicia excelsa</i> (e)	C	B	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2	5
<i>Harungana madagascariensis</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Agarista salicifolia</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Brugmansia suaveolens</i> (e)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Dodonaea viscosa</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Eriobotrya japonica</i> (e)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Ficus elastica</i> (e)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Ficus sycomorus</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Galiniera saxifraga</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Psychotria mahonii</i> (n)	C	C	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	4
<i>Terminalia superba</i> (e)	C	C	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	4
<i>Anthocleista grandiflora</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4
<i>Capparis tomentosa</i> (n)	C	C	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	4
<i>Carissa spinarum</i> (n)	C	C	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	4
<i>Commiphora africana</i> (n)	C	C	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	4
<i>Cussonia arborea</i> (n)	C	C	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	4
<i>Nuxia congesta</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4
<i>Olinia rochetiana</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4
<i>Psydrax parviflorus</i> (n)	C	C	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	4
<i>Tabernaemontana stapfiana</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4
<i>Oldeania alpina</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4
<i>Cedrela odorata</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4
<i>Eucalyptus dunnii</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4
<i>Erica mannii</i> (n)	C	C	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	4
<i>Ficus ingens</i> (n)	C	C	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	4
<i>Citrus limon</i> (e)	C	C	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	3
<i>Coffea arabica</i> (e)	C	C	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	3
<i>Euphorbia umbellata</i> (n)	C	C	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	3
<i>Morus alba</i> (e)	C	C	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	3
<i>Solanum aculeastrum</i> (n)	C	C	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	3
<i>Lannea schimperi</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Euphorbia candelabrum</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Albizia versicolor</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Pappea capensis</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Zanthoxylum chalybeum</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Afrocanthium lactescens</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Annona cherimola</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Annona muricata</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Apodytes dimidiata</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Camellia sinensis</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Cascabela thevetia</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Dichrostachys cinerea</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Flueggea virosa</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Gymnosporia senegalensis</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Hypericum revolutum</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNpgui	RFA5	Sources	Sources weighted
<i>Jatropha curcas</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Macadamia tetraphylla</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Ormocarpum trichocarpum</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Searsia longipes</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Senna didymobotrya</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Vachellia abyssinica</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Vangueria infausta</i> (n)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Vasconcellea pubescens</i> (e)	C	C	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	3
<i>Combretum collinum</i> (n)	C	C	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	3
<i>Callitris preissii</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Kigelia africana</i> (n)	C	C	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	3
<i>Mangifera indica</i> (e)	C	C	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2	3
<i>Senegalia brevispica</i> (n)	C	C	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	3
<i>Parinari curatellifolia</i> (n)	C	C	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Acacia koa</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Araucaria cunninghamii</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Desmodium uncinatum</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Eucalyptus camaldulensis</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Eucalyptus urophylla</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Mucuna pruriens</i> (e)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Sesbania macrantha</i> (n)	C	C	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	3
<i>Acacia podalyriifolia</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Alchornea hirtella</i> (n)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Bambusa vulgaris</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Carapa procera</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Coptosperma graveolens</i> (n)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Ekebergia capensis</i> (n)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Eugenia uniflora</i> (e)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Hura crepitans</i> (e)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Maytenus acuminata</i> (n)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Melaleuca citrina</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Melia azedarach</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Olea europaea</i> (n)	C	C	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
<i>Tecoma stans</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Terminalia catappa</i> (e)	C	C	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	3
<i>Alnus nepalensis</i> (e)	C	C	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	2
<i>Aloe volkensii</i> (n)	C	C	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	2
<i>Artocarpus altilis</i> (e)	C	C	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	2
<i>Azadirachta indica</i> (e)	C	C	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	2
<i>Citrus × aurantium</i> (e)	C	C	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	2

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNpgui	RFA5	Sources	Sources weighted
<i>Cupressus sempervirens</i> (e)	C	C	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	2
<i>Juniperus procera</i> (e)	C	C	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	2
<i>Tithonia diversifolia</i> (e)	C	C	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	2
<i>Desmodium intortum</i> (e)	C	C	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2
<i>Pinus elliottii</i> var. <i>elliottii</i> (e)	C	C	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2
<i>Searsia pyroides</i> (n)	C	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
<i>Alangium chinense</i> (n)	C	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
<i>Erica arborea</i> (n)	C	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
<i>Phytolacca dodecandra</i> (n)	C	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
<i>Senegalia senegal</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Aleurites moluccanus</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ceiba pentandra</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Vachellia gerrardii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Albizia adianthifolia</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Albizia amara</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Albizia petersiana</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Annona senegalensis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Bridelia micrantha</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Clausena anisata</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Maerua gilgii</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Osyris lanceolata</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Shirakiopsis elliptica</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Strychnos innocua</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Strychnos spinosa</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Abutilon angulatum</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Allophylus africanus</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Allophylus rubifolius</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Baikiaea insignis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Balthasaria schliebenii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Bauhinia monandra</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Bridelia brideliifolia</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Bridelia scleroneura</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Casimiroa edulis</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Cassipourea ruwensorensis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Celtis africana</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Celtis gomphophylla</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Citrus aurantiifolia</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Dalbergia nitidula</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Delonix elata</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Delonix regia</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNPgui	RFA5	Sources	Sources weighted
<i>Dombeya rotundifolia</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Duranta erecta</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Elaeis guineensis</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Elaeodendron buchananii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Englerophytum natalense</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ensete ventricosum</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ficus benjamina</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ficus natalensis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ficus vallis-choudae</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Flacourtia indica</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Gardenia ternifolia</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Gmelina arborea</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Grewia damine</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Hibiscus diversifolius</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Kigelia africana subsp. Moosa</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Lannea fulva</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Lannea humilis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Lannea schweinfurthii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Nuxia floribunda</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Opuntia humifusa</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ozoroa insignis</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Peddiea fischeri</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Pleiocarpa pycnantha</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Pleurostyliia africana</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Plumeria rubra</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Podocarpus latifolius</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Prunus persica</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Psidium cattleianum</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Pterolobium stellatum</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Punica granatum</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ravenala madagascariensis</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Rhamnus prinoides</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Rhodognaphalon mossambicense</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Rinorea angustifolia</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ritchiea albersii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Scutia myrtina</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Senna septemtrionalis</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Senna singueana</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Sterculia tragacantha</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Strychnos lucens</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2

continued on next page

Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNmp	GMNPbdv	LAFREC ₀₀₃	GMNPgui	RFA5	Sources	Sources weighted
<i>Syzygium cumini</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Syzygium jambos</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Tecoma capensis</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Trilepisium madagascariense</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Vangueria apiculata</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Yucca gloriosa</i> (e)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Zanthoxylum gillettii</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Ziziphus mucronata</i> (n)	C	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
<i>Euphorbia conspicua</i> (e)	C	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
<i>Alsophila manniana</i> (n)	C	C	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
<i>Anthocleista schweinfurthii</i> (n)	C	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
<i>Erica benguelensis</i> (n)	C	C	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
<i>Euphorbia dawei</i> (n)	C	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
<i>Eucalyptus globulus</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Blighia unijugata</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Garcinia buchananii</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Toddalia asiatica</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Agave sisalana</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Bothriocline glomerata</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Clerodendrum rotundifolium</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Discopodium penninervium</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Dovyalis macrocalyx</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Gymnanthemum auriculiferum</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Gymnanthemum myrianthum</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Jasminum schimperii</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Lantana camara</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Malus domestica</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Manihot carthaginensis</i> subsp. <i>glaziovii</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Mimosa pigra</i> (e)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Rothea myricoides</i> (n)	C	C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
<i>Grewia trichocarpa</i> (n)	C	C	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
<i>Croton macrostachyus</i> (n)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Combretum pisoniiflorum</i> (e)	C	C	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
<i>Casuarina cunninghamiana</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Eucalyptus paniculata</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Eucalyptus sideroxylon</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Haplocoelum gallaense</i> (n)	C	C	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
<i>Ficus sur</i> (n)	C	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Olea europaea</i> subsp. <i>Cuspidata</i> (e)	C	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1

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Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Albizia chinensis</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Allocasuarina littoralis</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Araucaria angustifolia</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Bambusa bambos</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Bambusa textilis</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Callitris endlicheri</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Casuarina junghuhniana</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Chamaecytisus prolifer</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Corymbia calophylla</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Corymbia ficifolia</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Crotalaria natalitia</i> (n)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Dendrocalamus barbatus</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Dendrocalamus giganteus</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Dendrocalamus strictus</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Erythrina caffra</i> (e)	C	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Eucalyptus cinerea</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Eucalyptus cloeziana</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Eucalyptus globulus</i> subsp. <i>Globulus</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Ficus lutea</i> (n)	C	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Macaranga grandifolia</i> (e)	C	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Millettia drastica</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Millettia laurentii</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Mimosa diplotricha</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Mitragyna stipulosa</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Neololeba atra</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Olea capensis</i> subsp. <i>Macrocarpa</i> (n)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Pinus caribaea</i> var. <i>hondurensis</i> €	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Pinus kesiya</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Pinus pseudostrobus</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Pinus radiata</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Pinus tecunumanii</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Sesbania bispinosa</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Sesbania grandiflora</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Terminalia neotaliala</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Tetraclinis articulata</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Thyrsostachys siamensis</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Vachellia farnesiana</i> (e)	C	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Vachellia sieberiana</i> var. <i>woodii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Annona reticulata</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Corymbia citriodora</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPgui	RFA5	Sources	Sources weighted
<i>Eucalyptus botryoides</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Macadamia integrifolia</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Coffea eugenioides</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cordia africana</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dombeya kirkii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Grewia mildbraedii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Landolphia owariensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maerua angolensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mondia whitei</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ozoroa insignis subsp. reticulata</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Syzygium cordatum</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tephrosia</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Achyranthes aspera</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adenocarpus mannii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Aeschynomene elaphroxylon</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Aeschynomene schimperii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Albizia grandibracteata</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Albizia zygia</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Alchemilla johnstonii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Allophylus abyssinicus</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Alsophila dregei</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anthonothea pynaertii</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Antiaris toxicaria</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Azima tetracantha</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Balanites aegyptiaca</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cadaba farinosa</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Capparis fascicularis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Catha edulis</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cissampelos mucronata</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cissus quadrangularis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cissus rotundifolia</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Clematis simensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Commiphora kua</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Craibia brownii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Crotalaria agatiflora</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Croton dichogamus</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cussonia holstii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cynanchum viminalis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cynometra alexandri</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cyperus latifolius</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Appendix 1. Continued

Species	Top-C	Top-W	Catalogue	Nursery	Book	SuitableApp	COMBIO	Mukuralinda	RTSC	Regreening	LakeKivu	GMNPmp	GMNPbdv	LAFREC ₀₀₃	GMNPGui	RFA5	Sources	Sources weighted
<i>Cyperus mundtii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cyperus papyrus</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dendrosenecio johnstonii</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diospyros abyssinica</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diospyros gabunensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dombeya buettneri</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dombeya burgessiae</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dracaena fragrans</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Drypetes gerrardii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ehretia cymosa</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Embelia schimperii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erica kingaensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Erythrococca bongensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Euclea divinorum</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eugenia capensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Fagaropsis angolensis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Faurea rochetiana</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ficus exasperata</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ficus glumosa</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ficus trichopoda</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ficus verruculosa</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Grewia mollis</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnosporia arbutifolia</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnosporia heterophylla</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Harrisonia abyssinica</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Helichrysum formosissimum</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hoffmannanthus abbotianus</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Kotschyia africana</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lecaniodiscus fraxinifolia</i> (e)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidotrichilia volkensii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lobelia stuhlmannii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lobelia wollastonii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lovoa trichilioides</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Macaranga schweinfurthii</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maerua triphylla</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Margaritaria discoidea</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maytenus undata</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mikania chenopodiifolia</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Millettia dura</i> (n)	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Appendix 2. Full list of species with taxonomic details

The list gives unique accepted species names after standardizing their names with World Flora Online via the *WorldFlora* (Kindt 2020) *R* package (different versions of the package were used, most recently version 1.13-2). The 'New name' column indicates a newer accepted name detected with the most recent static version of the World Flora Online taxonomic backbone (version 2023.01).

No.	Species	New name	Taxon ID	Authorship	Family
1	<i>Polyscias fulva</i>		wfo-0000280060	(Hiern) Harms	Araliaceae
2	<i>Prunus africana</i>		wfo-0000995790	(Hook.f.) Kalkman	Rosaceae
3	<i>Entandrophragma excelsum</i>		wfo-0000668220	Sprague	Meliaceae
4	<i>Erythrina abyssinica</i>		wfo-0001054737	Lam.	Fabaceae
5	<i>Hagenia abyssinica</i>		wfo-0000994920	(Bruce) J.F.Gmel.	Rosaceae
6	<i>Markhamia lutea</i>		wfo-0000779039	K.Schum.	Bignoniaceae
7	<i>Symphonia globulifera</i>		wfo-0000438147	L.f.	Clusiaceae
8	<i>Acacia melanoxydon</i>		wfo-0000204086	R.Br.	Fabaceae
9	<i>Carapa grandiflora</i>		wfo-0000586377	Sprague	Meliaceae
10	<i>Grevillea robusta</i>		wfo-0000709544	A.Cunn. ex R.Br.	Proteaceae
11	<i>Maesopsis eminii</i>		wfo-0000452431	Engl.	Rhamnaceae
12	<i>Acacia mearnsii</i>		wfo-0000203882	De Wild.	Fabaceae
13	<i>Afrocarpus falcatus</i>		wfo-0000522640	(Thunb.) C.N.Page	Podocarpaceae
14	<i>Croton megalocarpus</i>		wfo-0000931666	Hutch.	Euphorbiaceae
15	<i>Dombeya torrida</i>		wfo-0000654003	(J.F.Gmel.) Bamps	Malvaceae
16	<i>Maesa lanceolata</i>		wfo-0000448927	Forssk.	Primulaceae
17	<i>Myrianthus holstii</i>		wfo-0000374679	Engl.	Urticaceae
18	<i>Pinus patula</i>		wfo-0000481882	Schltld. & Cham.	Pinaceae
19	<i>Bersama abyssinica</i>		wfo-0000564438	Fresen.	Francoaceae
20	<i>Casuarina equisetifolia</i>		wfo-0000590663	L.	Casuarinaceae
21	<i>Cupressus lusitanica</i>		wfo-0000630722	Mill.	Cupressaceae
22	<i>Entada abyssinica</i>		wfo-0000205748	Steud. ex A.Rich.	Fabaceae
23	<i>Eucalyptus saligna</i>		wfo-0000955842	Sm.	Myrtaceae
24	<i>Faurea saligna</i>		wfo-0000686024	Harv.	Proteaceae
25	<i>Ficus thonningii</i>		wfo-0000690599	Blume	Moraceae
26	<i>Neoboutonia macrocalyx</i>		wfo-0000249996	Pax	Euphorbiaceae
27	<i>Parinari excelsa</i>		wfo-0000817744	Sabine	Chrysobalanaceae
28	<i>Persea americana</i>		wfo-0000465160	Mill.	Lauraceae
29	<i>Pterygota mildbraedii</i>		wfo-0001141220	Engl.	Malvaceae
30	<i>Senegalia polyacantha</i>		wfo-0000744649	(Willd.) Seigler & Ebinger	Fabaceae
31	<i>Syzygium guineense</i>		wfo-0000318724	DC.	Myrtaceae
32	<i>Syzygium parvifolium</i>		wfo-0000319170	(Engl.) Mildbr.	Myrtaceae
33	<i>Acaciella angustissima</i>		wfo-0000182389	(Mill.) Britton & Rose	Fabaceae
34	<i>Acokanthera schimperi</i>		wfo-0000336741	(A.DC.) Benth. & Hook.f. ex Schweinf.	Apocynaceae
35	<i>Alnus acuminata</i>		wfo-0000944034	Kunth	Betulaceae
36	<i>Artocarpus heterophyllus</i>		wfo-0000550491	Lam.	Moraceae
37	<i>Cajanus cajan</i>		wfo-0000203743	(L.) Huth	Fabaceae
38	<i>Eucalyptus grandis</i>		wfo-0001086255	W.Hill ex Maiden	Myrtaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
39	<i>Eucalyptus microcorys</i>		wfo-0000955365	F.Muell.	Myrtaceae
40	<i>Ficalhoa laurifolia</i>		wfo-0000687151	Hiern	Sladeniaceae
41	<i>Gambeya gorungosana</i>		wfo-0000970702	(Engl.) Liben	Sapotaceae
42	<i>Gliricidia sepium</i>		wfo-0000178022	(Jacq.) Steud.	Fabaceae
43	<i>Gymnanthemum amygdalinum</i>		wfo-0000096111	(Delile) Sch.Bip.	Asteraceae
44	<i>Harungana montana</i>		wfo-0001296044	Spirlet	Hypericaceae
45	<i>Jacaranda mimosifolia</i>		wfo-0000778761	D.Don	Bignoniaceae
46	<i>Leucaena diversifolia</i>		wfo-0000173706	(Schltdl.) Benth.	Fabaceae
47	<i>Leucaena leucocephala</i>		wfo-0000164084	(Lam.) de Wit	Fabaceae
48	<i>Macaranga kilimandscharica</i>		wfo-0000232043	Pax	Euphorbiaceae
49	<i>Mitragyna rubrostipulata</i>		wfo-0000244942	(K.Schum.) Havil.	Rubiaceae
50	<i>Newtonia buchananii</i>		wfo-0000166618	(Baker) G.C.C.Gilbert & Boutique	Fabaceae
51	<i>Phoenix reclinata</i>		wfo-0000269796	Jacq.	Arecaceae
52	<i>Pinus caribaea</i>		wfo-0000482235	Morelet	Pinaceae
53	<i>Psidium guajava</i>		wfo-0000284421	L.	Myrtaceae
54	<i>Senna siamea</i>		wfo-0000164745	(Lam.) H.S.Irwin & Barneby	Fabaceae
55	<i>Senna spectabilis</i>		wfo-0000164878	(DC.) H.S.Irwin & Barneby	Fabaceae
56	<i>Sesbania sesban</i>		wfo-0001050790	Britton	Fabaceae
57	<i>Solanecio mannii</i>		wfo-0000037040	(Hook.f.) C.Jeffrey	Asteraceae
58	<i>Spathodea campanulata</i>		wfo-0001348910	Buch.-Ham. ex DC.	Bignoniaceae
59	<i>Strombosia scheffleri</i>		wfo-0000505590	Engl.	Olacaceae
60	<i>Tephrosia vogelii</i>		wfo-0000204544	Hook.f.	Fabaceae
61	<i>Vachellia hockii</i>		wfo-0000745799	(De Wild.) Seigler & Ebinger	Fabaceae
62	<i>Vachellia sieberiana</i>		wfo-0001356425	(DC.) Ali	Fabaceae
63	<i>Vepris nobilis</i>		wfo-0000420153	(Delile) Mziray	Rutaceae
64	<i>Acrocarpus fraxinifolius</i>		wfo-0000211685	Wight & Arn.	Fabaceae
65	<i>Albizia gummifera</i>		wfo-0000183535	(J.F.Gmel.) C.A.Sm.	Fabaceae
66	<i>Alnus glutinosa</i>		wfo-0000945215	(L.) Gaertn.	Betulaceae
67	<i>Biancaea decapetala</i>		wfo-0001056568	(Roth) O.Deg.	Fabaceae
68	<i>Carica papaya</i>		wfo-0000588009	L.	Caricaceae
69	<i>Cornus volkensii</i>		wfo-0000924882	Harms	Cornaceae
70	<i>Corymbia maculata</i>		wfo-0000925549	(Hook.) K.D.Hill & L.A.S.Johnson	Myrtaceae
71	<i>Dovyalis caffra</i>		wfo-0001062885	(Hook.f. & Harv.) Warb.	Salicaceae
72	<i>Dracaena afromontana</i>		wfo-0000765656	Mildbr.	Asparagaceae
73	<i>Dracaena steudneri</i>		wfo-0000765951	Engl.	Asparagaceae
74	<i>Eucalyptus tereticornis</i>		wfo-0000956012	Sm.	Myrtaceae
75	<i>Euclea racemosa</i>		wfo-0000681125	L.	Ebenaceae
76	<i>Euphorbia tirucalli</i>		wfo-0000965116	L.	Euphorbiaceae
77	<i>Faidherbia albida</i>		wfo-0000186081	(Delile) A.Chev.	Fabaceae
78	<i>Ficus laurifolia</i>		wfo-0000689024	hort. ex Lam.	Moraceae
79	<i>Grewia similis</i>		wfo-0000710313	K.Schum.	Malvaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
80	<i>Ilex mitis</i>		wfo-0000729632	Radlk.	Aquifoliaceae
81	<i>Leucaena trichandra</i>		wfo-0000192519	(Zucc.) Urb.	Fabaceae
82	<i>Macaranga capensis</i>		wfo-0000231857	(Baill.) Sim	Euphorbiaceae
83	<i>Markhamia obtusifolia</i>		wfo-0000779030	Sprague	Bignoniaceae
84	<i>Mimosa scabrella</i>		wfo-0000165568	Benth.	Fabaceae
85	<i>Moringa oleifera</i>		wfo-0001085051	Lam.	Moringaceae
86	<i>Morus nigra</i>		wfo-0000447931	L.	Moraceae
87	<i>Myrsine melanophloeos</i>		wfo-0000449092	(L.) R.Br. ex Sweet	Primulaceae
88	<i>Psydrax schimperianus</i>		wfo-0000288205	(A.Rich.) Bridson	Rubiaceae
89	<i>Ricinus communis</i>		wfo-0000297077	L.	Euphorbiaceae
90	<i>Searsia natalensis</i>		wfo-0000434889	(Bernh. ex Krauss) F.A.Barkley	Anacardiaceae
91	<i>Solanum betaceum</i>		wfo-0001026534	Cav.	Solanaceae
92	<i>Terminalia mantaly</i>		wfo-0000408827	H.Perrier	Combretaceae
93	<i>Tetradenia riparia</i>		wfo-0000321572	(Hochst.) Codd	Lamiaceae
94	<i>Toona sinensis</i>		wfo-0000455502	(Juss.) M.Roem.	Meliaceae
95	<i>Trema orientalis</i>		wfo-0000457758	(L.) Blume	Cannabaceae
96	<i>Vachellia kirkii</i>		wfo-0001336852	(Oliv.) Kyal. & Boatwr.	Fabaceae
97	<i>Ximenia caffra</i>		wfo-0000428236	Sond.	Olacaceae
98	<i>Xymalos monospora</i>		wfo-0001084373	Baill.	Monimiaceae
99	<i>Acacia koa</i>		wfo-0000173762	A.Gray	Fabaceae
100	<i>Acacia podalyriifolia</i>		wfo-0000209495	A.Cunn. ex G.Don	Fabaceae
101	<i>Afrocanthium lactescens</i>		wfo-0000335943	(Hiern) Lantz	Rubiaceae
102	<i>Agarista salicifolia</i>		wfo-0000523244	G.Don	Ericaceae
103	<i>Albizia versicolor</i>		wfo-0000187086	Welw. ex Oliv.	Fabaceae
104	<i>Alchornea hirtella</i>		wfo-0000939025	Benth.	Euphorbiaceae
105	<i>Alnus nepalensis</i>		wfo-0000946943	D.Don	Betulaceae
106	<i>Aloe volkensii</i>		wfo-0000759004	Engl.	Asphodelaceae
107	<i>Annona cherimola</i>		wfo-0000537707	Mill.	Annonaceae
108	<i>Annona muricata</i>		wfo-0000537848	L.	Annonaceae
109	<i>Anthocleista grandiflora</i>		wfo-0000538477	Gilg	Gentianaceae
110	<i>Apodytes dimidiata</i>		wfo-0000540853	E.Mey. ex Arn.	Metteniusaceae
111	<i>Araucaria cunninghamii</i>		wfo-0000260301	Mudie	Araucariaceae
112	<i>Artocarpus altilis</i>		wfo-0000550425	(Parkinson) Fosberg	Moraceae
113	<i>Azadirachta indica</i>		wfo-0000557668	A.Juss.	Meliaceae
114	<i>Brugmansia suaveolens</i>		wfo-0001019783	(Willd.) Sweet	Solanaceae
115	<i>Callitris preissii</i>		wfo-0000580768	Miq.	Cupressaceae
116	<i>Camellia sinensis</i>		wfo-0000582676	(L.) Kuntze	Theaceae
117	<i>Capparis tomentosa</i>		wfo-0000585223	Lam.	Capparaceae
118	<i>Carapa procera</i>		wfo-0001083560	DC.	Meliaceae
119	<i>Carissa spinarum</i>		wfo-0000803913	L.	Apocynaceae
120	<i>Cascabela thevetia</i>		wfo-0000810099	(L.) Lippold	Apocynaceae
121	<i>Cedrela odorata</i>		wfo-0000592446	L.	Meliaceae
122	<i>Citrus limon</i>		wfo-0001133139	(L.) Osbeck	Rutaceae
123	<i>Coffea arabica</i>		wfo-0000910097	L.	Rubiaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
124	<i>Combretum collinum</i>		wfo-0000616192	Fresen.	Combretaceae
125	<i>Commiphora africana</i>		wfo-0001328094	Engl.	Burseraceae
126	<i>Coptosperma graveolens</i>		wfo-0000336089	(S.Moore) Degreef	Rubiaceae
127	<i>Cupressus sempervirens</i>		wfo-0000630789	L.	Cupressaceae
128	<i>Cussonia arborea</i>		wfo-0000933615	Hochst. ex A.Rich.	Araliaceae
129	<i>Desmodium intortum</i>		wfo-0000177239	(Mill.) Urb.	Fabaceae
130	<i>Desmodium uncinatum</i>		wfo-0000177526	(Jacq.) DC.	Fabaceae
131	<i>Dichrostachys cinerea</i>		wfo-0000176871	(L.) Wight & Arn.	Fabaceae
132	<i>Dodonaea viscosa</i>		wfo-0000653170	Jacq.	Sapindaceae
133	<i>Ekebergia capensis</i>		wfo-0000663623	Sparrm.	Meliaceae
134	<i>Erica mannii</i>		wfo-0000672564	(Hook.f.) Beentje	Ericaceae
135	<i>Eriobotrya japonica</i>		wfo-0000986002	(Thunb.) Lindl.	Rosaceae
136	<i>Eucalyptus camaldulensis</i>		wfo-0000954597	Dehnh.	Myrtaceae
137	<i>Eucalyptus dunni</i>		wfo-0000954854	Maiden	Myrtaceae
138	<i>Eucalyptus urophylla</i>		wfo-0000956096	S.T.Blake	Myrtaceae
139	<i>Euphorbia umbellata</i>		wfo-0000806876	(Pax) Bruyns	Euphorbiaceae
140	<i>Ficus elastica</i>		wfo-0000688216	Roxb. ex Hornem.	Moraceae
141	<i>Ficus ingens</i>		wfo-0000688813	Miq.	Moraceae
142	<i>Ficus sycomorus</i>		wfo-0000690537	L.	Moraceae
143	<i>Flueggea virosa</i>		wfo-0000967255	(Roxb. ex Willd.) Royle	Phyllanthaceae
144	<i>Galiniera saxifraga</i>		wfo-0000968178	(A.Rich.) Bridson	Rubiaceae
145	<i>Gymnosporia senegalensis</i>		wfo-0000713049	Loes.	Celastraceae
146	<i>Harungana madagascariensis</i>		wfo-0000716096	Lam. ex Poir.	Hypericaceae
147	<i>Hura crepitans</i>		wfo-0000215711	L.	Euphorbiaceae
148	<i>Hypericum revolutum</i>		wfo-0000728231	Vahl	Hypericaceae
149	<i>Jatropha curcas</i>		wfo-0000219580	L.	Euphorbiaceae
150	<i>Juniperus procera</i>		wfo-0000355729	Hochst. ex Endl.	Cupressaceae
151	<i>Kigelia africana</i>		wfo-0000778884	(Lam.) Benth.	Bignoniaceae
152	<i>Lannea schimperi</i>		wfo-0000360221	Engl.	Anacardiaceae
153	<i>Macadamia tetraphylla</i>		wfo-0000452229	L.A.S.Johnson	Proteaceae
154	<i>Mangifera indica</i>		wfo-0000371248	L.	Anacardiaceae
155	<i>Maytenus acuminata</i>		wfo-0000369427	(L.f.) Loes.	Celastraceae
156	<i>Melia azedarach</i>		wfo-0000450150	L.	Meliaceae
157	<i>Milicia excelsa</i>		wfo-0000447908	(Welw.) C.C.Berg	Moraceae
158	<i>Morus alba</i>		wfo-0000447905	L.	Moraceae
159	<i>Mucuna pruriens</i>		wfo-0000182545	(L.) DC.	Fabaceae
160	<i>Nuxia congesta</i>		wfo-0000797418	R.Br. ex Fresen.	Stilbaceae
161	<i>Olea europaea</i>		wfo-0000817273	L.	Oleaceae
162	<i>Olinia rochetiana</i>		wfo-0000389231	A.Juss.	Penaeaceae
163	<i>Ormocarpum trichocarpum</i>		wfo-0000176231	(Taub.) Engl.	Fabaceae
164	<i>Parinari curatellifolia</i>		wfo-0000817683	Planch. ex Benth.	Chrysobalanaceae
165	<i>Psychotria mahonii</i>		wfo-0000286554	C.H.Wright	Rubiaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
166	<i>Psydrax parviflorus</i>		wfo-0000288194	(Afzel.) Bridson	Rubiaceae
167	<i>Searsia longipes</i>		wfo-0000510261	(Engl.) Moffett	Anacardiaceae
168	<i>Senegalia brevispica</i>		wfo-0000745791	(Harms) Seigler & Ebinger	Fabaceae
169	<i>Senna didymobotrya</i>		wfo-0000163726	(Fresen.) H.S.Irwin & Barneby	Fabaceae
170	<i>Sesbania macrantha</i>		wfo-0000178241	Welw. ex E.Phillips & Hutch.	Fabaceae
171	<i>Solanum aculeastrum</i>		wfo-0001025704	Dunal	Solanaceae
172	<i>Tabernaemontana stapfiana</i>		wfo-0000320128	Britten	Apocynaceae
173	<i>Tecoma stans</i>		wfo-0000779839	(L.) Griseb.	Bignoniaceae
174	<i>Terminalia catappa</i>		wfo-0000406800	L.	Combretaceae
175	<i>Terminalia superba</i>		wfo-0000408519	Engl. & Diels	Combretaceae
176	<i>Tithonia diversifolia</i>		wfo-0000018279	(Hemsl.) A.Gray	Asteraceae
177	<i>Vachellia abyssinica</i>		wfo-0001336820	(Hochst. ex Benth.) Kyal. & Boatwr.	Fabaceae
178	<i>Vangueria infausta</i>		wfo-0000331237	Burch.	Rubiaceae
179	<i>Vasconcellea pubescens</i>		wfo-0000421667	A.DC.	Caricaceae
180	<i>Zanthoxylum chalybeum</i>		wfo-0001133237	Engl.	Rutaceae
181	<i>Abutilon angulatum</i>		wfo-0000511722	(Guill. & Perr.) Mast. in Oliv.	Malvaceae
182	<i>Agave sisalana</i>		wfo-0001257076	Perrine	Asparagaceae
183	<i>Alangium chinense</i>		wfo-0000936752	(Lour.) Harms	Cornaceae
184	<i>Albizia adianthifolia</i>		wfo-0000179990	(Schumach.) W.Wight	Fabaceae
185	<i>Albizia amara</i>		wfo-0001054132	(Roxb.) Boivin	Fabaceae
186	<i>Albizia chinensis</i>		wfo-0000182103	(Osbeck) Merr.	Fabaceae
187	<i>Albizia petersiana</i>		wfo-0000185697	(Bolle) Oliv.	Fabaceae
188	<i>Aleurites moluccanus</i>		wfo-0000940858	Willd.	Euphorbiaceae
189	<i>Allocasuarina littoralis</i>		wfo-0000526460	(Salisb.) L.A.S.Johnson	Casuarinaceae
190	<i>Allophylus africanus</i>		wfo-0000526543	P.Beauv.	Sapindaceae
191	<i>Allophylus rubifolius</i>		wfo-0000526853	Engl.	Sapindaceae
192	<i>Alsophila manniana</i>		wfo-0001120066	(Hook.) R.M.Tryon	Cyatheaceae
193	<i>Annona senegalensis</i>		wfo-0000537928	Pers.	Annonaceae
194	<i>Anthocleista schweinfurthii</i>		wfo-0000538513	Gilg	Gentianaceae
195	<i>Araucaria angustifolia</i>		wfo-0000260143	(Bertol.) Kuntze	Araucariaceae
196	<i>Baikiaea insignis</i>		wfo-0001057033	Benth.	Fabaceae
197	<i>Balthasaria schliebenii</i>		wfo-0000558961	(Melch.) Verdc.	Theaceae
198	<i>Bambusa bambos</i>		wfo-0000853060	(L.) Voss	Poaceae
199	<i>Bambusa textilis</i>		wfo-0000853505	McClure	Poaceae
200	<i>Bauhinia monandra</i>		wfo-0000213034	Kurz	Fabaceae
201	<i>Blighia unijugata</i>		wfo-0000566874	Baker	Sapindaceae
202	<i>Bothriocline glomerata</i>		wfo-0000038505	(O.Hoffm. & Muschl.) C.Jeffrey	Asteraceae
203	<i>Bridelia brideliifolia</i>		wfo-0000416440	(Pax) Fedde	Phyllanthaceae
204	<i>Bridelia micrantha</i>		wfo-0000421441	(Hochst.) Baill.	Phyllanthaceae
205	<i>Bridelia scleroneura</i>		wfo-0000426024	Müll.Arg.	Phyllanthaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
206	<i>Callitris endlicheri</i>		wfo-0000580741	(Parl.) F.M.Bailey	Cupressaceae
207	<i>Casimiroa edulis</i>		wfo-0000589005	La Llave	Rutaceae
208	<i>Cassipourea ruwensorensis</i>		wfo-0000589693	Alston	Rhizophoraceae
209	<i>Casuarina cunninghamiana</i>		wfo-0000590647	Miq.	Casuarinaceae
210	<i>Casuarina junghuhniana</i>		wfo-0000590691	Miq.	Casuarinaceae
211	<i>Ceiba pentandra</i>		wfo-0000592594	(L.) Gaertn.	Malvaceae
212	<i>Celtis africana</i>		wfo-0000593393	Burm.f.	Cannabaceae
213	<i>Celtis gomphophylla</i>		wfo-0000593541	Baker	Cannabaceae
214	<i>Chamaecytisus prolifer</i>		wfo-0001057343	(L.f.) Link	Fabaceae
215	<i>Citrus aurantiifolia</i>		wfo-0001242548	(Christm.) Swingle	Rutaceae
216	<i>Clausena anisata</i>		wfo-0000608620	(Willd.) Hook.f.	Rutaceae
217	<i>Clerodendrum rotundifolium</i>		wfo-0000885987	Oliv.	Lamiaceae
218	<i>Combretum molle</i>	<i>Combretum pisoniiflorum</i>	wfo-0000616658	Engl.	Combretaceae
219	<i>Combretum pisoniiflorum</i>		wfo-0000616658	Engl.	Combretaceae
220	<i>Corymbia calophylla</i>		wfo-0000925421	(Lindl.) K.D.Hill & L.A.S.Johnson	Myrtaceae
221	<i>Corymbia ficifolia</i>		wfo-0000925520	(F.Muell.) K.D.Hill & L.A.S.Johnson	Myrtaceae
222	<i>Crotalaria natalitia</i>		wfo-0001054642	Meisn.	Fabaceae
223	<i>Croton macrostachyus</i>		wfo-0000931591	Hochst. ex Delile	Euphorbiaceae
224	<i>Dalbergia nitidula</i>		wfo-0000172371	Welw. ex Baker	Fabaceae
225	<i>Delonix elata</i>		wfo-0000166378	(L.) Gamble	Fabaceae
226	<i>Delonix regia</i>		wfo-0000166389	(Bojer ex Hook.) Raf.	Fabaceae
227	<i>Dendrocalamus barbatus</i>		wfo-0000862304	Hsueh & D.Z.Li	Poaceae
228	<i>Dendrocalamus giganteus</i>		wfo-0000862329	Munro	Poaceae
229	<i>Dendrocalamus strictus</i>		wfo-0000862391	Nees	Poaceae
230	<i>Discopodium penninervium</i>		wfo-0001021443	Hochst.	Solanaceae
231	<i>Dombeya rotundifolia</i>		wfo-0000653948	(Hochst.) Planch.	Malvaceae
232	<i>Dovyalis macrocalyx</i>		wfo-0000925156	(Oliv.) Warb.	Salicaceae
233	<i>Duranta erecta</i>		wfo-0000946828	L.	Verbenaceae
234	<i>Elaeis guineensis</i>		wfo-0000947985	Jacq.	Arecaceae
235	<i>Elaeodendron buchananii</i>		wfo-0000664922	Loes.	Celastraceae
236	<i>Englerophytum natalense</i>		wfo-0000949110	(Sond.) T.D.Penn.	Sapotaceae
237	<i>Ensete ventricosum</i>		wfo-0000407924	(Welw.) Cheesman	Musaceae
238	<i>Erica arborea</i>		wfo-0000671391	L.	Ericaceae
239	<i>Erica benguelensis</i>		wfo-0000671493	(Welw. ex Engl.) E.G.H.Oliv.	Ericaceae
240	<i>Eucalyptus cinerea</i>		wfo-0000954651	F.Muell. ex Benth.	Myrtaceae
241	<i>Eucalyptus cloeziana</i>		wfo-0000954668	F.Muell.	Myrtaceae
242	<i>Eucalyptus globulus</i>		wfo-0000954998	Labill.	Myrtaceae
243	<i>Eucalyptus paniculata</i>		wfo-0000955553	Sm.	Myrtaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
244	<i>Eucalyptus sideroxylon</i>		wfo-0000955894	A.Cunn. ex Woolls	Myrtaceae
245	<i>Euphorbia candelabrum</i>	<i>Euphorbia conspicua</i>	wfo-0000961474	N.E.Br.	Euphorbiaceae
246	<i>Euphorbia conspicua</i>		wfo-0000961474	N.E.Br.	Euphorbiaceae
247	<i>Euphorbia dawei</i>		wfo-0000961657	N.E.Br.	Euphorbiaceae
248	<i>Ficus benamina</i>		wfo-0000687511	L.	Moraceae
249	<i>Ficus lutea</i>		wfo-0000689147	Vahl	Moraceae
250	<i>Ficus natalensis</i>		wfo-0000689419	Hochst.	Moraceae
251	<i>Ficus sur</i>		wfo-0000690530	Forssk.	Moraceae
252	<i>Ficus vallis-choudae</i>		wfo-0000690786	Delile	Moraceae
253	<i>Flacourtia indica</i>		wfo-0000925655	(Burm.f.) Merr.	Salicaceae
254	<i>Garcinia buchananii</i>		wfo-0000694189	Baker	Clusiaceae
255	<i>Gardenia ternifolia</i>		wfo-0000971206	Schumach. & Thonn.	Rubiaceae
256	<i>Gmelina arborea</i>		wfo-0001144396	Roxb. ex Sm.	Lamiaceae
257	<i>Grewia damine</i>		wfo-0000709875	Gaertn.	Malvaceae
258	<i>Grewia trichocarpa</i>		wfo-0000710360	Hochst. ex A.Rich.	Malvaceae
259	<i>Gymnanthemum auriculiferum</i>		wfo-0000056957	(Hiern) Isawumi	Asteraceae
260	<i>Gymnanthemum myrianthum</i>		wfo-0000081175	(Hook.f.) H.Rob.	Asteraceae
261	<i>Haplocoelum gallaense</i>		wfo-0000715415	(Engl.) Radlk.	Sapindaceae
262	<i>Hibiscus diversifolius</i>		wfo-0000722500	Jacq.	Malvaceae
263	<i>Jasminum schimperi</i>		wfo-0000813544	Vatke	Oleaceae
264	<i>Lannea fulva</i>		wfo-0001051269	Engl.	Anacardiaceae
265	<i>Lannea humilis</i>		wfo-0000360290	Engl.	Anacardiaceae
266	<i>Lannea schweinfurthii</i>		wfo-0000360222	Engl.	Anacardiaceae
267	<i>Lantana camara</i>		wfo-0000223016	L.	Verbenaceae
268	<i>Maerua gilgii</i>		wfo-0000375739	Schinz	Capparaceae
269	<i>Malus domestica</i>		wfo-0001008355	(Suckow) Borkh.	Rosaceae
270	<i>Millettia drastica</i>		wfo-0000199845	Welw. ex Baker	Fabaceae
271	<i>Millettia laurentii</i>		wfo-0000200277	De Wild.	Fabaceae
272	<i>Mimosa diplotricha</i>		wfo-0001053831	C.Wright	Fabaceae
273	<i>Mimosa pigra</i>		wfo-0000165078	L.	Fabaceae
274	<i>Mitragyna stipulosa</i>		wfo-0000244944	Kuntze	Rubiaceae
275	<i>Neololeba atra</i>		wfo-0000881401	(Lindl.) Widjaja	Poaceae
276	<i>Nuxia floribunda</i>		wfo-0000797428	Benth.	Stilbaceae
277	<i>Opuntia humifusa</i>		wfo-0000385811	(Raf.) Raf.	Cactaceae
278	<i>Osyris lanceolata</i>		wfo-0000388245	Hochst. & Steud.	Santalaceae
279	<i>Ozoroa insignis</i>		wfo-0000385517	Delile	Anacardiaceae
280	<i>Peddiea fischeri</i>		wfo-0000475752	Engl.	Thymelaeaceae
281	<i>Phytolacca dodecandra</i>		wfo-0000482089	L'Hér.	Phytolaccaceae
282	<i>Pinus kesiya</i>		wfo-0000481052	Royle ex Gordon	Pinaceae
283	<i>Pinus radiata</i>		wfo-0000481837	D.Don	Pinaceae
284	<i>Pinus tecunumanii</i>		wfo-0000481660	F.Schwerdtf. ex Eguiluz & J.P.Perry	Pinaceae
285	<i>Pleiocarpa pycnantha</i>		wfo-0000276286	Stapf	Apocynaceae

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Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
286	<i>Pleurostyliia africana</i>		wfo-0000394863	Loes.	Celastraceae
287	<i>Plumeria rubra</i>		wfo-0000279184	L.	Apocynaceae
288	<i>Prunus persica</i>		wfo-0001005458	(L.) Batsch	Rosaceae
289	<i>Psidium cattleianum</i>		wfo-0000284334	Sabine	Myrtaceae
290	<i>Pterolobium stellatum</i>		wfo-0000170624	(Forssk.) Brenan	Fabaceae
291	<i>Punica granatum</i>		wfo-0000468843	L.	Lythraceae
292	<i>Ravenala madagascariensis</i>		wfo-0000509912	Sonn.	Strelitziaceae
293	<i>Rhamnus prinoides</i>		wfo-0000460040	L'Hér.	Rhamnaceae
294	<i>Rhodognaphalon mossambicense</i>		wfo-0000402220	(A.Robyns) A.Robyns	Malvaceae
295	<i>Rinorea angustifolia</i>		wfo-0000464488	Baill.	Violaceae
296	<i>Ritchiea albersii</i>		wfo-0000399079	Gilg	Capparaceae
297	<i>Rothea myricoides</i>		wfo-0000298156	(Hochst.) Steane & Mabb.	Lamiaceae
298	<i>Scutia myrtina</i>		wfo-0000504062	Kurz	Rhamnaceae
299	<i>Searsia pyroides</i>		wfo-0000510287	(Burch.) Moffett	Anacardiaceae
300	<i>Senegalia senegal</i>		wfo-0001281302	(L.) Britton	Fabaceae
301	<i>Senna septemtrionalis</i>		wfo-0000163813	(Viv.) H.S.Irwin & Barneby	Fabaceae
302	<i>Senna singueana</i>		wfo-0000184163	(Delile) Lock	Fabaceae
303	<i>Sesbania grandiflora</i>		wfo-0000178509	(L.) Poir.	Fabaceae
304	<i>Shirakiopsis elliptica</i>		wfo-0000309756	(Hochst.) Esser	Euphorbiaceae
305	<i>Sterculia tragacantha</i>		wfo-0000492472	Lindl.	Malvaceae
306	<i>Strychnos innocua</i>		wfo-0000502968	Delile	Loganiaceae
307	<i>Strychnos lucens</i>		wfo-0000503015	Baker	Loganiaceae
308	<i>Strychnos spinosa</i>		wfo-0000502889	Lam.	Loganiaceae
309	<i>Syzygium cumini</i>		wfo-0000318521	(L.) Skeels	Myrtaceae
310	<i>Syzygium jambos</i>		wfo-0000318809	(L.) Alston	Myrtaceae
311	<i>Tecoma capensis</i>		wfo-0000780286	Lindl.	Bignoniaceae
312	<i>Terminalia neotaliala</i>		wfo-0001296419	Capuron	Combretaceae
313	<i>Tetraclinis articulata</i>		wfo-0000456325	Mast.	Cupressaceae
314	<i>Thyrsostachys siamensis</i>		wfo-0000903708	Gamble	Poaceae
315	<i>Toddalia asiatica</i>		wfo-0000455337	(L.) Lam.	Rutaceae
316	<i>Trilepisium madagascariense</i>		wfo-0000456825	DC.	Moraceae
317	<i>Vachellia farnesiana</i>		wfo-0000182273	(L.) Wight & Arn.	Fabaceae
318	<i>Vachellia gerrardii</i>		wfo-0001284775	(Benth.) P.J.H.Hurter	Fabaceae
319	<i>Vangueria apiculata</i>		wfo-0000331184	K.Schum.	Rubiaceae
320	<i>Yucca gloriosa</i>		wfo-0000752281	L.	Asparagaceae
321	<i>Zanthoxylum gillettii</i>		wfo-0000429498	(De Wild.) P.G.Waterman	Rutaceae
322	<i>Ziziphus mucronata</i>		wfo-0000430319	Willd.	Rhamnaceae
323	<i>Achyranthes aspera</i>		wfo-0000516177	L.	Amaranthaceae
324	<i>Adenocarpus mannii</i>		wfo-0000213120	(Hook.f.) Hook.f.	Fabaceae
325	<i>Aeschynomene elaphroxylon</i>		wfo-0000173255	Taub.	Fabaceae
326	<i>Aeschynomene schimperii</i>		wfo-0000173989	Hochst. ex A.Rich.	Fabaceae
327	<i>Albizia grandibracteata</i>		wfo-0000183441	Taub.	Fabaceae

continued on next page

Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
328	<i>Albizia zygia</i>		wfo-0000173024	(DC.) J.F.Macbr.	Fabaceae
329	<i>Alchemilla johnstonii</i>		wfo-0001003003	Oliv.	Rosaceae
330	<i>Allophylus abyssinicus</i>		wfo-0000526540	Radlk.	Sapindaceae
331	<i>Alsophila dregei</i>		wfo-0001110754	(Kunze) R.M.Tryon	Cyatheaceae
332	<i>Annona reticulata</i>		wfo-0000537905	L.	Annonaceae
333	<i>Anthonothea pyraertii</i>		wfo-0000212472	(De Wild.) Exell & Hillc.	Fabaceae
334	<i>Antiaris toxicaria</i>		wfo-0000538857	(J.F.Gmel.) Lesch.	Moraceae
335	<i>Azima tetracantha</i>		wfo-0000558022	Lam.	Salvadoraceae
336	<i>Balanites aegyptiaca</i>		wfo-0000313273	(L.) Delile	Zygophyllaceae
337	<i>Cadaba farinosa</i>		wfo-0000578357	Forssk.	Capparaceae
338	<i>Capparis fascicularis</i>		wfo-0000584695	DC.	Capparaceae
339	<i>Catha edulis</i>		wfo-0000590815	(Vahl) Forssk. ex Endl.	Celastraceae
340	<i>Cissampelos mucronata</i>		wfo-0000605848	A.Rich.	Menispermaceae
341	<i>Cissus quadrangularis</i>		wfo-0000606737	L.	Vitaceae
342	<i>Clematis simensis</i>		wfo-0000610651	Fresen.	Ranunculaceae
343	<i>Coffea eugenoides</i>		wfo-0000910997	S.Moore	Rubiaceae
344	<i>Commiphora kua</i>		wfo-0000617330	(R.Br. ex Royle) Vollesen	Burseraceae
345	<i>Cordia africana</i>		wfo-0000620224	Lam.	Boraginaceae
346	<i>Corymbia citriodora</i>		wfo-0000925431	(Hook.) K.D.Hill & L.A.S.Johnson	Myrtaceae
347	<i>Craibia brownii</i>		wfo-0000198707	Dunn	Fabaceae
348	<i>Crotalaria agatiflora</i>		wfo-0000206398	Schweinf. ex L.Höhn.	Fabaceae
349	<i>Croton dichogamus</i>		wfo-0000927820	Pax	Euphorbiaceae
350	<i>Cussonia holstii</i>		wfo-0000933639	Harms ex Engl.	Araliaceae
351	<i>Cynanchum viminalis</i>		wfo-0000633723	(L.) L.	Apocynaceae
352	<i>Cynometra alexandri</i>		wfo-0000165801	C.H.Wright	Fabaceae
353	<i>Cyperus mundtii</i>		wfo-0000378143	(Nees) Kunth	Cyperaceae
354	<i>Cyperus papyrus</i>		wfo-0000379135	L.	Cyperaceae
355	<i>Dendrosenecio johnstonii</i>		wfo-0000063507	(H.H.Johnst.) B.Nord.	Asteraceae
356	<i>Diospyros abyssinica</i>		wfo-0000648453	(Hiern) F.White	Ebenaceae
357	<i>Diospyros gabunensis</i>		wfo-0000648975	Gürke	Ebenaceae
358	<i>Dombeya buettneri</i>		wfo-0000653633	K.Schum.	Malvaceae
359	<i>Dombeya burgessiae</i>		wfo-0000653634	Gerrard ex Harv.	Malvaceae
360	<i>Dombeya kirkii</i>		wfo-0000653769	Mast.	Malvaceae
361	<i>Dracaena fragrans</i>		wfo-0000765769	(L.) Ker Gawl.	Asparagaceae
362	<i>Drypetes gerrardii</i>		wfo-0000946481	Hutch.	Putranjivaceae
363	<i>Embelia schimperii</i>		wfo-0000666993	Vatke	Primulaceae
364	<i>Erica kingaensis</i>		wfo-0000672378	Engl.	Ericaceae
365	<i>Erythrococca bongensis</i>		wfo-0000953993	Pax	Euphorbiaceae
366	<i>Eucalyptus botryoides</i>		wfo-0000954529	Sm.	Myrtaceae
367	<i>Euclea divinorum</i>		wfo-0000681081	Hiern	Ebenaceae
368	<i>Eugenia capensis</i>		wfo-0001086193	(Eckl. & Zeyh.) Sond.	Myrtaceae
369	<i>Fagaropsis angolensis</i>		wfo-0000685062	(Engl.) H.M.Gardner	Rutaceae
370	<i>Faurea rochetiana</i>		wfo-0000686021	Chiov. ex Pic.Serm.	Proteaceae
371	<i>Ficus glumosa</i>		wfo-0000688513	Delile	Moraceae

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Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
372	<i>Ficus verruculosa</i>		wfo-0000690821	Warb.	Moraceae
373	<i>Grewia mildbraedii</i>		wfo-0000710105	Burret	Malvaceae
374	<i>Grewia mollis</i>		wfo-0000710110	Juss.	Malvaceae
375	<i>Gymnosporia arbutifolia</i>		wfo-0000712845	Loes.	Celastraceae
376	<i>Gymnosporia heterophylla</i>		wfo-0000712953	Loes.	Celastraceae
377	<i>Harrisonia abyssinica</i>		wfo-0000715900	Oliv.	Rutaceae
378	<i>Helichrysum formosissimum</i>		wfo-0000109302	Sch.Bip.	Asteraceae
379	<i>Hoffmannanthus abbotianus</i>		wfo-0001339939	(O.Hoffm.) H.Rob., S.C.Keeley & Skvarla	Asteraceae
380	<i>Kotschya africana</i>		wfo-0000175259	Endl.	Fabaceae
381	<i>Landolphia owariensis</i>		wfo-0000222837	P.Beauv.	Apocynaceae
382	<i>Lecaniodiscus fraxinifolia</i>		wfo-0000445971	Baker	Sapindaceae
383	<i>Lepidotrichilia volkensii</i>		wfo-0000443847	(Gürke) J.-F.Leroy	Meliaceae
384	<i>Lobelia stuhlmannii</i>		wfo-0001290302	Schweinf. & E.A.Bruce	Campanulaceae
385	<i>Lobelia wollastonii</i>		wfo-0000814667	Baker f.	Campanulaceae
386	<i>Lovoa trichilioides</i>		wfo-0000443844	Harms	Meliaceae
387	<i>Macadamia integrifolia</i>		wfo-0000452329	Maiden & Betcher	Proteaceae
388	<i>Macaranga schweinfurthii</i>		wfo-0000232237	Pax	Euphorbiaceae
389	<i>Maerua angolensis</i>		wfo-0000375297	DC.	Capparaceae
390	<i>Maerua triphylla</i>		wfo-0001290558	A.Rich.	Capparaceae
391	<i>Margaritaria discoidea</i>		wfo-0000236310	(Baill.) G.L.Webster	Phyllanthaceae
392	<i>Maytenus undata</i>		wfo-0000374940	(Thunb.) Blakelock	Celastraceae
393	<i>Mikania chenopodiifolia</i>		wfo-0000021577	Willd.	Asteraceae
394	<i>Millettia dura</i>		wfo-0000199876	Dunn	Fabaceae
395	<i>Mimusops bagshawei</i>		wfo-0000244495	S.Moore	Sapotaceae
396	<i>Mondia whitei</i>		wfo-0000367920	(Hook.f.) Skeels	Apocynaceae
397	<i>Nymphaea nouchali</i>		wfo-0000382053	Burm.f.	Nymphaeaceae
398	<i>Ochna holstii</i>		wfo-0000389162	Engl.	Ochnaceae
399	<i>Ocotea kenyanensis</i>		wfo-0000382832	(Chiov.) Robyns & R.Wilczek	Lauraceae
400	<i>Olea capensis</i>		wfo-0000817299	L.	Oleaceae
401	<i>Pavetta oliveriana</i>		wfo-0000265713	Hiern	Rubiaceae
402	<i>Peddiea africana</i>		wfo-0000475736	Harv.	Thymelaeaceae
403	<i>Piliostigma thonningii</i>		wfo-0000170413	(Schumach.) Milne-Redh.	Fabaceae
404	<i>Pittosporum viridiflorum</i>		wfo-0000487907	Sims	Pittosporaceae
405	<i>Pouteria adolfi-friedericii</i>		wfo-0000281508	(Engl.) A.Meeuse	Sapotaceae
406	<i>Pouteria altissima</i>		wfo-0000281522	(A.Chev.) Baehni	Sapotaceae
407	<i>Pseudospondias microcarpa</i>		wfo-0000393818	Engl.	Anacardiaceae
408	<i>Psychotria peduncularis</i>		wfo-0000287049	(Salisb.) Steyerl.	Rubiaceae
409	<i>Rhamnus staddo</i>		wfo-0000460142	A.Rich.	Rhamnaceae
410	<i>Rhoicissus revoilii</i>		wfo-0001145277	Planch.	Vitaceae
411	<i>Rhoicissus tridentata</i>		wfo-0000464567	(L.f.) Wild & R.B.Drumm.	Vitaceae
412	<i>Rubus apetalus</i>		wfo-0001016849	Poir.	Rosaceae

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Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
413	<i>Schrebera alata</i>		wfo-0000818537	Welw.	Oleaceae
414	<i>Senecio subsessilis</i>		wfo-0000115971	Oliv. & Hiern	Asteraceae
415	<i>Smilax anceps</i>		wfo-0000740727	Willd.	Smilacaceae
416	<i>Solanecio cydoniifolius</i>		wfo-0000067791	(O.Hoffm.) C.Jeffrey	Asteraceae
417	<i>Steganotaenia araliacea</i>		wfo-0000431247	Hochst.	Apiaceae
418	<i>Sterculia quinqueloba</i>		wfo-0000491820	(Garcke) K.Schum.	Malvaceae
419	<i>Strychnos potatorum</i>		wfo-0000502951	L.f.	Loganiaceae
420	<i>Syzygium cordatum</i>		wfo-0000318491	Hochst.	Myrtaceae
421	<i>Tamarindus indica</i>		wfo-0000170926	L.	Fabaceae
422	<i>Tephrosia</i>		wfo-4000037774	Pers.	Fabaceae
423	<i>Trichocladus ellipticus</i>		wfo-0000413901	Eckl. & Zeyh.	Hamamelidaceae
424	<i>Vachellia seyal</i>		wfo-0001284777	(Delile) P.J.H.Hurter	Fabaceae
425	<i>Vepris trichocarpa</i>		wfo-0000420112	(Engl.) Mziray	Rutaceae
426	<i>Vitex doniana</i>		wfo-0000333061	Sweet	Lamiaceae
427	<i>Ximenia americana</i>		wfo-0000428247	L.	Olcaceae
428	<i>Zanha golungensis</i>		wfo-0000430160	Hiern	Sapindaceae
429	<i>Zanthoxylum usambarense</i>		wfo-0001133239	(Engl.) Kokwaro	Rutaceae
430	<i>Ziziphus abyssinica</i>		wfo-0000430509	Hochst. ex A.Rich.	Rhamnaceae
431	<i>Bambusa vulgaris</i>	<i>Bambusa balcooa</i>	wfo-0000853059	Roxb.	Poaceae
432	<i>Calliandra houstoniana</i> var. <i>calothyrsus</i>		wfo-0000199357	(Meisn.) Barneby	Fabaceae
433	<i>Cissus rotundifolia</i>	<i>Cissus verticillata</i>	wfo-0000607033	(L.) Nicolson & C.E.Jarvis	Vitaceae
434	<i>Citrus aurantium</i>		wfo-0000607909	L.	Rutaceae
435	<i>Cyperus latifolius</i>	<i>Cyperus platyphyllus</i>	wfo-0000379955	Roem. & Schult.	Cyperaceae
436	<i>Ehretia cymosa</i>	<i>Heliotropium verdcourtii</i>	wfo-0000719031	Craven	Boraginaceae
437	<i>Erythrina caffra</i>	<i>Erythrina fusca</i>	wfo-0000180759	Lour.	Fabaceae
438	<i>Eucalyptus globulus</i> subsp. <i>globulus</i>		wfo-0000955002		Myrtaceae
439	<i>Eucalyptus globulus</i> subsp. <i>maidenii</i>		wfo-0000955003	(F.Muell.) J.B.Kirkp.	Myrtaceae
440	<i>Eugenia uniflora</i>	<i>Eugenia bergii</i>	wfo-0000336714	Nied.	Myrtaceae
441	<i>Ficus exasperata</i>	<i>Ficus ampelos</i>	wfo-0000687279	Burm.f.	Moraceae
442	<i>Ficus trichopoda</i>	<i>Ficus sarmentosa</i> var. <i>luducca</i>	wfo-0000690206	(Roxb.) Corner	Moraceae
443	<i>Kigelia africana</i> subsp. <i>moosa</i>		wfo-0000808925	(Sprague) Bidgood & Verdc.	Bignoniaceae
444	<i>Macaranga grandifolia</i>	<i>Macaranga magna</i>	wfo-0000232082	Turrill	Euphorbiaceae
445	<i>Manihot carthaginensis</i> subsp. <i>glaziovii</i>		wfo-0000235456	(Müll.Arg.) Allem	Euphorbiaceae

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Appendix 2. Continued

No.	Species	New name	Taxon ID	Authorship	Family
446	<i>Melaleuca citrina</i>	<i>Melaleuca lutea</i>	wfo-0000918120	Craven	Myrtaceae
447	<i>Ocotea usambarensis</i>		wfo-0001070285	Engl.	Lauraceae
448	<i>Olea capensis</i> subsp. <i>macrocarpa</i>		wfo-0000820678	(C.H.Wright) I.Verd.	Oleaceae
449	<i>Olea europaea</i> subsp. <i>cuspidata</i>		wfo-0000817789	(Wall. & G.Don) Cif.	Oleaceae
450	<i>Ozoroa insignis</i> subsp. <i>reticulata</i>		wfo-0000385516	(Baker f.) J.B.Gillett	Anacardiaceae
451	<i>Pappea capensis</i>	<i>Choritaenia capensis</i>	wfo-0000603432	Benth.	Apiaceae
452	<i>Pinus caribaea</i> var. <i>hondurensis</i>		wfo-0000490090	Barrett & Golfari	Pinaceae
453	<i>Pinus elliottii</i> var. <i>elliottii</i>		wfo-0001091650		Pinaceae
454	<i>Pinus pseudostrobus</i>	<i>Pinus montezumae</i>	wfo-0000481750	Lamb.	Pinaceae
455	<i>Podocarpus latifolius</i>	<i>Nageia wallichiana</i>	wfo-0000380815	Kuntze	Podocarpaceae
456	<i>Sesbania aculeata</i>		wfo-0000176765	(Schreb.) Pers.	Fabaceae
457	<i>Vachellia sieberiana</i> var. <i>woodii</i>		wfo-0001443221	(Burt Davy) Kyal. & Boatwr.	Fabaceae
458	<i>Yushania alpina</i>		wfo-0000907601	(K.Schum.) W.C.Lin	Poaceae

Part 3.

Tree seed sector analysis

Seed-seedling demand and certification of seed sources

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Contents

1	Introduction	129
1.1	Purpose of the study	129
1.2	Background	129
2	Current and planned planting programmes in the country	130
2.1	Rwanda Forestry Authority survey of seedlings in Nurseries 2023–2024	130
2.2	Desktop review of support to tree planting in Rwanda	134
2.3	Sales of seed from the National Tree Seed Centre (NTSC)	135
2.4	Seed sources	136
2.5	Strategy for reproductive material, seed cooperatives and the National Tree Seed Centre (NTSC)	137
2.6	Observations specifically for the Congo-Nile Watershed Divide	138
3	Summary of observations and recommendations	141
3.1	Observations	141
3.2	Recommendations	141
	References	142
	Appendices	144
1	Average seed sales (2016–2019) from the National Seed Centre, Huye	144
2	RFA survey – organizations expecting to support nursery production in districts of Rwanda	146
3	Types of organizations expecting to support nursery production in the districts for the 2023–2024 planting season	148
4	Projects/programmes in districts	150
5	One Acre Fund - Seedlings in districts in 2022	157
6	Definitions of tree seed sources and compliance with the OECD Scheme for the Certification of Forest Reproductive Material	158
7	Area of districts overlapping with the Congo-Nile Watershed Divide	161

List of figures and tables

Figures

1	Numbers of all seedlings in district nurseries	132
2	Numbers of seedlings for forestry in district nurseries	132
3	Numbers of seedlings for agroforestry in district nurseries	133
4	Numbers of fruit tree seedlings in district nurseries	133
5	One Acre Fund <i>Grevillea robusta</i> in nurseries in 2022	135
6	Distribution of seed source sites in potential vegetation types and regions	137
7	Locations (sectors) for the 10 contracted seed cooperatives	137
8	Districts in the Congo-Nile Watershed Divide overlaid on the potential vegetation map of Rwanda	139

Tables

1	Types of organizations expecting to support nursery production (numbers of seedlings) in districts for the 2023–2024 planting season	130
2	Expected nursery production (numbers of seedlings) in districts for the 2023–2024 planting season	131
3	Numbers (#) of projects/programmes in districts	134
4	Ten most sold species. Sales of seed from NTSC – average of period 2016-2019 seasons	136
5	Extract from SWOT analysis	137
6	Indigenous species in Afromontane forest (Fa) and Lake Victoria transitional rainforest (Ff)	139

1 Introduction

1.1 Purpose of the study

This report provides a baseline survey of seedling production and seed sources with a view to possible improvements in organization of the sector.

The report is an output of a study for the World Bank to provide Technical Assistance in Forestry and Rural Development in Rwanda under PROGREEN (https://www.progreen.info/about_page).

The report has been provided as part of Task 1 of this study: analytical work and development of action plans for improved genetic material (native and exotic species), their productivity, promotion and distribution. This study takes a national perspective to make it relevant to other ongoing restoration projects and broader tree-based interventions.

1.2 Background

The Government of Rwanda has pledged to restore two million hectares of land under the Bonn Challenge/AFR100 by increasing forest cover to 30 percent of the national land area, in addition to promoting agroforestry systems to cover 85 percent of cultivated landscapes (National TRM Strategy 2018). While these are ambitious goals to achieve by the year 2030, access to quality and adequate tree planting materials (seeds and seedlings) represents a significant stumbling block to achieving these goals. Understanding the current national tree sector in Rwanda is key to addressing tree seed/seedling access, distribution and management, which, in turn, is instrumental to meeting the national restoration target.

The first aim of this study is to create an overview of ongoing and planned planting programmes in Rwanda. This is done by estimating the number of seedlings and tree species in nurseries across the country. A second aim is to understand how nursery seedling production is supported by various actors. A third aim is to gain insight into seed sourcing strategies, and investigate how genetic quality is estimated.

We utilized three main sources:

1. Desktop review of projects supporting tree planting in Rwanda - secondary information gathered from published articles, reports, government documents including policies, strategies, development plans etc., and online information on tree planting projects. A total of 191 documents were reviewed to identify any regional, national, provincial and local programmes/projects involved in tree planting in Rwanda. A total of 64 programmes/projects were identified that contained a tree planting component. These 64 programmes were spread across 30 districts in 217 operational sites.
2. Through the Rwanda Forestry Authority (RFA), we sourced data compiled from a 2023 survey that investigated the expected seedling production in nurseries by district. The data contained information on supported nursery production, but lacked information on tree species. It lists production by district, and lump sum figures for seedling production were given by category: forests, agroforestry, fruits, bamboo, and ornamentals.
3. One Acre Fund kindly provided information on the species-wise production of seedlings across districts in the year 2022, and its newly revised approach to support nursery production in 27 districts.
4. We benefitted from previous work carried out by staff and consultants of the National Tree Seed Centre (NTSC) on identified seed sources in the country (compiled by Pedercini et al. 2023).

2 Current and planned planting programmes in the country

2.1 Rwanda Forestry Authority survey of seedlings in Nurseries 2023–2024

The Rwanda Forestry Authority asked districts for their expectations on seedling production for the 2023–2024 planting season. The expectations included targets for district government contributions as well as organizations investing in seedling production in the districts. The expected contributions involved about 44 different organizations (many working in several districts) supporting planting for forestry, agroforestry, fruits, bamboo and ornamental purposes. The largest contribution came from international NGOs (IGNOs), followed by international projects. Tree planting cooperatives came third (Tables 1, 2 and 3 below). Although the allocation of government budgets for tree planting were still pending at the time of the survey, the figures indicate that most tree planting is funded by earmarked projects. Interestingly, tea companies conduct a considerable amount of planting in specific districts (see also Appendices 2, 3 and 4).

Planting intensity varies between districts, both in numbers of seedlings and distribution for different purposes (Table 2 and Figures 1, 2, 3 and 4).

Table 1. Types of organizations expecting to support nursery production (numbers of seedlings) in districts for the 2023–2024 planting season

Type of organization	Count	Forestry	Agroforestry	Fruits	Bamboo	Ornamental	Sum
INGO	36	3,578,495	22,007,122	284,480	30,000		25,900,097
International project	33	1,066,800	16,029,385	893,000	134,000		18,123,185
Cooperative	5	1,347,000	347,000	2,289,000		6,250,000	10,233,000
Tea company	12	1,016,831					1,016,831
Private company	7	552,081	110,000	111,000			773,081
NGO	3		321,000	6,500			327,500
Government budget	3	131,200	100,000	54,000	2,000	1,200	288,400
Unknown	2	14,000	15,000	6,000		80,000	115,000
District (not yet budgeted)	8				5,000		5,000
Sum of rows		7,706,407	38,929,507	3,643,980	171,000	6,331,200	56,777,094

Note: Most districts had not yet budgeted for government nursery production. In three districts, government-funded seedlings accounted for 2%, 2% and 20% of the total number of seedlings. Numbers in the table may therefore be underestimated by less than 20%.

Source: Survey in 2023 by Rwanda Forestry Authority

Table 2. Expected nursery production (numbers of seedlings) in districts for the 2023–2024 planting season

District	Forestry	Agroforestry	Fruits	Bamboo	Ornamental	Sum of districts
Musanze	20,000	800,000	52,500	2,000	1,200	875,700
Gicumbi	474,112	1,420,500	417,500	20,000		2,332,112
Rutsiro	56,230					56,230
Gakenke		813,000	2,500			815,500
Burera	4,000	869,000	6,000			879,000
Rulindo		2,222,426	2,000			2,224,426
Rubavu		539,000	1,500	5,000		545,500
Nyabihu	118,250	924,000	145,000			1,187,250
Nyamasheke	458,645	1,160,200	13,000	15,000		1,646,845
Karongi	107,885	1,701,500	217,500	8,000		2,034,885
Ngororero		797,000	252,500			1,049,500
Rusizi		2,343,400	2,500	105,000		2,450,900
Rutsiro		399,000				399,000
Kirehe	2,907,440	1,873,625	16,400	16,000		4,813,465
Nyagatare	1,159,600	1,841,056	4,580			3,005,236
Gatsibo		1,196,400	2,000			1,198,400
Kayanza		764,000	12,000			776,000
Ngoma		831,000	13,500			844,500
Rwamagana		771,000	13,500			784,500
Bugesera		1,589,000				1,589,000
Ruhango	15,000	5,578,000	1,500			5,594,500
Kamonyi	43,000	801,000				844,000
Muhanga		1,329,400				1,329,400
Nyanza	25,000	1,152,000	54,000			1,231,000
Huye	262,081	865,000				1,127,081
Nyamagabe		849,000				849,000
Nyaruguru	591,164	1,004,000				1,595,164
Gisagara	50,000	4,086,000	15,000			4,151,000
Kicukiro	350,000	100,000	175,000		800,000	1,425,000
Nyarugenge	50,000	50,000	20,000		1,500,000	1,620,000
Gasabo	1,014,000	260,000	2,204,000		4,030,000	7,508,000
Sum of rows	7,706,407	38,929,507	3,643,980	171,000	6,331,200	56,782,094

Note: Several districts had not yet budgeted for government nursery production

Source: Survey in 2023 by Rwanda Forestry Authority

The numbers of seedlings in districts are graphically depicted in figures 1, 2, 3 and 4. Some districts have higher overall seedling targets. Seedlings for forestry and fruit trees appear to be targeted to fewer districts than those for agroforestry, which is supported – at different intensities – in all districts.

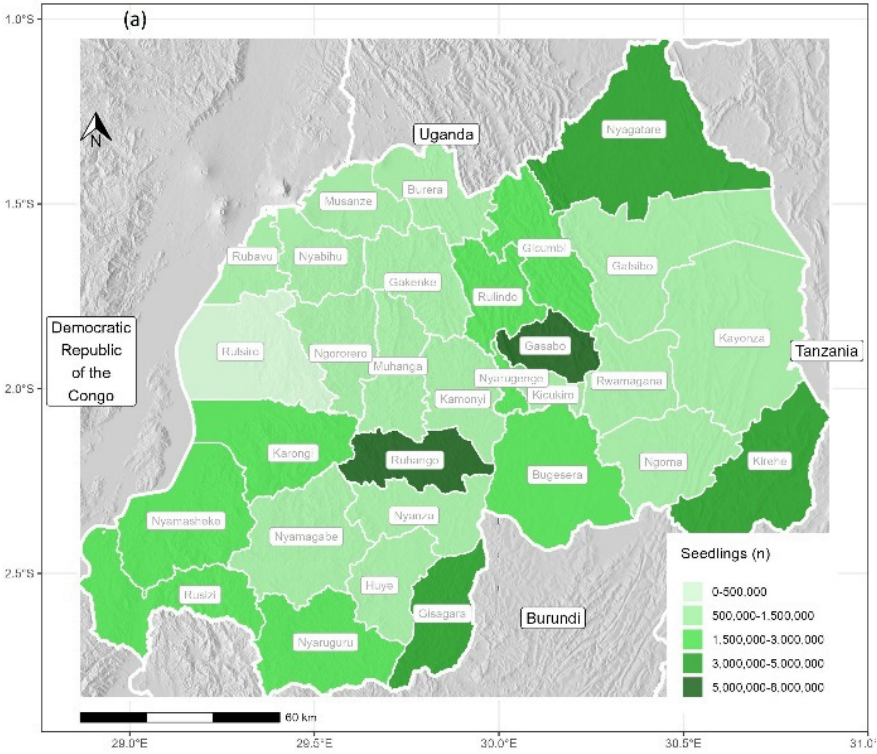


Figure 1. Numbers of all seedlings in district nurseries
Note: For some districts, government contributions had not yet been budgeted.
Source: Survey in 2023 by Rwanda Forestry Authority

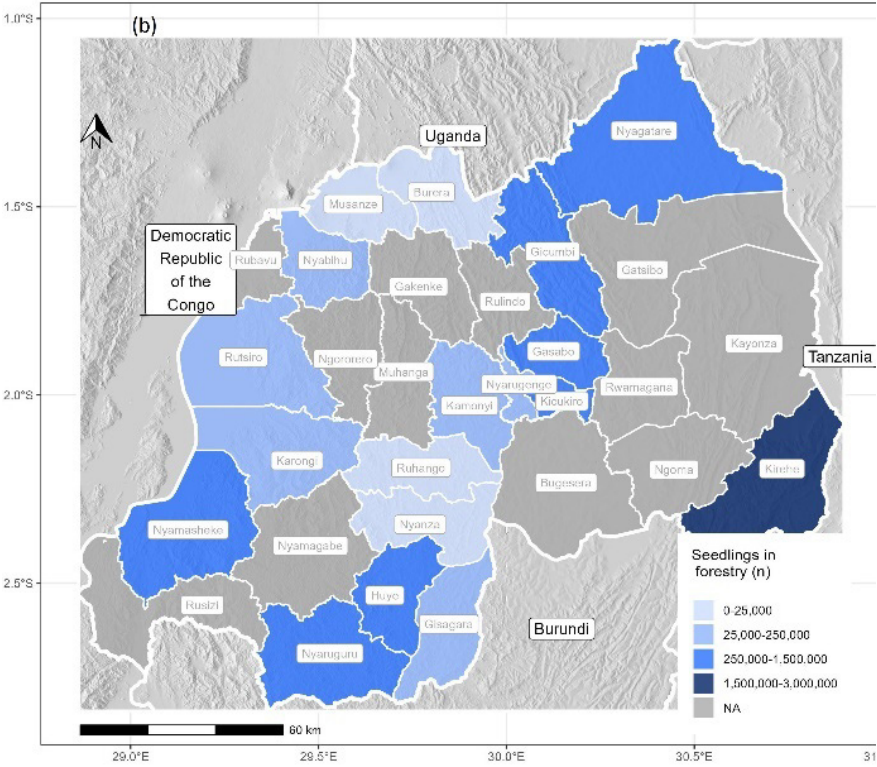
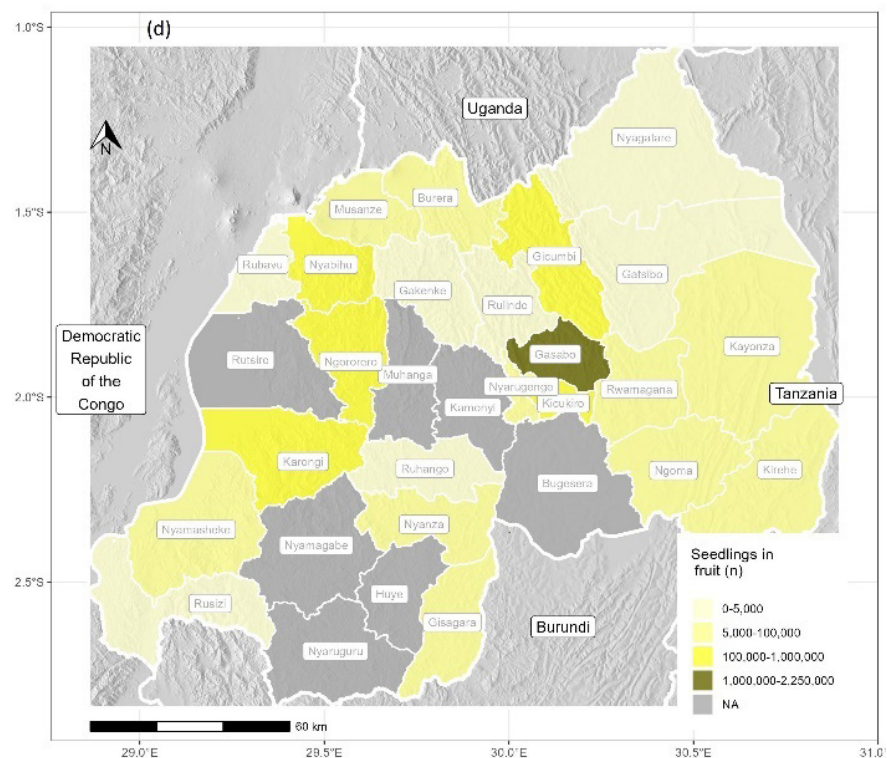


Figure 2. Numbers of seedlings for forestry in district nurseries
Note: For some districts, government contributions had not yet been budgeted.
Source: Survey in 2023 by Rwanda Forestry Authority



2.2 Desktop review of support to tree planting in Rwanda

All programmes from the RFA survey were identified in the desktop review. The desktop review indicates that many small projects are not included in the RFA survey information.

For each of the 64 identified projects, we collected information relating to the lead organization, source of funding, implementing partners, project timelines, expected targets to be achieved, tree species and quantities distributed, and areas of operation in Rwanda (Table 3 and Appendix 4).

It is however noted that not all information was available for all projects identified, and it was not always possible to translate their targets into numbers of seedlings to be produced. Importantly, it was possible to document the location (district) of operation for almost all projects.

One Acre Fund provided information on its seedling production for 2022, which totalled 20,153,522 seedlings. This corresponds to more than a third of the expected total seedling production for 2023 in Rwanda, and more if compared to 2022, when total seedling production appeared to be less (information from 2022 is not complete). Almost 16 million seedlings (80 percent of total) were of *Grevillea robusta* (see Figure 5 for distribution in districts). Eucalypts were not produced in One Acre Fund nurseries, but several indigenous as well as exotic fodder species were produced. For some species listed by One Acre Fund (see Appendix 5) no seedlings were produced, reflecting that One Acre Fund had the intention to produce, but could not obtain seeds from NTSC.

Table 3. Numbers (#) of projects/programmes in districts

No.	District	#	No.	District	#
1	Musanze	9	16	Kayanza	13
2	Gicumbi	8	17	Ngoma	3
3	Gakenke	6	18	Rwamagana	8
4	Burera	4	19	Bugesera	13
5	Rulindo	7	20	Ruhango	8
6	Rubavu	6	21	Kamonyi	4
7	Nyabihu	10	22	Muhanga	5
8	Nyamasheke	8	23	Nyanza	7
9	Karongi	4	24	Huye	7
10	Ngororero	10	25	Nyamagabe	3
11	Rusizi	3	26	Nyaruguru	4
12	Rutsiro	11	27	Gisagara	8
13	Kirehe	14	28	Kicukiro	4
14	Nyagatare	11	29	Nyarugenge	2
15	Gatsibo	10	30	Gasabo	7

Source: Compilation by authors, see also Appendix 4

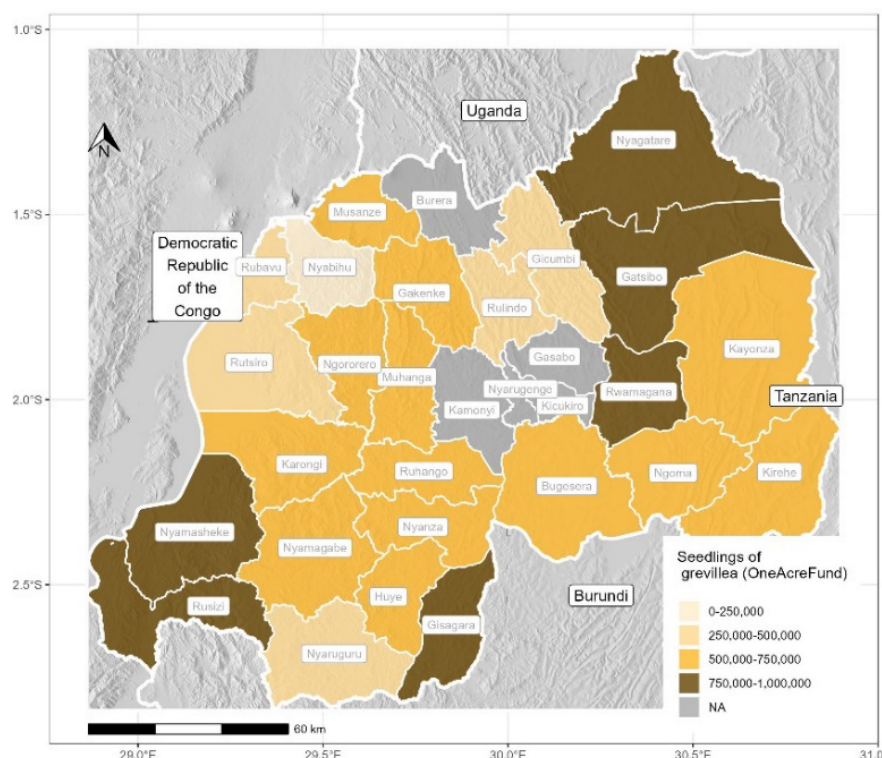


Figure 5. One Acre Fund *Grevillea robusta* in nurseries in 2022

Source: Excel Sheet sent to the authors by One Acre Fund in August 2023 (see table in Appendix 5)

2.3 Sales of seed from the National Tree Seed Centre (NTSC)

Appendix D, Table 12 in Pedersen (2019) provided a summary of sales by NTSC for the 2016 to 2019 period. NTSC sold seed of 55 species. Pedersen (op. cit.) provides data in kilogrammes of seed per species. As the number of seeds per kilogramme varies significantly between species, the consultants converted kilogrammes of seeds to numbers of seeds by consulting the Society for Ecological Restoration's Seed Information Database (<https://ser-sid.org/>) for each species. The 10 most important species in terms of kg sold x number of seeds per kg are all exotics (see Table 4 and Appendix 1 for the full list). In principle NTSC has at least one seed source for each of these 55 species (see the next section below).

Table 4 below, shows that the ten species sold in the largest quantities are all exotics. When calculated in number of seedlings, the numbers are very high. For example, with a planting density of 1,000 seedling/hectare, and a seed and seedling mortality factor of $\frac{1}{4}$, the number of seed for the 10 most planted species (820,906,727 seeds) corresponds to about 200,000 hectares of plantations. It is not likely that such a high number of seedlings were produced. It is more likely that customers overestimate their seed needs, when their estimates are based on seed weight alone. The most sold species are typically exotic species with small orthodox seeds, which is like what was found in a similar review for the Forest Landscape Restoration in Ethiopia (Lillesø and Derero 2018).

Table 4. Ten most sold species. Sales of seed from NTSC – average of period 2016-2019 seasons

Rank (kg)	Rank 2 (seeds)	Seeds kg ⁻¹	Origin	Current name	kg average 2016-18-19	Seeds average 2016-18-19	Potential seedlings*
16	1	3,267,974	Exotic	<i>Eucalyptus grandis</i>	46.8	152,832,251	38,208,063
6	2	719,424	Exotic	<i>Eucalyptus microcorys</i>	207.1	148,968,825	37,242,206
11	3	1,887,507	Exotic	<i>Eucalyptus camaldulensis</i>	74.6	140,823,751	35,205,938
15	4	2,325,581	Exotic	<i>Alnus acuminata</i>	47.8	111,085,271	27,771,318
1	5	78,751	Exotic	<i>Grevillea robusta</i>	1,242.3	97,832,367	24,458,092
18	6	1,850,000	Exotic	<i>Eucalyptus saligna</i>	39.4	72,828,333	18,207,083
19	7	1,176,470	Exotic	<i>Casuarina equisetifolia</i>	36.3	42,666,645	10,666,661
12	8	393,701	Exotic	<i>Eucalyptus globulus subsp. maidenii</i>	74.1	29,160,105	7,290,026
8	9	177,305	Exotic	<i>Solanum betaceum</i>	100.4	17,807,329	4,451,832
7	10	47,037	Exotic	<i>Senna spectabilis</i>	146.7	6,901,850	1,725,463

Note: Ratio of expected seedlings* from seed is 4:1.

Source: Pedersen (2019, Appendix D, Table 12). See Appendix 1 for full list.

2.4 Seed sources

Pedercini et al. (2023) discuss a species prioritization for Rwanda and summarize the previous work done by the staff and consultants to the Rwanda NTSC.

Pedercini et al. (2023) list 183 seed sources registered by NTSC. From the descriptions of the tree seed sources (remarks and notes collated in the database of seed sources), they deem that around 79 seed sources may be suitable and in use.

We would be more stringent and require that each source is carefully described according to agreed criteria (see Appendix 6). Considering such certification criteria, we suggest that without detailed documentation, only 15 could be considered suitable for immediate use, and a somewhat larger number could possibly be taken into use after suitable management (thinning, etc.). However, the 183 tree seed sources should be described in a way that enables evaluation of their genetic quality, such that they can be included in a public certification system of seed sources (see Appendix 6).

In principle, NTSC identifies seed sources, but seed collection is carried out by the ten seed cooperatives that are contracted by the Rwanda Forestry Authority (RFA) to collect seed for NTSC (IUCN/REMA/RWFA 2019). NTSC and the seed cooperatives are not obligated to document the sources they collect from. The distribution of seed source sites can be seen in Figure 6, and the distribution of the seed collection cooperatives is shown in Figure 7. We cannot say for sure whether the seed cooperatives collect from the identified seed sources, or from undescribed seed sources in farmlands, plantations or natural vegetation.

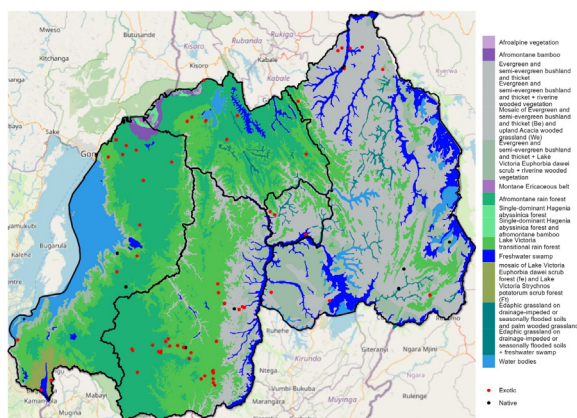


Figure 6. Distribution of seed source sites in potential vegetation types and regions

Source: Pedercini, Kindt, Graudal 2023, Figure 5.1.

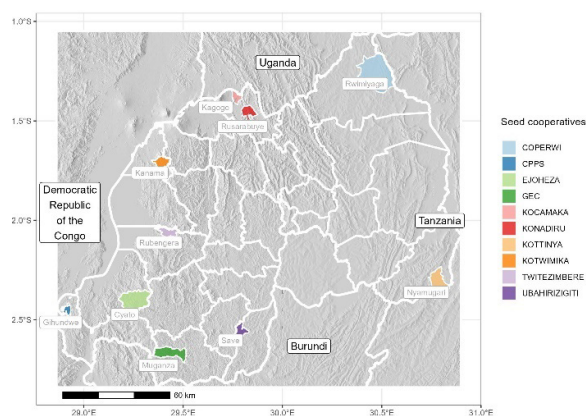


Figure 7. Locations (sectors) for the 10 contracted seed cooperatives

Source: Pedercini, for this report, based on IUCN/REMA/RWFA 2019

2.5 Strategy for reproductive material, seed cooperatives and the National Tree Seed Centre (NTSC)

The National Tree Reproductive Materials Strategy (Anon 2018) lists many strengths and weaknesses in the seed and seedling systems in Rwanda, among which we find the availability and quality of seed sources, and the potential production and distribution channels particularly important and insufficiently implemented (Table 5).

We suggest that defining quality should be the starting point for a strategy (quality is only vaguely described in the strategy document), and central to the strategy will be to envisage how the current tree seed and seedling distribution system can be tweaked with the aim of facilitating decentralized producers and distributors to utilize quality as an important parameter in their choice of seeds and seedlings.

Table 5. Extract from SWOT analysis

Strengths	Weaknesses
- Availability of tree seed sources (identified and established) - Existence of tree seedlings producer cooperatives (Source: Anon 2018)	- Poor quality seed sources due to lack of adequate management - Insufficient tree species diversification in tree seed stands - Undocumented seeds from farmers cooperatives

Source: IUCN/REMA/RWFA, 2019, Table 1

Tree seed quality is – first and foremost – genetic quality of seed sources, while the commonly used “germination capacity” is only a measure of how much seed can be expected from a given seed lot. Genetic quality of seed sources must be described according to the seed source type. For **immediate production** of seed there are: (i) ‘Farmland’ seed sources (existing trees growing on farms); (ii) ‘Plantation’ seed sources (mostly exotic species growing in plantations and woodlots); and (iii) ‘Natural Forest’ (or in woodland or bushland) seed sources (natural vegetation containing indigenous species adapted to the current environment) (Lillesø et al. 2011). Genetic quality is evaluated by different criteria for each of the three types of seed source. Generally, it can be said that Natural Forest seed sources in intact forest contain the highest genetic quality, and are also the most difficult to efficiently organize seed production and distribution from. Farmland and Plantation seed sources are easy to collect from, but require special considerations to minimize inbreeding and fragmentation. The National Tree Reproductive Materials Strategy puts much emphasis on seed orchards, which are sources for **future production**. Such seed orchards may indeed produce superior planting material; however, it is important to consider that it takes several years before such orchards become productive, and that seed orchards would only cover part of the demand for species. See Appendix 6 for how this classification complies with the OECD classification.

There is therefore an urgent need to develop production and distribution chains for **immediate production** that can meet the demands for seed across the landscapes in Rwanda (Lillesø et al. 2018). This will require the creation of networks for production and distribution of seed and seedlings – by identifying and facilitating quality seed sources for immediate production and their seed source custodians, and linking them with production and distribution of seedlings in the thousands of nurseries across the landscapes of Rwanda.

Twagirayezu (2015) investigated a sample of 53 nurseries in three districts (Bugesera, Nyabihu, Rubavu) grouped into government, group, and private nurseries. The nurseries received from 41%–48% of their seed from NTSC. Private seed dealers delivered from 0%–18% of the seed, and the remaining seed were collected by the nurseries themselves. NTSC thus seems to deliver a higher proportion of seed to nurseries than most other such centres in Africa (Lillesø 2020), but currently it cannot be verified that the seed delivered by NTSC provides seed of higher quality than locally collected seed.

It is commonly observed in Africa that governments and NGOs favour centralized nurseries at the expense of small private nurseries (Holtne 2012; Lillesø and Derero 2019; Lillesø 2020). We did not have access to statistics on the size distribution (in terms of seedling capacity) across the districts for government, group and private nurseries. However, information from One Acre Fund on their current nursery production strategy is pertinent as One Acre Fund supports about one third of nursery production in Rwanda. One Acre Fund has four central nurseries with a production capacity of around two million seedlings, but for the current season the intention is to produce 300,000 fruit tree seedlings centrally. The expected production of 20.8 million tree seedlings will be from 1,847 decentralized nurseries in the 27 supported districts – around 11,000 seedlings per nursery (One Acre Fund, Email 12 September 2023). This seems to be a model that could be integrated with the development of a decentralized network of seed sources.

2.6 Observations specifically for the Congo-Nile Watershed Divide

Most of the natural vegetation in the Congo Nile Ridge (CNR), also referred to as the Congo-Nile Watershed Divide (CNWD), has been converted to agriculture and small-scale plantations of exotic tree species. In Figure 8, the districts covering the CNWD region are overlaid over the potential natural vegetation map of Rwanda, while in Appendix 7 the extent of overlap of districts with the CNWD are tabulated. The map of Figure 8 shows that most of the region is potentially covered by two forest types - Afromontane forest and, to a more limited extent, Lake Victoria transitional rainforest. In the north-west, Volcanoes National Park is characterized by high altitude vegetation types. The potential vegetation types and relative tree species list can be sourced from the Vegetationmap4africa website.

Nyungwe, Mukura-Gishwati and Volcanoes national parks are part of the CNWD region, and although considerable areas were converted in recent history (Arakwiye et al. 2021), these protected areas contain the remaining populations of indigenous tree species that could function as sources of tree reproductive material. The national parks are the only areas in Rwanda, where good quality seed sources for immediate propagation of important indigenous trees can be found.

In Table 6 below, we analyse whether the top-31 priority species of priority level “AA”; see Part 2 (Pedercini et al. 2025) are native to the potential natural vegetation types found in the CNWD.

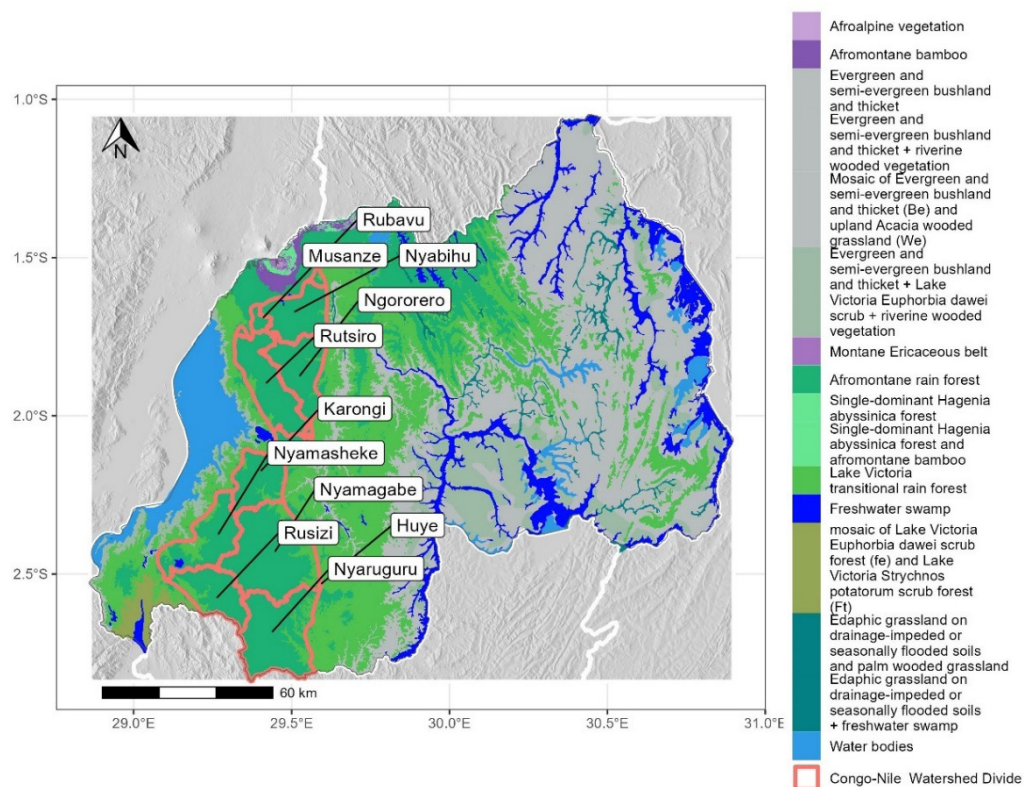


Figure 8. Districts in the Congo-Nile Watershed Divide overlaid on the potential vegetation map of Rwanda

Table 6. Indigenous species in Afromontane forest (Fa) and Lake Victoria transitional rainforest (Ff)

Fa	Ff	Indigenous species – priority species from natural forest
P	N	<i>Myrianthus holstii</i> , <i>Carapa grandiflora</i>
N	P	<i>Maesopsis eminii</i> , <i>Markhamia lutea</i>
P	P	<i>Afrocarpus falcatus</i> , <i>Bersama abyssinica</i> , <i>Croton megalocarpus</i> , <i>Dombeya torrida</i> , <i>Entandrophragma excelsum</i> , <i>Hagenia abyssinica</i> , <i>Maesa lanceolata</i> , <i>Neoboutonia macrocalyx</i> , <i>Parinari excelsa</i> , <i>Polyscias fulva</i> , <i>Prunus africana</i> , <i>Symphonia globulifera</i> , <i>Syzygium guineense</i>
		Exotic species – priority, but not in natural forest
N	N	<i>Acacia melanoxylon</i> , <i>Acacia mearnsii</i> , <i>Calliandra houstoniana</i> var. <i>calothyrsus</i> , <i>Casuarina equisetifolia</i> , <i>Cupressus lusitanica</i> , <i>Eucalyptus globulus</i> subsp. <i>maidenii</i> , <i>Eucalyptus saligna</i> , <i>Grevillea robusta</i> , <i>Persea americana</i> , <i>Pinus patula</i> , <i>Syzygium parvifolium</i>

Note: N = Not present; P = present

Utilizing such seed sources in natural forests with tall trees requires identifying, training and equipping seed source custodians, and organizing efficient distribution of seed. These activities should be facilitated by the National Tree Seed Centre.

Participatory forest management is practiced in Rwanda for community-based conservation (Umuziranenge 2019). This approach has the potential to be utilized for seed sourcing in natural forest. Seed collection from tall trees requires skilled tree climbers and safe climbing equipment. Furthermore, there are three conditions for a successful enterprise: (i) identification and documentation of the seed source for each species to define the genetic quality of the source; (ii) collection of seed lots from a minimum of 30 unrelated trees is needed to ensure genetic diversity (see Appendix 6); and (iii) successful sales of all the seed collected is needed to make seed collection economically viable.

A successful enterprise thus requires efficient distribution networks to customers in the districts in the CNWD. These networks would include other seed source custodians and networks of private nurseries as well as the National Tree Seed Centre. With proper management of the seed sources, seed collection will have a minimal impact on the ecology of the forest (Schmidt 2016a, 2016b).

3 Summary of observations and recommendations

3.1 Observations

The national programme on Forest Landscape Restoration in Rwanda is supported by many different organizations. More than 56 million seedlings are planted every year. This is a very impressive investment in improving the livelihoods of rural and urban populations in the country.

In Rwanda, genetic quality is not utilized as a concept for ensuring quality of tree seed and seedlings. Consequently, the potential benefits of forest landscape restoration are not fully achieved.

Sourcing quality tree seed is generally only a very small fraction of the overall cost of any tree or forest establishment activity. However, planting good quality seed enables the growing of superior products and enhancing the provision of tree environmental services. These benefits are generally much larger than any initial extra cost incurred in sourcing better quality seed (Lillesø et al. 2021).

Specifically for native tree seed species, tree seed sources must be identified and documented in the remaining natural forest, which occurs in protected areas. Decentralized input supply chains (documented seed sources > seed collection > nurseries) for these species need to be developed and supported to ensure that nurseries receive viable desiccation-sensitive seed.

3.2 Recommendations

Genetic quality for tree seed should be introduced as a concept in Rwanda. The concept will only be relevant if good quality seed sources are identified and made available to customers.

Breeding seed orchards should be established for the future production of improved seed of priority exotic and indigenous species.

For immediate production, NTSC should supervise the identification of quality seed sources that can produce seed of good genetic quality. At the same time, RFA should create an enabling environment for the collection, production and distribution of seeds based on quality sources which are widely distributed across the country. The custodians of seed sources in farmland, plantations (mainly exotic species) and in natural forest (native species) will need support in terms of information, and skills in protection, collection and sales. Furthermore, users of seed – the many organizations and nurseries in the landscapes of Rwanda – must have access to information on suitable sources for the species that they require.

The remaining natural forest in national parks in Rwanda contains many indigenous priority species for planting. Seed sources should be identified and documented for these species, and NTSC has a key role in supporting the development of economically viable decentralized production and distribution of tree seed from these seed sources.

The goal for the tree seed-seedling sector should be that NTSC guides producers and distributors on the use of good genetic quality seed rather than acting as the sole producer of seed. This goal is the norm for agricultural seed in most countries, and should be the goal for the tree seed and seedling sector in Rwanda (Lillesø et al. 2021).

References

- Anon. 2018. National Tree Reproductive Materials Strategy 2018–2024. February 2018. Republic of Rwanda. Ministry of Lands and Forestry. Rwanda.
- Arakwiye B, Rogan J, Eastman JR. 2021. Thirty years of forest-cover change in Western Rwanda during periods of wars and environmental policy shifts. *Regional Environmental Change* 21: 27.
- Global Administrative Areas. 2022. GADM database of Global Administrative Areas. Version [4.1]. Accessed from <http://www.gadm.org>
- Holtne N. 2012. Assessment of the current status of small-scale nurseries in Kenya – effectiveness of the input supply system. MSc Thesis. University of Copenhagen, Denmark.
- IUCN/REMA/RWFA. 2019. Building the capacity of cooperatives involved in tree seeds sector for the delivery of quality seeds. Cooperatives organizational and technical capacity assessment for tree seed sector development. International Union for Conservation of Nature (IUCN), Rwanda Environment Management Authority (REMA) and Rwanda Water and Forest Authority (RWFA)
- Lillesø J-PB. 2020. Defining and implementing quality of planting material for smallholder and restoration planting in sub-Saharan Africa. PhD Thesis. Department of Geosciences and Natural Resource Management. University of Copenhagen.
- Lillesø J-PB, Harwood C, Derero A, Graudal L, Roshetko JM, Kindt R, Moestrup S, Omondi WO, Holtne N, Mbora A, et al. 2018. Why institutional environments for agroforestry seed systems matter. *Development Policy Review* 36: O89–O112
- Lillesø, J-P. B., Dawson, I., Graudal, L. and Jamnadass, R. 2021. Quality seed for tree planting: Supporting more effective agroforestry and forest landscape restoration by learning from crop Integrated Seed System Development. Policy Brief 54. World Agroforestry Centre. Nairobi, Kenya.
- Lillesø J-PB and Derero A. 2019. Consultancy on a tree seed sub-sector assessment. Discussion of the tree seed supply/demand situation in Ethiopia 2018. Provision of Adequate Tree Seed Portfolios (PATSPo). Consultancy Report, February 2019. World Agroforestry Centre and University of Copenhagen. <http://www.worldagroforestry.org/project/PATSPo/outputs>
- Lillesø J-PB, Graudal L, Moestrup S, Kjær EDK, Kindt R, Mbora A, Dawson I, Muriuki J, Ræbild A, Jamnadass R. 2011. Innovation in input supply systems in smallholder agroforestry: Seed sources, supply chains and support systems. *Agroforestry Systems* 83: 347–359. <https://doi.org/10.1007/s10457-011-9412-5>
- Pedercini F, Kindt R, Graudal L. 2025. Selection of a master list of priority tree species, including some potential seed sources for tree improvement in Rwanda. Part 2 of Task 1 on tree improvement for the Congo-Nile Ridge landscape in Rwanda. Technical Study. Supplement to Graudal L, Dawson IK, Pedercini F, Ntawuhiganayo EB, Nduwamungu J, Mukuralinda A, Bizuru E, Lillesø J-PB, Kindt R, Dobie P, Ngethe E, Ndiramiye L, Nsabimana JdeD, Jamnadass R. 2025. *Supporting healthy environments and livelihoods in the Congo-Nile Ridge landscape of Rwanda: Synthesis report*. Working Paper 46. Bogor, Indonesia: CIFOR and Nairobi, Kenya: ICRAF. <https://doi.org/10.17528/cifor-icraf/00937>.
- Pedersen AP. 2019. Support to quality Tree Reproductive Material (TRM) supply in Rwanda. Final Report. Rwanda Water and Forest Authority. Kigali, Rwanda.
- Rwanda Forestry Authority. 2023. Survey in 2023 by Rwanda Forestry Authority. Raw data sheet in an Excel file sent to ICRAF upon request.
- Schmidt L. 2016a. *Forest Seed Collection, Processing, and Testing*. pp. 959–994. Tropical Forestry Handbook. Berlin, Germany: Springer-Verlag.
- Schmidt L. 2016b. *Genetics and Forest Seed Handling*. pp. 921–957. Tropical Forestry Handbook. Berlin, Germany: Springer-Verlag .
- Twagirayezu D. 2015. Understanding challenges and opportunities associated with the tree seed and seedling supply systems for improving agroforestry adoption in Rwanda - Case Study of Bugesera, Nyabihu and Rubavu Districts. M.Sc. Thesis, University of Rwanda.

- Umuziranenge G. 2019. Parks' governance and management in Rwanda: Opportunities and challenges of the community participation for a sustainable conservation – Case Study of Nyungwe National Park. *International Journal of Environmental Protection and Policy* 7: 61–71.
- Verdoodt A and van Ranst E. 2003. Land evaluation for agricultural production in the tropics. A large-scale land suitability classification for Rwanda. Ghent University. Laboratory of Soil Science. [Map 4.4. p. 79] <https://library.wur.nl/WebQuery/isric/2263128>

Appendices

Appendix 1. Average seed sales (2016–2019) from the National Seed Centre, Huye

Rank (kg)	Rank 2 (seeds)	Seeds kg ⁻¹	N/E	Current name	kg average 2016-18-19	Seeds average 2016-18-19	Potential seedlings*
16	1	3,267,974	E	<i>Eucalyptus grandis</i>	46.8	152,832,251	38,208,063
6	2	719,424	E	<i>Eucalyptus microcorys</i>	207.1	148,968,825	37,242,206
11	3	1,887,507	E	<i>Eucalyptus camaldulensis</i>	74.6	140,823,751	35,205,938
15	4	2,325,581	E	<i>Alnus acuminata</i>	47.8	111,085,271	27,771,318
1	5	78,751	E	<i>Grevillea robusta</i>	1,242.30	97,832,367	24,458,092
18	6	1,850,000	E	<i>Eucalyptus saligna</i>	39.4	72,828,333	18,207,083
19	7	1,176,470	E	<i>Casuarina equisetifolia</i>	36.3	42,666,645	10,666,661
12	8	393,701	E	<i>Eucalyptus globulus subsp. maidenii</i>	74.1	29,160,105	7,290,026
8	9	177,305	E	<i>Solanum betaceum</i>	100.4	17,807,329	4,451,832
7	10	47,037	E	<i>Senna spectabilis</i>	146.7	6,901,850	1,725,463
20	11	188,679	E	<i>Toona sinensis</i>	35.6	6,716,981	1,679,245
30	12	625,000	E	<i>Eucalyptus tereticornis</i>	9.3	5,833,333	1,458,333
5	13	19,000	E	<i>Calliandra houstoniana var. calothyrsus</i>	299.3	5,687,333	1,421,833
25	14	205,939	N	<i>Spathodea campanulata</i>	16.8	3,452,911	863,228
10	15	39,510	E	<i>Leucaena diversifolia</i>	86.8	3,428,158	857,040
21	16	98,058	E	<i>Jacaranda mimosifolia</i>	33.4	3,275,137	818,784
14	17	50,000	E	<i>Carica papaya</i>	56.7	2,833,333	708,333
31	18	310,000	N	<i>Polyscias fulva</i>	8.6	2,666,000	666,500
26	19	149,700	E	<i>Pinus patula</i>	16.5	2,475,040	618,760
24	20	83,056	E	<i>Callitris preissii</i>	27	2,242,525	560,631
22	21	64,683	E	<i>Passiflora edulis</i>	29.7	1,918,931	479,733
23	22	48,662	N	<i>Markhamia lutea</i>	29.6	1,440,389	360,097
17	23	24,201	N	<i>Tephrosia vogelii</i>	39.9	965,634	241,409
27	24	67,500	E	<i>Acacia mearnsii</i>	14	945,000	236,250
42	25	257,069	E	<i>Desmodium uncinatum</i>	3.3	856,898	214,225
32	26	86,207	E	<i>Acacia angustissima</i>	8.5	729,885	182,471
13	27	11,545	E	<i>Cajanus cajan</i>	57.4	663,049	165,762
4	28	1,603	N	<i>Afrocarpus falcatus</i>	330.3	529,524	132,381
35	29	84,592	E	<i>Acacia melanoxylon</i>	5.3	445,518	111,380
3	30	1,000	N	<i>Croton megalocarpus</i>	396	396,033	99,008
40	31	102,249	E	<i>Mimosa scabrella</i>	3.8	385,140	96,285
2	32	785	N	<i>Maesopsis eminii</i>	427.3	335,553	83,888
39	33	72,643	N	<i>Sesbania sesban</i>	3.9	283,308	70,827
33	34	39,000	E	<i>Senna siamea</i>	6.7	260,000	65,000

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Appendix 1. Continued

Rank (kg)	Rank 2 (seeds)	Seeds kg ⁻¹	N/E	Current name	kg average 2016-18-19	Seeds average 2016-18-19	Potential seedlings*
38	35	50,454	N	<i>Sesbania macrantha</i>	4.2	211,907	52,977
43	36	57,372	E	<i>Pinus caribaea</i>	3.3	191,241	47,810
34	37	29,002	E	<i>Eucalyptus urophylla</i>	5.4	155,646	38,912
46	38	31,348	N	<i>Acrocarpus fraxinifolius</i>	2	62,696	15,674
36	39	10,576	N	<i>Terminalia superba</i>	5	52,882	13,221
28	40	3,571	N	<i>Vachellia sieberiana</i>	12.2	43,452	10,863
50	41	55,000	E	<i>Leucaena trichandra</i>	0.5	27,500	6,875
44	42	9,641	E	<i>Gliricidia sepium</i>	2.7	25,710	6,428
41	43	3,577	E	<i>Araucaria cunninghamii</i>	3.7	13,115	3,279
55	44	184,162	E	<i>Mimosa invisa</i>	0.1	12,277	3,069
49	45	13,722	N	<i>Senegalia polyacantha</i>	0.7	9,148	2,287
48	46	11,001	E	<i>Acacia koa</i>	0.7	7,701	1,925
51	47	11,447	N	<i>Faidherbia albida</i>	0.4	4,960	1,240
54	48	21,437	E	<i>Leucaena leucocephala</i>	0.2	3,573	893
9	49	15	E	<i>Persea americana</i>	100	1,500	375
47	50	1,533	N	<i>Entandrophragma excelsum</i>	0.8	1,277	319
29	51	99	E	<i>Artocarpus heterophyllus</i>	11.7	1,159	290
45	52	384	E	<i>Terminalia microcarpa</i> subsp. <i>microcarpa</i>	2.7	1,023	256
52	53	1,262	E	<i>Mucuna pruriens</i>	0.3	421	105
53	54	803	E	<i>Biancaea decapetala</i>	0.3	268	67
37	55	29	N	<i>Carapa grandiflora</i>	4.3	126	32

Note: *Ratio of expected seedlings from seed is 4:1. N = Native; E = Exotic

Source: Pedersen (2019, Appendix D, Table 12)

Appendix 2. RFA survey – organizations expecting to support nursery production in districts of Rwanda

Institution type	Institution	# of districts
Cooperative	KAREMUCO Cooperative	1
	KOANDU Cooperative	1
	OPPC RABAGIRANA Cooperative	1
	UMUKINDO Cooperative	1
	URURABO NIBOYE Cooperative	1
District (not yet budgeted)	District has not yet budgeted for nurseries	8
Government	Government project	2
	VUP-Pw – road project	1
INGO	Action Aid	1
	ARCOS (Albertine Rift Conservation Society)	2
	AREECA (The Alliance for Restoration of Forest Ecosystems in Africa)	5
	One Acre Fund	27
	RDB/African Parks (Rwanda Development Board/African Parks)	1
International project	CDAT PROJECT	12
	COMBIO (Reducing vulnerability to climate change through enhanced community-based biodiversity conservation in the Eastern Province of Rwanda)	3
	ETI/MINAGRI (Export Targeted Modern Irrigation)	1
	Green Gicumbi (Strengthening climate resilience of rural communities in Northern Rwanda)	1
	ICRAF (World Agroforestry's projects)	1
	SAIP Project (Sustainable Agricultural Intensification and Food Security Project)	8
	SAPMP Project (Sustainable Agricultural Productivity and Market Linkage Project)	2
	TREPA (Transforming Eastern Province through Adaptation)	2
	UNHCR – Refugee camps	3
NGO	KAGENO – local NGO	1
	NATURE RWANDA - local NGO	1
	REDIRE - local NGO	1
Private company	ABISHYZEHAMWE	3
	DALILA FAMILY Co. – Fruit seedlings	1
	KME Ltd. – Forest concession owner	1
	Private nurseries established in district, seedlings produced may be planted in another district	1
	Ultimate Company - Private wood company	1

continued on next page

Appendix 2. Continued

Institution type	Institution	# of districts
Tea company	Ekaterra	1
	GATARE Tea Company Ltd.	1
	Gisakura Tea Company	1
	Karongi Tea Company	1
	Mata Tea Company	1
	Muganza Kivu Tea Company Ltd.	1
	Mulindi Tea Factory Ltd.	1
	Nshili - Kivu Tea Company Ltd.	1
	Rugabano Tea Company/Silverback	1
	Rwanda Mountain Tea (RMT) 2	1
	Rwanda Mountain Tea (RMT) /Rutsiro	1
	SHAGASHA Tea Company Ltd.	1
Unknown	NDAHAYO Viateur Tel: 0788620975	1
	UWIMANA Salomon Tel: 0785723194	1

Appendix 3. Types of organizations expecting to support nursery production in the districts for the 2023–2024 planting season

District	Organization type	Forestry	Agroforestry	Fruits	Bamboo	Ornamental	Total
Bugesera	INGO	0	839,000	0	0	0	839,000
	International project	0	750,000	0	0	0	750,000
Burera	INGO	0	854,000	0	0	0	854,000
	Unknown	4,000	15,000	6,000	0	0	25,000
Gakenke	INGO	0	813,000	2,500	0	0	815,500
Gasabo	Cooperative	1,004,000	260,000	2,204,000	0	3,950,000	7,418,000
	Unknown	10,000	0	0	0	80,000	90,000
Gatsibo	INGO	0	859,000	0	0	0	859,000
	International project	0	337,400	2,000	0	0	339,400
Gicumbi	INGO	0	585,500	2,500	0	0	588,000
	International project	411,000	835,000	415,000	20,000	0	1,681,000
	Tea company	63,112	0	0	0	0	63,112
Gisagara	INGO	0	752,000	0	0	0	752,000
	International project	50,000	3,334,000	15,000	0	0	3,399,000
Huye	INGO	0	715,000	0	0	0	715,000
	International project	0	150,000	0	0	0	150,000
	Private company	262,081	0	0	0	0	262,081
Kamonyi	Cooperative	43,000	37,000	0	0	0	80,000
	INGO	0	764,000	0	0	0	764,000
	Private company	0	0	0	0	0	0
Karongi	INGO	0	781,500	2,500	0	0	784,000
	International project	0	920,000	215,000	8,000	0	1,143,000
	Tea company	107,885	0	0	0	0	107,885
Kayonza	INGO	0	644,000	0	0	0	644,000
	International project	0	120,000	12,000	0	0	132,000
Kicukiro	Cooperative	250,000	0	65,000	0	800,000	1,115,000
	International project	100,000	100,000	110,000	0	0	310,000
Kirehe	Cooperative	10,000	10,000	1,000	0	0	21,000
	Government	83,200	0	0	0	0	83,200
	INGO	2,233,440	1,010,000	5,400	0	0	3,248,840
	International project	580,800	853,625	10,000	16,000	0	1,460,425
Muhanga	INGO	0	697,000	0	0	0	697,000
	International project	0	632,400	0	0	0	632,400

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Appendix 3. Continued

District	Organization type	Forestry	Agroforestry	Fruits	Bamboo	Ornamental	Total
Musanze	Government	20,000	100,000	50,000	2,000	1,200	173,200
	INGO	0	700,000	2,500	0	0	702,500
Ngoma	INGO	0	781,000	2,500	0	0	783,500
	International project	0	50,000	11,000	0	0	61,000
Ngororero	INGO	0	797,000	252,500	0	0	1,049,500
	INGO	0	724,000	0	0	0	724,000
Nyabihu	International project	0	200,000	145,000	0	0	345,000
	Tea company	118,250	0	0	0	0	118,250
Nyagatare	INGO	1,159,600	1,115,696	4,580	0	0	2,279,876
	International project	0	725,360	0	0	0	725,360
Nyamagabe	INGO	0	849,000	0	0	0	849,000
Nyamasheke	Government	28,000	0	4,000	0	0	32,000
	INGO	170,455	898,000	2,500	0	0	1,070,955
	International project	0	241,200	0	15,000	0	256,200
	NGO	0	21,000	6,500	0	0	27,500
	Tea company	260,190	0	0	0	0	260,190
Nyanza	INGO	0	662,000	0	0	0	662,000
	International project	25,000	490,000	54,000	0	0	569,000
Nyarugenge	Cooperative	50,000	50,000	20,000	0	1,500,000	1,620,000
Nyaruguru	INGO	0	704,000	0	0	0	704,000
	International project	0	300,000	0	0	0	300,000
	Private company	180,000	0	0	0	0	180,000
	Tea company	411,164	0	0	0	0	411,164
Rubavu	INGO	0	539,000	1,500	0	0	540,500
Ruhango	INGO	15,000	754,000	1,500	0	0	770,500
	International project	0	4,824,000	0	0	0	4,824,000
Rulindo	INGO	0	2,172,426	0	0	0	2,172,426
	International project	0	50,000	2,000	0	0	52,000
Rusizi	INGO	0	862,000	2,500	30,000	0	894,500
	International project	0	1,181,400	0	75,000	0	1,256,400
	NGO	0	300,000	0	0	0	300,000
Rutsiro	INGO	0	399,000	0	0	0	399,000
	Tea company	56,230	0	0	0	0	56,230
Rwamagana	INGO	0	736,000	1,500	0	0	737,500
	International project	0	35,000	12,000	0	0	47,000

Appendix 4. Projects/programmes in districts

No.	District	#	List of projects/programmes	Category type
1	Musanze	9	Climate Justice programme	INGO/NGO
			Green Amagaya I; LDCF-II Project titled “Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach”	Government
			Poverty-Environment Action for the Sustainable Development Goals (PEA)	Government
			Reducing Vulnerability to Climate Change in North West Rwanda through Community-based Adaptation	Government
			Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
			Virunga Transboundary Initiative	INGO/NGO
			Kitchen gardens and tree planting programme	INGO/NGO
			Tubura - OAF	INGO/NGO
2	Gicumbi	8	Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Rural Community Support Project (RCSP)	Government
			Strengthening climate resilience of rural communities in Northern Rwanda	INGO/NGO
			Forest Management and Woody Biomass Energy Support Project	Government
			Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
			Kitchen gardens and tree planting programme	INGO/NGO
			Tubura – OAF	INGO/NGO
3	Gakenke	6	Landscape Approach to Climate Proof the Rural Settlements Project	Government
			Rural Community Support Project (RCSP)	Government
			Forest Management and Woody Biomass Energy Support Project	Government
			Project for Inclusive Small Livestock Markets	Government
			Tubura – OAF	INGO/NGO
			Forest Investment Program: Development of agroforestry for sustainable agriculture in Rwanda	Government
4	Burera	4	Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
			Virunga Transboundary Initiative	INGO/NGO
			Tubura - OAF	INGO/NGO
5	Rulindo	7	Building Resilience to Climate Change and Sustainable Livelihoods in Rwanda’s Agrosystems	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Forest Management and Woody Biomass Energy Support Project	Government
			Rwandan Youth Development and Voluntary Organization	NGO - local
			Project for Inclusive Small Livestock Markets	Government
			Kitchen gardens and tree planting programme	INGO/NGO
			Tubura - OAF	INGO/NGO
6	Rubavu	6	Landscape Restoration and Integrated Water Resources Management in Sebeya Catchment and Other Catchments Project	Government
			Sebeya Project - Embedding Water Resources Management in Rwanda	INGO/NGO
			Trees on Farm project - I & II	INGO/NGO

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Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
7	Nyabihu	10	Rwanda Dairy Development Project – RDDP	Government
			Virunga Transboundary Initiative	INGO/NGO
			Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
			Landscape Restoration and Integrated Water Resources Management in Sebeya Catchment and Other Catchments Project	Government
			Sebeya Project - Embedding Water Resources Management in Rwanda	INGO/NGO
			Trees on Farm project - I & II	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Reducing Vulnerability to Climate Change in North West Rwanda through Community-based Adaptation	Government
			Project for Inclusive Small Livestock Markets	Government
8	Nyamasheke	8	Rwanda Dairy Development Project – RDDP	Government
			Virunga Transboundary Initiative	INGO/NGO
			Tubura - OAF	INGO/NGO
			Community gardens and kitchens	INGO/NGO
			Building the capacity of Rwanda's government to advance the National Adaptation Planning (NAP) process	Government
			Feed the Future Hinga Waze	INGO/NGO
			Reinforcement of Developing Initiatives in Rural Environment (REDIRE)	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Coffee agroforestry project	INGO/NGO
			Project for Inclusive Small Livestock Markets	Government
9	Karongi	4	Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Project for Inclusive Small Livestock Markets	Government
10	Ngororero	10	Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
			Building resilience to climate change and sustainable agriculture value chains in agro-systems around Mukura Forest and Lake Kivu Catchment Landscape	INGO/NGO
			Landscape Restoration and Integrated Water Resources Management in Sebeya Catchment and Other Catchments project	INGO/NGO
			Sebeya Project - Embedding Water Resources Management in Rwanda	INGO/NGO
			Green Amagaya I; LDCF-II Project titled "Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach"	Government
			Landscape Approach to Forest Restoration and Conservation (LAFREC)	Government
			Project for Inclusive Small Livestock Markets	Government
			Kitchen gardens and tree planting programme	INGO/NGO
			Food for the Hungry - Child support and tree planting	INGO/NGO
			Tubura - OAF	INGO/NGO

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Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
11	Rusizi	3	Building the capacity of Rwanda's government to advance the National Adaptation Planning (NAP) process	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Tubura - OAF	INGO/NGO
12	Rutsiro	11	Feed the Future Hinga Waze	INGO/NGO
			Building resilience to climate change and sustainable agriculture value chains in agro-systems around Mukura Forest and Lake Kivu Catchment Landscape	INGO/NGO
			Landscape Restoration and Integrated Water Resources Management in Sebeya Catchment and Other Catchments project	INGO/NGO
			Sebeya Project - Embedding Water Resources Management in Rwanda	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Community partners' interventions through nature-based villages	INGO/NGO
			Landscape Approach to Forest Restoration and Conservation (LAFREC)	Government
			Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
			Kitchen gardens and tree planting programme	Government
13	Kirehe	14	Tubura - OAF	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Green Amagaya I; LDCF-II Project titled "Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach"	Government
			Building Capacity of Rwanda's Government to advance the national adaptation planning Process (NAP)	Government
			Transforming Eastern Province through Adaptation	INGO/NGO
			Green Amayaga Project II	Government
			Community partners' interventions through nature-based villages	INGO/NGO
			Alliance for Restoration of Forest Landscapes and Ecosystems in Africa	INGO/NGO
			Landscape Approach to Climate Proof the Rural Settlements Project	Government
			ARCOS tree planting	INGO/NGO
			Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Anchor Farm Project: Rwanda	INGO/NGO
			ETI (Export Targeted Modern Irrigation)	Government
			Management for Climate Change Mitigation and Adaptation around Mahama Refugee Camp	NGO - local
14	Nyagatare	11	Tubura - OAF	INGO/NGO
			Alliance for Restoration of Forest Landscapes and Ecosystems in Africa	INGO/NGO
			Building the capacity of Rwanda's government to advance the National Adaptation Planning (NAP) process	Government
			ARCOS tree planting	INGO/NGO
			Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Anchor Farm Project: Rwanda	INGO/NGO

continued on next page

Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
15	Gatsibo	10	Transforming Eastern Province through Adaptation	INGO/NGO
			Regreening Africa	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Rwanda Dairy Development Project – RDDP	Government
			Food for the Hungry - Child support and tree planting	INGO/NGO
			Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
			Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Anchor Farm Project: Rwanda	INGO/NGO
			Transforming Eastern Province through Adaptation	INGO/NGO
			Regreening Africa	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Rural Community Support Project (RCSP)	Government
			Food for the Hungry - Child support and tree planting	INGO/NGO
16	Kayonza	13	Tubura - OAF	INGO/NGO
			Kayonya Irrigation and Integrated Water Management project - I & II	Government
			Feed the Future Hinga Waze	INGO/NGO
			Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Anchor Farm Project: Rwanda	INGO/NGO
			Transforming Eastern Province through Adaptation	INGO/NGO
			Regreening Africa	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Coffee agroforestry project	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Rural Community Support Project (RCSP)	Government
			Green Amagaya I; LDCF-II Project titled “Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach”	Government
			Rwanda Dairy Development Project – RDDP	Government
			Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
17	Ngoma	3	Transforming Eastern Province through Adaptation	INGO/NGO
			Tubura - OAF	INGO/NGO
			Rwanda Wildlife Conservation Society	NGO - local
18	Rwamagana	8	Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Anchor Farm Project: Rwanda	INGO/NGO
			Transforming Eastern Province through Adaptation	INGO/NGO
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government

continued on next page

Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
19	Bugesera	13	Forest Management and Woody Biomass Energy Support Project	Government
			Rwanda Dairy Development Project – RDDP	Government
			Tubura - OAF	INGO/NGO
			Feed the Future Hinga Waze	INGO/NGO
			Rwanda Environmental Conservation Organization (RECOR)	NGO - local
			Reducing climate change vulnerability through increased community-based biodiversity conservation in the Eastern Province of Rwanda	Government
			Transforming Eastern Province through Adaptation	INGO/NGO
			Regreening Africa	INGO/NGO
			Building Resilience to Climate Change and Sustainable Livelihoods in Rwanda's Agrosystems	Government
			Trees on Farm project - I & II	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Green Amagaya I; LDCF-II Project titled "Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach"	Government
			Poverty-Environment Action for the Sustainable Development Goals (PEA)	Government
20	Ruhango	8	Community partners' interventions through nature-based villages	INGO/NGO
			Kitchen gardens and tree planting programme	INGO/NGO
			Tubura - OAF	INGO/NGO
			FLR Green Mayaga project - I & II	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Green Amayaga Project II	Government
			Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
21	Kamonyi	4	Food for the Hungry - Child support and tree planting	INGO/NGO
			Tubura - OAF	INGO/NGO
			Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			FLR Green Mayaga project - I & II	Government
			Food for the Hungry - Child support and tree planting	INGO/NGO
22	Muhanga	5	Tubura - OAF	INGO/NGO
			Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Rural Community Support Project (RCSP)	Government
			Food for the Hungry - Child support and tree planting	INGO/NGO
23	Nyanza	7	Tubura - OAF	INGO/NGO
			Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			FLR Green Mayaga project - I & II	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government

continued on next page

Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
24	Huye	7	Sustainable Agricultural Productivity and Market Linkage Project (SAPMP)	Government
			Sustainable Agricultural Intensification and Food Security Project (SAIP)	Government
			Rwanda Dairy Development Project – RDDP	Government
			Tubura - OAF	INGO/NGO
			Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Project for Inclusive Small Livestock Markets	Government
			Rwanda Dairy Development Project – RDDP	Government
			Rwanda National Tree Seed Centre - Huye	Government
			Kitchen gardens and tree planting programme	INGO/NGO
			Tubura - OAF	INGO/NGO
25	Nyamagabe	3	Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			Feed the Future Hinga Waze	INGO/NGO
			Project for Inclusive Small Livestock Markets	Government
26	Nyaruguru	4	Tubura - OAF	INGO/NGO
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Project for Inclusive Small Livestock Markets	Government
			Tubura - OAF	INGO/NGO
27	Gisagara	8	Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			FLR Green Mayaga project - I & II	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
			Coffee agroforestry project	INGO/NGO
			Sustainable Agricultural Productivity and Market Linkage Project (SAPMP)	Government
			Project for Inclusive Small Livestock Markets	Government
			Kitchen gardens and tree planting programme	Government
28	Kicukiro	4	Tubura - OAF	INGO/NGO
			Forest Investment Program: Development of Agroforestry for Sustainable Agriculture in Rwanda	Government
			Building the capacity of Rwanda's government to advance the National Adaptation Planning (NAP) process	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government
29	Nyarugenge	2	Second Rwanda Urban Development Project (RUDP II)	Government
			Forest Management and Woody Biomass Energy Support Project	Government
			Second Rwanda Urban Development Project (RUDP II)	Government
30	Gasabo	7	Forest Management and Woody Biomass Energy Support Project	Government
			Building the capacity of Rwanda's government to advance the National Adaptation Planning (NAP) process	Government
			Commercialization and De-risking for Agricultural Transformation project (CDAT)	Government

continued on next page

Appendix 4. Continued

No.	District	#	List of projects/programmes	Category type
			Rural Community Support Project (RCSP)	Government
			Green Amagaya I; LDCF-II Project titled “Building Resilience of Communities Living in Degraded Forests, Savannahs and Wetlands through an Ecosystem-based Adaptation (EbA) Approach”	Government
			Second Rwanda Urban Development Project (RUDP II)	Government
			Forest Management and Woody Biomass Energy Support Project	Government

Appendix 5. One Acre Fund - Seedlings in districts in 2022

District	<i>Grevillea robusta</i>	<i>Calliandra houstoniana</i> <i>var. calothyrsus</i>	<i>Prunus africana</i>	<i>Jacaranda mimosifolia</i>	<i>Acrocarpus sp.</i>	<i>Polyscias fulva</i>	<i>Leucaena sp.</i>	<i>Toona sinensis</i>	<i>Senna sp.</i>	<i>Maesopsis eminii</i>	<i>Croton sp.</i>	<i>Markhamia lutea</i>	<i>Alnus acuminata</i>
Bugesera	629,250						128,100	83,900				125,850	
Burera	555,100												170,800
Gakenke	731,700												81,300
Gatsibo	757,680								86,100	17,220			
Gicumbi	470,400						58,800		58,800				
Gisagara	752,000												
Huye	715,000												
Kamonyi	496,600												
Karongi	609,800	139,400									24,679	242,723	34,800
Kayanza	515,200											128,800	
Kirehe	723,360									16,440			
Muhanga	561,600						82,200	70,200	70,200				
Musanze	630,400			157,600									
Ngoma	709,200											78,800	
Ngororero	663,700												153,300
Nyabihu	244,000										143,400		329,600
Nyagatare	920,550							108,300				54,150	
Nyamagabe	509,400											339,600	
Nyamasheke	763,200			76,320									
Nyanza	529,600												
Nyaruguru	352,000							66,200				66,200	
Rubavu	262,080							70,400				281,600	
Ruhango	583,200												283,920
Rulindo	310,800						88,800		44,400			145,800	
Rusizi	775,800	86,200											
Rutsiro	343,300										16,700		39,000
Rwamagana	788,000												
Grand Total	15,902,920	225,600	0	233,920	0	0	357,900	399,000	259,500	33,660	184,779	1,463,523	1,092,720

Note: Empty columns - for species intended to be planted, but seed unavailable for the NGO

Source: Based on table of seedling production provided directly to the consultant by One Acre Fund in August 2023 in Kigali

Appendix 6. Definitions of tree seed sources and compliance with the OECD Scheme for the Certification of Forest Reproductive Material

Introduction

Rwanda is a member of the OECD Scheme for the Certification of Forest Reproductive Material, which sets rules and regulations for international trade in forest seed as well as nationally for member states. The OECD rules have a bias towards temperate climates with few species and with advanced infrastructure for production and distribution of tree seeds and seedlings (Lillesø et al. 2011). In this Appendix 6, the consultants propose how to establish a certification scheme that is relevant for conditions in Rwanda and in compliance with OECD rules and regulations.

Forest landscape restoration (FLR) has become an increasingly important concern in recent years, with ambitious commitments made in the last two decades. An example is the current Bonn Challenge which aims to restore 350 million hectares of degraded and deforested landscapes by the year 2030, of which 100 million is under the African chapter, AFR100. Rwanda has pledged two million hectares for AFR100.

FLR consists of restoring natural forests and woodlands through natural regeneration and planting; establishment of plantations; and agroforestry tree planting on smallholder farms.

Definitions of tree seed sources have been developed and applied in many countries, and standardized (slightly differently) by OECD, EU, FAO, DFSC, GTZ¹ and others (for convenience we call it the OECD system). These guidelines generally rank seed sources into identified, selected and qualified sources; and for selected sources, into tested and untested reproductive material (e.g., OECD 2023).

The OECD classification assumes that a central organization (designated authority) has the capacity to control every seed source in the country. The classification does not explain how seed sources are evaluated, it only provides the decision of the designated authority. Other potentially important actors are precluded from having any agency in the tree seed-seedling system.

The shortcoming of the OECD system is that it does not explain how the different types of seed sources need to be evaluated differently to determine how seed collection will ensure genetic quality. This shortcoming can quite easily be remedied by classifying seed sources into five types (see below) that can then be classified according to the OECD system.

Most seed for smallholder plantings is from trees that are scattered on farmland or from natural forests, and common-sense criteria of quality can be applied to such sources. These criteria will enable collaboration between public and private organizations (including NGOs), and the entrepreneurial sector (small-scale nurseries and small-scale seed vendors) where the public sector actively supports entrepreneurial development (see also Graudal et al. 2021; Lillesø et al. 2021).

The support to tree planting in Rwanda seems to be both very centralized, i.e., seed collection and sales through NTSC; and very decentralized, i.e., seedling production in thousands of nurseries in the 30 districts. The justification for centralization (best possible seed quality) is not substantiated, and the potential advisory role of NTSC is not utilized.

Region of Provenance

OECD requires that Regions of Provenance are delineated for untested (identified, selected, qualified) sources of a species. The reason for this requirement is that for untested material, the Region of

1 OECD (Organisation for Economic Co-operation and Development), EU (European Union), FAO (Food and Agriculture Organization of the United Nations), DFSC (Danida Forest Seed Centre), GTZ (German Agency for Technical Cooperation)

Provenance provides information on the assumed adaptation of the source – “For a species or sub-species, the Region of Provenance is the area or group of areas subject to sufficiently uniform ecological conditions in which stands or seed sources showing similar phenotypic or genetic characters are found” (OECD Forest 2022).

For Rwanda, ICRAF utilizes the atlas of Potential Vegetation of Rwanda as a planting zone system. A shinyapps tool is under development for Rwanda, which corresponds to Regions of Provenance. Many Rwanda tree species occur across planting zones, and the same species can thus have seed sources that are adapted to different planting zones.

The Centre of Excellence in Biodiversity has recently developed a map of ecosystem types in Rwanda (<https://rbis.ur.ac.rw/map/>) that has been integrated into the Rwanda Biodiversity Spatial Assessment. This is regarded as the most accurate map of ecosystem types for planning purposes. However, it does not at present list the tree species occurring in each of the ecosystem types. It is therefore not at present possible to use this map for a species-specific planting zone system (reference also Part 1 of this report).

Categories of seed sources

OECD Forest scheme

OECD Forest (2022) categorizes reproductive material into: (i) Identified; (ii) Selected; (iii) Qualified; and (iv) Tested.

- (i) Identified: This is the minimum standard permitted in which the location and altitude of the place(s) from which reproductive material is collected must be recorded; little or no phenotypic selection has taken place.
- (ii) Selected: The basic material must be phenotypically selected at the population level.
- (iii) Qualified: The components of the basic material have been selected at the individual level; however, evaluation may not have been undertaken or completed.
- (iv) Tested: The superiority of the reproductive material must have been demonstrated by comparative testing, or an estimate of its superiority calculated from the genetic evaluation of the components of the basic material.

The purpose of this categorization is to enable a decentralized registration of seed sources. The description of seed sources therefore aims to produce a phenotypical description of the seed source at a population level, and to include an evaluation of a sample of individual trees in a source. The sources for *immediate production* therefore correspond to the OECD category of *Qualified*. The seed sources for *future production* (breeding seed orchards and seedling seed orchards) correspond to the OECD category of *Tested*.

Seed sources

ICRAF differentiates between sources for:

Immediate production: (i) Natural vegetation; (ii) Farmland; and (iii) Plantation. These three types of sources are untested, but they can still be documented with respect to phenotypical condition, number of potential seed trees, and vegetation type (Region of Provenance). Each of the three types has a unique distribution of genetic variation among individual trees, and the evaluation of genetic quality must be made separately for each type. The minimum number of trees to be collected from is different for each type, but they should all have healthy seed trees, and the number of seeds collected from each seed tree should be equal.

- (i) Natural vegetation: This contains the largest diversity of species and genetic variability within species, and pollination is good in intact forest. In most cases, mature trees are large and difficult to collect from. Collection is best done by skilled tree climbers, favouring actors that can specialize

in natural forest. The minimum number of selected, sexually mature good trees to be included in a genetically qualified natural forest seed source is preferably 50 trees or more, all of which are further than 100 m from another tree of the same species. The minimum number of trees that must have contributed equally to a given seed lot is preferably 40 trees or more that should all grow in the same planting zone. All trees are healthy and of acceptable quality (in traits as relevant). Trees should not be remnants left over after severe logging of superior trees

- (ii) Farmland: Trees are either remnants of natural vegetation or planted trees. Easy access makes farmland a favourite for seed collection. Origin is often unknown; genetic variability may be low, possibly suffering from inbreeding; and pollination is not ensured. The minimum number of selected, good trees to be included in a genetically qualified farmland seed source is 50, all of which are further than 100 m from another seed tree of the same species. A seed tree must at the same time be within pollination distance of other trees of the same species. The minimum number of trees that must have contributed to a given seed lot is 30. The minimum number of farms on which seed trees grow (when origin is unknown) is 5.
- (iii) Plantation (of unknown origin): There is a grey zone between 'plantations' and 'planted farmland seed sources'. For the purpose of classification, we suggest that trees planted in shelterbelts, farm borders, and permanently intercropped are considered to be farmland seed sources, whereas trees planted as even-aged blocks (most often in monocultures) are considered plantations. A minimum area of one hectare where seeds can be collected may be sufficient, provided it is known that the plantation was established from well-mixed seeds of a good representative collection. This size of area will ensure possibilities of collecting from 50–100 seed trees at a sufficient spacing (10–14 m) even after thinning. Many of the smaller agroforestry tree species have a small size at reproductive maturity, so spacing might only need to be 5–10 m depending on species. In such cases, 0.5 hectares should be adequate. The plantation shall exhibit good growth and performance indicating that the genetic origin is suitable for the site (in terms of health and other characters as relevant for the given species). The minimum size of the plantation of unknown origin is 75 trees, preferable larger. Seed should be collected from at least 40 trees, preferably more. Previous thinning(s) should not have removed the best trees to any severe extent (in characters as relevant), and future thinning(s) should be selective, leaving superior trees.

Future production: (iv) Planted seed orchard - breeding seed orchards (BSOs) and Planted seed orchard - seedling seed orchards (SSOs). Both sub-types are established from seed collection across the area of natural distribution of the species, and with seeds from selected unrelated trees. The relative contribution of seedlings from mother trees is controlled and equal, and with a minimum number of families contributing to the seed orchard.

- (iv) Planted seed orchard - BSOs maintain family identity, which enables analysis of genetic variation and selection of the best families for final seed production.
- (iv) Planted seed orchard - SSOs are established from bulked seed lots (family identity is not controlled), which makes them easier to establish, the layout is simpler and there is no workload of analysing the genetic variation. SSOs are phenotypically thinned, which will increase the genetic potential in the final seed production.

A fifth type is (v) Vegetative propagation. Propagation by vegetative means is an important way to maintain selected genotypes of trees. In the tropics this is particularly relevant for well-known varieties of fruit trees like mango, avocado and papaya. Vegetative propagation can also be considered if seedling production is very complicated. However, considering the many disadvantages to vegetative propagation (in particular high costs of production), it is usually easier and more sustainable to handle the seed problem rather than developing vegetative propagation.

Appendix 7. Area of districts overlapping with the Congo-Nile Watershed Divide

District	Agroecological zone	Area (km ²)
Nyamagabe	Congo-Nile Watershed Divide	829.04
Nyaruguru	Congo-Nile Watershed Divide	664.56
Rutsiro	Congo-Nile Watershed Divide	454.52
Nyamasheke	Congo-Nile Watershed Divide	432.65
Karongi	Congo-Nile Watershed Divide	410.42
Ngororero	Congo-Nile Watershed Divide	386.42
Rusizi	Congo-Nile Watershed Divide	338.83
Nyabihu	Congo-Nile Watershed Divide	337.73
Rubavu	Congo-Nile Watershed Divide	54.53
Musanze	Congo-Nile Watershed Divide	22.34
Huye	Congo-Nile Watershed Divide	1.59

Note: Calculated by Pedercini by overlaying relevant districts with AEZ zones of Rwanda

Source: GADM 2022; Verdoodt 2003



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