UNECE

National forest landscape restoration strategies

A manual

UNITED NATIONS

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This publication is issued in English, French and Russian.

United Nations publication issued by the United Nations Economic Commission for Europe.

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ECE/TIM/SP/64

UNITED NATIONS PUBLICATION

Sales No. E.25.II.E.19

ISBN 978-92-1-159185-9

PDF ISBN 978-92-1-154530-2

ISSN 1020-2269

eISSN 2518-6450

Abstract

This manual is a comprehensive guide designed to empower decision-makers and field managers in the development and implementation of national Forest Landscape Restoration (FLR) strategies. It provides a dual-focused approach to ensure both strategic vision and on-the-ground success.

The manual outlines the essential steps for developing a national FLR strategy, from defining a clear vision and goals to establishing robust monitoring and evaluation frameworks. It then provides detailed technical guidelines for effective, on-the-ground execution. This dual approach ensures users are equipped with both the high-level planning knowledge and the specific operational instructions needed to successfully bring FLR projects to life, transforming national plans into tangible, on-the-ground action.

Acknowledgements

The following publication was prepared by the United Nations Economic Commission for Europe (UNECE) Forest and Bioeconomy Section. The production of the study was funded by the United Nations Regular Programme of Technical Cooperation (RPTC) 2025.

UNECE thanks the authors—Liviu Nichiforel, Bernhard Von Puttkamer, and Veronika Wendt—for their valuable contributions and expertise in writing the study's chapters.

We extend our sincere appreciation to the experts, organizations, contributors from both the public and private sectors, and all the staff from our organizations who collaborated on this publication. The insights and recommendations provided in this year's *Review* are critical for fostering discussions among governments, businesses and environmental groups, and for initiatives that focus on balancing and aligning economic development and environmental concerns within the forestry sector.

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AURORA	Assessment, Understanding and Reporting of Restoration Actions
CIFOR	Center for International Forestry Research
EUFORGEN	European Forest Genetic Resources Programme
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest Landscape Restoration
FPIC	Free, Prior and Informed Consent
FRM	Forest Reproductive Material
FSC	Forest Stewardship Council
GCF	Green Climate Fund
GEF	Global Environmental Facility
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature
LCIP	Local Communities and Indigenous Peoples
NDC	Nationally Determined Contributions
NGO	Non-Governmental Organization
NPGP	National Policy Guiding Principles
PES	Payment for Ecosystem Services
PPE	Personal Protective Equipment
REDD+	Reducing Emissions from Deforestation and Forest Degradation
ROAM	Restoration Opportunities Assessment Methodology
RPTC	United Nations Regular Programme of Technical Cooperation
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNGA	United Nations General Assembly
UNHCR	United Nations High Commissioner for Refugees
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research (Eidg. Forschungsanstalt für Wald, Schnee und Landschaft)

1. Setting the Scene

1.1. Forest Landscape Restoration

Forests globally, including those in the United Nations Economic Commission for Europe (UNECE) region, are essential for mitigating climate change. They act as vital carbon sinks, absorbing vast amounts of carbon dioxide from the atmosphere, playing a critical role in regulating global temperatures. Beyond carbon sequestration, forests provide crucial ecosystem services: they regulate climate, purify air and water, prevent soil erosion, support immense biodiversity, and offer countless products and livelihoods for people.

Given the growing threats of deforestation and degradation, Forest Landscape Restoration (FLR) has emerged as a holistic approach that turned into a prominent strategy to combat these issues. FLR is not merely about planting trees; it's an ongoing process of regaining ecological functionality and enhancing human well-being across entire deforested or degraded landscapes, aiming to restore a mosaic of land uses for multiple benefits. This comprehensive approach ensures that forests continue to deliver their vital services, contributing significantly to climate change mitigation and biodiversity conservation, fostering long-term resilience for both nature and people.

The **Bonn Challenge**[1], of 2011 laid the groundwork for global Forest Landscape Restoration (FLR) efforts, setting an ambitious goal to restore 350 million hectares by 2030. These efforts have since been amplified by two crucial United Nations' initiatives. The ongoing **United Nations Decade on Ecosystem Restoration (2021-2030)** (UNGA, 2021) and the recently declared **United Nations Decade on Afforestation and Reforestation (2027-2036)** (UNGA, 2025), which will focus specifically on large-scale tree planting to combat environmental challenges, particularly in arid regions. Together, these initiatives underscore the urgent global commitment to restore the planet's vital forest ecosystems for a sustainable future.

1.2. Forest Landscape Restoration in the United Nations Economic Commission for Europe Region

The UNECE Forest and Bioeconomy Section has been actively supporting countries in scaling up their efforts to restore degraded forests and landscapes for many years. Activities include facilitating **capacity-building** and offering essential **policy advice** for the formulation of national and regional strategies, policies, technical monitoring frameworks, and financial solutions. The UNECE spearheaded several significant FLR commitments through two ministerial meetings, resulting in pledges to **restore over 7 million hectares in the Caucasus, Central Asia, Eastern, and South-East Europe regions** through:

- The Ministerial Meeting on Forest Landscape Restoration in Eastern and South-East Europe (October 2021, online).
- The Ministerial Roundtable on Forest Landscape Restoration and the Bonn Challenge in the Caucasus and Central Asia (June 2018, Kazakhstan).

Despite a wealth of existing tools and training for FLR practitioners and policymakers, there's a recognized gap in country-tailored guidance for creating a supportive policy environment for successful and sustainable FLR interventions. To address this, in 2022 the UNECE developed the National Policy Guiding Principles (NPGP). They assist national forest authorities in identifying and aligning their FLR-related policies, strategies, and laws with best practices and evidence.

In response to the need for practical guidance on implementing Forest Landscape Restoration (FLR), UNECE collaborated with Uzbekistan's Ministry of Ecology, United Nations Development Programme (UNDP), and United Nations High Commissioner for Refugees (UNHCR). This partnership created technical guidelines for a masterplan to support the country's "Yashil Makon" initiative,

1 https://www.bonnchallenge.org/.

which focuses on afforestation and sustainable forest management.

1.3. A Manual

To meet the growing demand for a comprehensive **Forest Landscape Restoration (FLR)** guide, UNECE has developed this technical manual. It is designed as a universal resource, applicable to any country looking to build its own national FLR strategy. The manual offers a dual-focus approach. It provides a strategic guide for developing an FLR strategy, setting visions and goals to establishing monitoring and evaluation frameworks, and offers detailed technical guidelines for practical, on-the-ground implementation. This ensures that users have both the high-level planning knowledge and the specific operational instructions needed for successful FLR projects.

1.3.1. Developing national FLR strategies

The first part of the manual details how to develop a national **Forest Landscape Restoration (FLR)** strategy. It emphasizes defining a clear vision and goals, setting **SMART** (Specific, Measurable, Achievable, Relevant, Time-bound) objectives, and implementing a robust **monitoring and evaluation framework** to ensure success and continuous learning.

1.3.2. Technical guidelines for FLR implementation

The second part of the manual offers technical guidelines for the practical implementation of **FLR**, covering a range of critical topics:

- **Site and species selection**, including mapping and prioritization.
- **Seedling production** and integrated nursery management.
- **Pest and disease management**, emphasizing an Integrated Pest Management (IPM) approach.
- **Transplanting and pruning** methods.

Additionally, this section presents model time and productivity norms as a framework for sustainable forestry.

This manual is a comprehensive resource for planners and practitioners, though its guidance should always be tailored to specific national and local contexts which can vary widely.

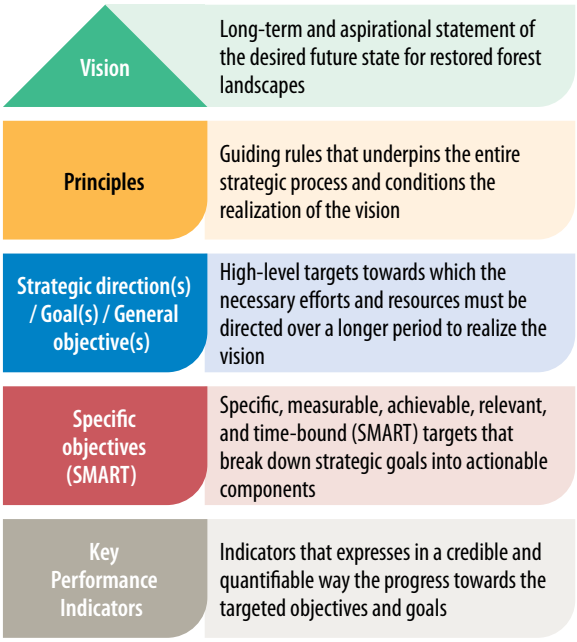
2. Guide on Developing National Forest Landscape Restoration Strategy

This Chapter outlines the critical aspects of crafting a robust national FLR strategy, namely (1) defining the vision, principles and goals of the strategy, (2) developing specific objectives, (3) creating an action plan, and (4) monitoring and evaluation of the strategy.

Strategies create the "pattern in a stream of decisions" (Mintzberg 1978) by defining the direction, priorities, and coordination mechanisms that ensure FLR efforts are effective, inclusive, and aligned with broader national and international goals. Designing and visualizing the structure of a strategy can be very helpful for understanding its components and how they relate (Figure 1).

Figure 1:

Strategic framework hierarchy for Forest Landscape Restoration



2.1. Defining Vision, Principles and Goals

Defining the vision, principles, and goals of a strategy is paramount because they form the foundational bedrock upon which all subsequent strategic planning, execution, and evaluation are built. Without clear definitions of these elements, a strategy risks being unfocused, inconsistent, and ultimately ineffective. The strategic directions and goals provide the foundation for targeted FLR strategies that align international and national priorities with tangible, on-the-ground impacts. They signal what is most important to achieve within the strategic timeframe.

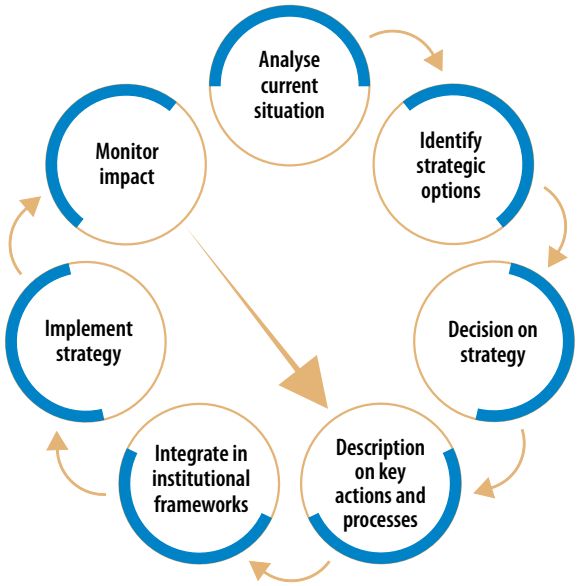
Developing an FLR strategy requires a thorough understanding of the existing policy landscape. Where national policies already contain strategic directions for forest restoration, the new FLR strategy should aim to strengthen and integrate these. For countries embarking on this process without prior frameworks, strategic goals must be newly identified and formally integrated into the institutional structure.

A foundational step in creating a national FLR strategy is to define core principles that will guide and ensure the consistency of the entire reforestation process. These principles can encompass effective governance of the strategic process (e.g., ensuring transparency, science-based decision-making, stakeholder engagement, and multi-level participation) and/or specific FLR approaches (e.g., focusing on landscape scale, restoring multiple ecosystem services, enhancing natural ecosystems, and supporting local livelihoods). The **National Policy Guiding Principles**, developed by UNECE (2022)[2], offer **guidance** to national forest authorities in creating a supportive policy environment for successful **FLR** interventions. The principles include a rationale, proposed criteria, and expected benefits, organized into thematic and cross-cutting categories.

2 https://unece.org/sites/default/files/2022-09/ECE_TIM_2022_7_en.pdf.

Figure 2:

Steps of iterative strategy development



The process of defining strategic goals and principles is often iterative and highly collaborative, especially in the context of a national strategy involving multiple stakeholders (Figure 2).

Setting the goals for the FLR strategy based on sound evidence involves: i) a comprehensive understanding of the national context; ii) a review of past experiences with FLR processes; and iii) identifying key strategic and operational challenges and developing appropriate approaches to overcome them.

2.1.1. Understand national context

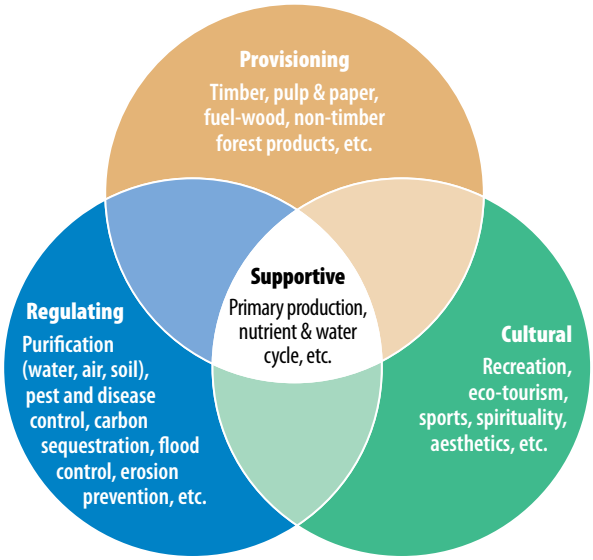
A national-scale evaluation work of the forest restoration potential based on historical landscape data (e.g., forest cover, degradation hotspots) and current trends in environmental processes and the socio-economic context of the country is essential for the subsequent planning. The process may begin with (1) mapping national policies and international commitments to ensure alignment with future FLR goals, (2) continue with compiling existing statistics and geo-referenced data, and proceed to (3) an analysis of deforestation and degradation drivers.

Furthermore, it can help clarify (4) which ecosystem services should be prioritized for support by the strategy to ensure benefits for communities. Figure 3 shows examples for different regulating, supportive, cultural, and provisioning ecosystem services. In this context, it is also recommended that the definition of "forest" is clearly stated within a national strategy for forest restoration, taking into account geographic and climatic conditions, and, where appropriate, aligned with the Food and Agriculture Organization of the United Nations (FAO) criteria[3]. This is important e.g., for legal clarity, cross-sectoral alignment, land use planning, targeted funding, and for setting appropriate interventions.

Some of these steps may already be part of routine procedures, such as forest inventories or related assessments, and therefore may not require repetition specifically for an FLR strategy. Otherwise, by following the steps described in Table 1—from policy mapping to data synthesis—teams can develop a baseline that informs realistic restoration targets and strategies.

Figure 3:

Different categories and examples of Ecosystem Services



3 https://openknowledge.fao.org/server/api/core/bitstreams/a6e225da-4a31-4e06-818d-ca3aeadfd635/content.

Table 1:

Steps to understand the national forest restoration context

ACTIVITY	DESCRIPTION	TOOLS AND SOURCES
1 **Policy & Planning Alignment**	Map national policies, development plans, and international commitments, e.g., National Determined Contributions, Aichi Targets, and Bonn Challenge commitments, etc. to align future FLR goals with those.	Relevant databases: *Bonn challenge pledges*[4] *Aichi Biodiversity Targets*[5] *Nationally Determined Contributions Registry*[6]
2 **Desk Review & Data Compilation on Forest Cover and Degradation Hotspots**	Preparation of summary maps and tables derived from e.g., national forest statistics, land cover and use maps, remote sensing imagery, and land degradation assessments to identify current forest cover, historical deforestation trends, and degradation hotspots.	The *European Union Observatory on Deforestation and Forest Degradation*[7] provides first insights on forest cover, forest cover change and drivers of deforestation. National-level, higher-resolution data (from national forest inventories, specific remote sensing analyses, or local ground-truthing) is crucial for detailed planning.
3 **Socio-Economic Driver Analysis**	Identify and analyze root causes of degradation (such as agricultural expansion and illegal logging) through e.g., structured stakeholders' platforms, focus group workshops, review of land tenure records and/or social indices (such as poverty, food security, etc.).	National statistical offices (for poverty, food security data), land registries, academic studies, local community organizations, reports from Non-Governmental Organizations (NGOs) working on land rights or rural development.
4 **Prioritization**	Prioritize landscapes based on their relevance for the provision of co-benefits (e.g., biodiversity conservation, water security, carbon sequestration, livelihood improvement).	Multi-Criteria Analysis frameworks, GIS-based (Geographic Information System) spatial analysis for overlaying different benefit layers, stakeholder workshops for weighting criteria and validating priorities, scientific literature, national biodiversity assessments, climate vulnerability maps, expert consultations.

4 Available from the International Union for Conservation of Nature (IUCN) website regarding the Bonn Challenge: https://www.bonnchallenge.org/pledges: https://bonnchallenge.org/pledges.

5 Available from the website on Convention on Biodiversity of the UN Environment Programme: https://ort.cbd.int.

6 Available from NDC Registry at the UNFCCC website: https://unfccc.int/NDCREG.

7 Available from the EU Forest Observatory website: https://forest-observatory.ec.europa.eu/forest/tmf.

2.1.2. Learning from past FLR initiatives

Before developing new strategies, it is crucial to compile and review experiences from past FLR projects implemented in the country. In many cases, a variety of organizations—including government agencies, NGOs, and international donors—have already conducted several cycles of restoration projects and have gained valuable knowledge regarding feasibility, challenges, and success factors. A structured review of these efforts helps avoid duplication, builds on existing experience, and enhances strategy quality. To facilitate this process, a "Green Table" meeting may be organized before each new major FLR initiative. This format gathers key actors around one table to promote knowledge exchange, coordinate efforts, and ensure a smooth transfer of know-how.

2.1.3. Identify key strategic and operational challenges and opportunities

The development of strategies includes identifying key challenges and opportunities, clarifying the logic of intervention, and setting clear spatial and thematic priorities. It provides a reference for:

- Integrating restoration into existing land use, forestry and climate policies.
- Clarifying roles and responsibilities among stakeholders.
- Ensuring functional and spatial coherence of work done on local level.
- Coordinating local work and planning, by this optimizing use of resources and efficiency of restoration work.
- Mobilizing financial and technical resources.
- Establishing consolidated support/advisory service (protection, planning, funding) for local stakeholders, and
- Establishing efficient mechanisms for learning, adaptation, and long-term monitoring.

Consequently, a holistic FLR strategy needs to integrate two interlinked strategical approaches:

- Functional approaches address the enabling environment needed to support FLR implementation. These include governance and institutional arrangements, financing mechanisms, staffing and capacity development, infrastructure, facilities, and procurement strategies.
- Implementation (operational) approaches: These define the technical pathways for successful FLR. They provide clarity on e.g., specific areas suitable for FLR, priority-setting based on feasibility, stakeholder engagement, resource availability, complementarity, and expected sustainability.

Strategic planning creates complementary systems at the national, regional, and local levels, which is crucial for landscape-scale restoration. Without such systems in place, there is a high risk of underperformance, dispute and inefficiencies. At the national level, strategic planning creates coherence across ministries and sectors, aligns policies, and enables overall coordination. At the local level, it ensures that restoration goals are grounded in the realities of communities and ecosystems, producing more legitimate and sustainable interventions.

Distinguishing between strategic and operational planning is crucial in forest landscape restoration, as each serves a different but complementary purpose. Strategic planning defines the overarching vision, goals, and frameworks that guide restoration efforts. In contrast, technical planning translates these ambitions into concrete actions—such as localization, species choice, and implementation methods. Table 2 shows the different tasks undertaken within strategic and operational planning on the different hierarchical levels. The following guides (see Chapter 3) mostly help technical planning on local/regional level. The site assessment guideline is an exception, aiding strategic planning on national or regional level.

Table 2:

Differentiation between strategic and operational planning on different hierarchical levels

Decisions	Level	Strategic	Operational
Type of intervention	National	• Setting objectives • Financing • Steering restoration programme	• Technical guidelines (e.g., species selection, productivity norms, health and safety, monitoring)
	Local	• Project goals at community level • Integration of stakeholder needs (e.g., food security, income)	• Site analysis • Analysis of historical land use & drivers of degradation
Site location	National	• Macro-level planning: land availability and suitability maps (climate, soil, tenure) • Macro-level economic and environmental (connectivity) planning	• National data layers (soils, climate, land-use, tenure, etc.)
	Local	• Participatory planning • Accessibility • Land ownership and customary rights • Local-level economic and environmental (connectivity) planning	• Soil analysis • Topography • Site-specific threats (e.g., fire, grazing)
Choice of species	National	• Recommendations on forest types/tree groups (e.g., according to biodiversity goals or climate adaptation)	• National catalogues of forest types/ species and guidelines for their suitability
	Local	• Species pre-selection in accordance with ecosystem services (shade, erosion control) • Culturally relevant species	• Specific species selection • Planting recommendations for site and purpose planting timeline • Site-specific monitoring plan
Implementation	National	• Overall coordination and implementation of the strategy • National steering groups • Action plans • Information flows • Monitoring plans	• Management of regeneration material production, network of nurseries • Provision of central advisory services • Delivery of training and capacity to the local level • Monitoring assessment and evaluation
	Local	• Local project governance	• Implementation of the restoration work • Reporting to the national level

Once goals are defined, a national FLR strategy should clearly outline how to overcome key barriers. Based on this, the specific SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) restoration objectives of the FLR are set (see Section 2.2). Therefore, different strategic alternatives are identified and compared using criteria that consider ecological impact, resilience, risk, financial feasibility, and stakeholder support. The full range of relevant FLR intervention types—such as natural regeneration, assisted regeneration, agroforestry, afforestation with native or climate-resilient species, and urban/peri-urban greening should thereby be considered. Only by reflecting diversity, strategies achieve a holistic and context-sensitive restoration approach.

2.2. Set SMART FLR Specific Objectives

SMART objectives are the specific, measurable steps that collectively achieve the broader strategic goals. The objectives must directly contribute to the overarching national FLR vision and must align with the established FLR principles. Objectives must clearly define *what* will be achieved, *by how much*, *where*, and *by when*, using quantifiable metrics or verifiable indicators where possible, and always establishing a clear baseline (Table 3). Ensure the objectives are realistic given available resources and capacities, yet challenging enough to drive significant progress, while maintaining direct relevance to the strategy's core purpose.

Table 3:

Examples of SMART specific objectives for different strategic goals

Goals	Formulation of specific objective (examples)	SMART checklist
Extend forest cover	By 2030, restore and increase forest cover by 15% (equivalent to 250,000 hectares) in identified priority degraded landscapes through a mosaic of natural regeneration and assisted planting, contributing to the national climate change mitigation targets.	• **Specific**: e.g., 15% increase, 5 key indicators, 50 groups, €100 million • **Measurable**: e.g., quantifiable percentage, hectares, numbers, monetary amount • **Achievable**: Assumed feasible within the national context (adjust numbers as needed) • **Relevant**: e.g., directly contributes to forest cover increase, focus on biodiversity, social equity, financial sustainability • **Time-bound**: specified deadlines
Increase biodiversity	By 2035, reestablish viable populations of at least 5 key native forest species (e.g., specific tree species, ground flora, or endemic fauna) in 75% of restored priority areas, as evidenced by ecological monitoring surveys.	
Community engagement and empowerment	By 2027, establish and capacitate at least 50 community-based forest management groups in priority restoration landscapes, ensuring 70% effective participation of women and marginalized groups in decision-making, measured by participation rates in meetings and project governance structures.	
Resource mobilization	By 2029, mobilize an additional €100 million in public and private financing for FLR initiatives, representing a 30% increase in the national FLR budget compared to 2024 levels, tracked through national budgetary reports and donor agreements.	

Turning broad restoration ambitions into SMART targets can benefit from a structured and collaborative process. Tools like the Logical Framework (Team Technologies 2005) may be used to guide this work, and to further refine drafted targets by clearly distinguishing between overarching objectives, outcomes, and outputs.

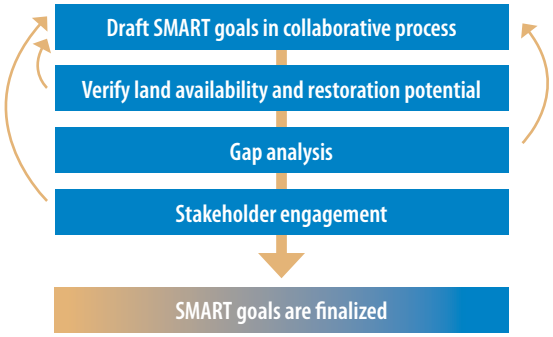
The feasibility of the drafted SMART goals can then be verified in several steps:

1. **Land Availability:** This step seeks to establish whether sufficient land with high restoration potential is available (physically and legally) to implement the drafted goals. Guidance on how to assess land suitability is provided in Chapter 3.1.
2. **Institutional Gap Analysis:** It may be necessary to assess existing institutions' capacity to implement the planned FLR strategy. This step can include identifying training needs or considering the creation of new institutions at either the steering or implementation level.
3. **Local Stakeholder Engagement:** This step ensures that Local Communities and Indigenous Peoples (LCIP) are informed and involved. It also helps to ensure that no harm results from the implementation of the FLR goals. The CIFOR guide "Participatory Tools for Forest Communities"[8] provides an overview of various tools, discussion of concepts, and guidance in the selection and use of participatory tools for engaging LCIP.

If any of these verification steps indicate that the drafted goals are not feasible or appropriate, the objectives may need to be revised. Revisions can occur across several iterations as new insights emerge. Figure 4 illustrates the verification process and the possible feedback loops involved. This systematic approach ensures that FLR targets are both ambitious and feasible, with a clear roadmap for measurement and accountability.

Figure 4:

Process to verify feasibility of SMART goals



8 Available for download at CIFOR: https://www.cifor-icraf.org/publications/pdf_files/Books/BKristen0601.pdf.

2.3. Implementation of a Strategy – Blueprints for Action

A national FLR strategy becomes actionable through a well-structured implementation blueprint – a detailed plan of action. This blueprint ensures that strategic goals are translated into coordinated field activities, supported by appropriate institutions, financing, capacity, and feedback systems (Figure 5).

Figure 5:

Overview of components and activities for implementing FLR Strategies, with "Knowledge, Learning and Risk Impact" interacting across all areas

COMPONENTS	Institutional setup and coordination	Prioritization and landscape planning	Operational planning	Resource mobilization and financing	Capacity development	Stakeholder engagement
	Knowledge, Learning, Risk Management					
ACTIVITIES	Establish bodies; assign mandates	Landscape assessment (see Chapter 3)	Create action plans and workstreams	Map funding sources; design instruments	Train local actors; establish knowledge transfer	Establish participatory mechanisms

The most common modular blueprint for an FLR strategy includes the following seven components:

1. **Institutional setup and coordination** to establish effective leadership and coordination structures considering the following key actions:
   - Form a cross-sectoral National FLR Steering Committee with representatives from forestry, agriculture, environment, finance, and Indigenous Peoples' organizations.
   - Define legal mandates, coordination protocols, and inter-agency communication mechanisms.
   - Create/assign regional and local FLR units, embedded in existing institutions where possible, responsible for day-to-day planning and stakeholder engagement.
   - Develop a national FLR charter or protocol to guide collaboration.
2. **Prioritization and landscape planning** to focus resources where impact is highest:
   - Use national-level suitability mapping (soil, climate, tenure, degradation hotspots) to shortlist landscapes.
   - Apply socio-economic filters (poverty, food insecurity, local demand) to identify FLR priority zones.
   - Select FLR intervention types for each zone (e.g., natural regeneration, agroforestry, reforestation).
   - Use participatory planning methods to incorporate local knowledge and validate land-use history.
3. **Operational planning** to translate priorities into time-bound, budgeted workplans:
   - Develop national and regional FLR action plans with specific objectives, indicators, budgets, timelines, and institutional responsibilities.
   - Build in flexibility to revise plans based on monitoring results or evolving risks.

- Use logframes or Gantt charts to coordinate parallel workstreams.
- Ensure alignment with climate, biodiversity, and land use policies.

4. Resource mobilization and financing to secure sustained financial support:

- Estimate lifecycle costs (planning, planting, maintenance, monitoring).
- Prepare a national FLR financing strategy including:
  - Domestic budget allocations (e.g., forestry, rural development).
  - International finance (REDD+, GCF, GEF, Adaptation Fund).
  - Public-private partnerships and green bonds.
  - Payment for ecosystem services (PES) schemes.
- Establish transparent fund management and disbursement channels.

5. Capacity development and technical support to build the skills, knowledge, and infrastructure needed for implementation:

- Conduct national and regional training needs assessments.
- Develop FLR training modules for different audiences (community facilitators, extension workers, nursery managers).
- Support the development and scaling of climate-resilient nurseries, including seed collection, storage, and propagation.
- Engage with international platforms for technical cooperation and knowledge transfer.

6. Stakeholder engagement and social safeguards to ensure legitimacy, inclusiveness, and local ownership:

- Set up multi-level participatory planning processes (e.g., landscape forums, FLR councils).
- Develop Free, Prior and Informed Consent (FPIC) protocols for work on Indigenous or customary lands.
- Design grievance mechanisms and gender-sensitive safeguards.
- Offer livelihood incentives aligned with restoration goals (e.g., tenure security, access to non-wood forest products, employment in FLR).

7. Knowledge, learning, and risk management to support adaptive implementation and avoid harm:

- Establish baselines for ecological and social indicators before implementation.
- Build feedback loops using digital and community-based monitoring tools.
- Conduct risk assessments for social conflict, climate variability, tenure disputes, and ecological failure.
- Use mid-term reviews to adjust goals and activities.
- Create a digital FLR knowledge hub and promote an annual national FLR learning forum.

All these components need to be approached in an integrative manner. For example, one of the most common reasons for failure in FLR implementation is the lack of long-term ownership after external funding ends. Many restoration projects collapse or degrade within a few years because no institution or stakeholder remains responsible once donor support or subsidy programs are exhausted. Therefore, a robust Blueprint for Action must include clear long-term institutional anchoring, sustainable financing mechanisms, and legal or contractual arrangements that define ongoing responsibilities. Without this, even technically successful FLR interventions risk becoming short-lived. Embedding restoration within existing governance frameworks and budget cycles can significantly improve long-term viability. This helps to provide clarity on how to turn strategic intent into measurable impact.

Blueprint for Action – *an example:*

The forest landscape restoration programme in Vietnam (Quang Tri Province), defined very specific actions such as assisted natural regeneration, improved Acacia plantation management, and upland soil conservation. This helped allocate clear responsibilities to local authorities, cooperatives, and communities, and made is possible to support the process by a monitoring system tracking biodiversity and livelihood outcomes. In addition, the blueprint also included adaptive feedback loops to revise actions based on field experience.

Source: Rizzeti *et al*., 2018.

2.4. Monitoring and Evaluation Framework

2.4.1. Developing indicators

To track the performance of the strategy, it is advisable to develop an indicator and monitoring framework—matrix tailored to the strategy's specific interventions, outputs, and outcomes[9]. Such a matrix, in addition to the monitored activity/output or outcome, should include specific indicator, related metrics, monitoring frequency, data sources, responsibilities for monitoring, and target values or thresholds.

2.4.2. Reporting and adaptive management

To maintain transparency and drive continuous improvement, it is recommended that regular progress updates are provided to the steering committee of the FLR strategy to ensure that decision-makers are kept informed of milestones achieved and challenges faced. A comprehensive annual report on key achievements and lessons learned should be prepared for the public. To ensure the strategy remains effective, a mid-term evaluation of the national FLR programme should be conducted to review its overall performance.

2.4.3. Learning and knowledge management

To foster continuous learning and ensure best practices are shared widely, a central knowledge hub may be established. This hub can serve as a repository for practitioners to access resources and contribute their own experiences. Complementing the hub, an annual FLR meeting may bring together restoration practitioners, government representatives, researchers, and community leaders to exchange lessons learned, showcase pilot successes, and explore innovative approaches. Examples of forest restoration digital platforms include the website developed by CIFOR (Evans and Guariguata 2019)[10] and the UNECE's forest landscape restoration hub[11] .

9 https://land.unece.org/forests/en/knowledge-hub/criteria-and-indicators-for-sfm.

10 https://www2.cifor.org/feature/restoration/#.

11 https://land.unece.org/forests/en/knowledge-hub/forest-landscape-restoration.

3. Technical Guidelines for Forest Landscape Restoration Implementation

3.1. Guidelines for Selecting Areas for Restoration Sites

3.1.1. Introduction

Forest landscape restoration is a vital strategy for tackling biodiversity loss, land degradation, and climate change. Selecting appropriate sites is essential to ensure high survival rates of planted vegetation, enhance ecosystem functions, and create positive socio-economic impacts. This guideline outlines a step-by-step approach to identifying high-potential areas for planting activities.

3.1.2. Planning the assessment

3.1.2.1. Defining the scope

The first step in planning a forest and landscape restoration (FLR) project is to define the scope of the intervention. This involves establishing its geographical boundaries—whether based on natural features, administrative divisions, accessibility, land ownership, or a combination of the above—determining the project timeframe, assessing the available budget, and evaluating the availability of human resources at both national and local implementation levels.

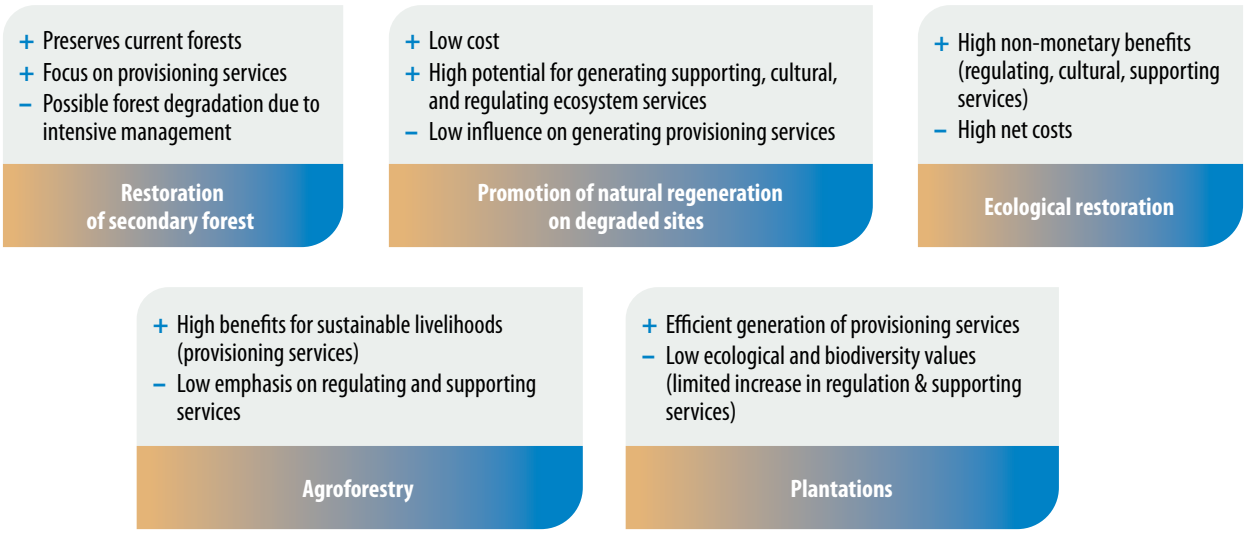
3.2.2.2. Defining types of intervention

FLR activities should be based on the objectives and strategies defined for the restoration project. These will determine which types of intervention are suitable for the project. The selection of site-specific FLR interventions, such as assisted natural regeneration, plantations or agroforestry, should be guided by the needs and preferences of stakeholders, provided they remain within the framework of the overarching strategy. Engagement with local actors can provide valuable insights into planting approaches that have proven effective in the past and help identify co-benefits considered most relevant by the communities involved. Figure 6 presents typical examples of interventions and their respective co-benefits.

Once interventions have been identified, their potential effectiveness can be assessed by reviewing similar past interventions in the area. Understanding the reasons behind their success or failure helps inform the new project's design. Where success factors are evident, these may be incorporated, while identified challenges can guide adjustments or lead to alternative approaches.

Figure 6:

Examples of different FLR interventions and their impact on ecosystem services (cultural services are not considered)



3.1.3. Establishing site selection criteria and indicators

After selecting the appropriate FLR intervention type(s), it is recommended to define measurable criteria to evaluate the suitability of deforested or degraded sites for FLR projects. These criteria should assess the specific characteristics of the site and consider the objectives of the project. The following list provides examples for criteria that help evaluate land suitability for FLR interventions:

1. Biophysical Criteria
   - Soil and water conditions (soil fertility, depth, and erosion levels, water availability).
   - Climate compatibility (temperature, precipitation, extreme weather risks).
   - Topography (slope, elevation, and aspect).
2. Land Tenure and Governance
   - Clear land tenure.
   - Owners/managers interest and support.
   - Legal and policy support (alignment with national or sub-national regulations and land-use plans).
   - Institutional capacity (presence of organizations or authorities capable of supporting project planning and monitoring).
3. Socio-Economic Factors
   - Community interest and participation.
   - Current land use and livelihoods (compatibility of FLR goals with existing uses such as agriculture, grazing, or resource harvesting).
   - Economic viability (potential to generate income, improve ecosystem services, or reduce restoration costs over time).
   - Labour and infrastructure access.
4. Environmental and Biodiversity Goals
   - Conservation priority: Location overlaps with areas of high biodiversity value or conservation interest.
   - Potential for ecosystem service enhancement: Opportunity to improve services like water regulation, climate mitigation, or soil fertility.
   - Landscape connectivity (potential to reconnect fragmented habitats and support wildlife corridors).

The criteria selected and the level of detail used in the analysis depend on the spatial scale (national, landscape, or local) and the availability of data and resources. A tailored **'suitability profile'** can be developed by defining the optimal conditions for each type of intervention for each criterion. Criteria can be weighted differently depending on the intervention type and categorized as "must haves" or "nice to haves".

3.1.4. Mapping and identifying sites

Once criteria are defined, all potential areas within the project scope may be assessed using GIS tools, land registries (cadastre), statistical data and/or other tools, like participatory mapping (Corbett 2009) involving local communities. This process generates overview maps and tables that identify areas matching the suitability profiles of the different intervention types.

For the areas matching the suitability profiles it is recommended that a risk assessment identifies potential threats that may come up during the project's lifetime, evaluates their likelihood and impact, and proposes strategies to address them. Key risk areas include land use history, environmental and social factors, and governance:

1. Land Use History
    - Potential risks: Disputes over previous ownership or tenure, environmental degradation (e.g., soil contamination), and the need for extensive site preparation.
    - Possible mitigation strategies: Review land records and consult local stakeholders, conduct baseline environmental assessments.
2. Environmental Risks
    - Potential risks: Climate variability, fire risk, flooding or erosion, pests and diseases, and invasive species.
    - Possible mitigation strategies: Develop climate-adapted plans, integrate firebreaks, erosion control, and pest monitoring.
3. Social Risks
    - Potential risks: Community reliance on land, illegal land use, unclear tenure, and stakeholder conflict.
    - Possible mitigation strategies: Engage stakeholders regularly, define land use agreements, offer alternative livelihoods and monitor land use.

4. Division of Responsibilities
    - Potential risks: Undefined responsibilities, insecure funding, lack of sustainability, absent monitoring plans.
    - Potential mitigation measures: Establish a governance structure; draft a management plan, offer capacity-building, ensure fair access to restoration benefits.

A summary risk table can be a useful tool for decision-makers in the assessment of suitability or non-suitability of a specific site.

3.1.5. Prioritization opportunities

If more suitable areas are identified than can be considered for the FLR project, strategic prioritization may consider the following criteria (their importance may vary according to local conditions):

- Risk of further degradation or deforestation.
- Urgency (e.g., severity of erosion).
- Potential to address underlying drivers of forest loss.
- Opportunities to enhance ecosystem connectivity.
- Cost value for money.
- Interest, stakeholders support.
- Availability of funding.

Once the most promising areas for FLR projects have been found, the individual areas are examined more closely to develop planting designs and select species (see Chapter 3.3) that suit their individual circumstances.

3.2. Guidelines for Species Selection and Planting Techniques

3.2.1. Introduction

The positive effects of forest restoration, such as erosion prevention, carbon sequestration, agroforestry, urban and semi-urban greening, and wind or coastal protection, can be maximized by selecting appropriate tree[12] species. Furthermore, the intended use of the trees has implications for planting design and care practices. This guideline outlines practices for species selection and planting techniques applicable across diverse ecological zones and socio-economic contexts.

3.2.2. Species selection

3.2.2.1. Site assessment

Before selecting species or determining appropriate planting methods, it is crucial to assess the site's biophysical and socio-economic conditions. Although many site characteristics may have been evaluated during the initial site selection process (see Section 3.1), further assessments are often necessary to tailor planting techniques and species combinations to the local or even site context. Project planners should identify key factors—such as relief, soil types and contamination, salinity, wildlife presence, surrounding land uses and site exposure to wind or frost—that influence species suitability and planting design. The examples below illustrate how certain assessments are linked to particular environmental settings:

- Mountainous areas: erosion assessments, slope stability checks, evaluation of the need for wildlife protection measures such as migration corridors or anti-poaching infrastructure.
- Pollution-affected zones: Pollution testing at multiple locations to identify variations in pollution levels and depth of pollution layers, assessment of past irrigation practices and potential for soil rehabilitation.
- Areas in and around settlements: Assessment of soil compaction, pollution levels (e.g., heavy metals), and the availability of space for root and canopy growth, evaluation of potential conflicts with infrastructure (such as underground utilities, overhead powerlines, and traffic visibility concerns).
- Floodplains: Hydrology assessments to determine water levels, seasonal flooding patterns, and soil moisture retention capacity, mapping of flood risk zones and consideration of sediment deposition rates.
- Non-arid valleys: Soil fertility and drainage tests, evaluation of exposure to wind or frost, identification of microclimatic effects.
- Arid and semi-arid zones: Analysis of water availability and rainfall variability, soil texture and infiltration capacity.
- Degraded forests: Evaluation of past land use impacts, soil organic matter content and nutrient cycles, and future conditions under climate change scenarios, assessment of existing vegetation structure and biodiversity value, and risks of invasive species or disease spread during intervention.
- Peatlands and wetlands: Groundwater table monitoring, sensitivity to drainage or fire, and need for rewetting interventions.

3.2.2.2. Purpose of the restoration activity

In addition to the site's biophysical and socio-economic conditions, the planting objective is a key factor in species selection. Depending on what the planting aims to achieve, trees must possess specific attributes to fulfil the intended function (see Chapter 2 on strategy development). Table 4 outlines which tree characteristics are most relevant for different planting goals:

12 This study refers to tree species, however, depending on the conditions bush species should be considered wherever found as better adjusted and relevant.

Table 4:

Tree attributes by primary planting objective

FLR Primary purpose	Desirable Tree Attributes
Soil Stabilization & Erosion Control	Deep, fibrous root systems, fast-growing, slope-adapted
Hydrological Regulation	High transpiration rate, tolerance to waterlogging and flooding, riparian suitability
Microclimate & Heat Regulation	Large canopy, high leaf area index, deciduous in temperate climates (allows exposure to winter sun while provides shade in the summer)
Biodiversity Habitat	Native species, structural diversity (canopy, understory), fruit/nectar/seed production
Timber & Wood Products	High wood quality, straight trunk
Fuelwood & Charcoal	Fast-growing, high calorific value, good coppicing ability
Agroforestry & Fodder	Nitrogen-fixing, light canopy, resprouting ability, edible leaves or pods for animals
Pollinator Support	Prolonged flowering, nectar-rich flowers, native associations
Carbon Sequestration	Fast-growing, dense wood, long-lived, resistance to pests and drought
Cultural & Aesthetic Values	Iconic species, traditional use, visual appeal
Invasive Species Control / Buffering	Dense growth, fast canopy closure

Priority should be given to native species that support local biodiversity, are well-adapted to prevailing climatic conditions, and deliver essential ecosystem services. In some cases, carefully selected non-native species may be considered—particularly if they are better suited to projected future climate conditions and pose no risk of becoming invasive.

Historical habitats for certain species may become unsuitable due to climate change. The viability of these habitats is significantly influenced by the specific climate change scenario, which underscores the need for flexible, long-term planning. Consequently, when selecting tree species to adapt to climate change, it's crucial to consider the suitability of habitats under various climate change projections (Chakraborty *et al.* 2021).

Tools such as Seed4Forest[13] map the vulnerability of tree species to future climate conditions, recommend optimally adapted species for specific sites, and provide information on seed sources for afforestation and reforestation from regions that are already experiencing the projected future climate of the planting site. However, care must be taken to balance the selection of species adapted to future conditions with those suited to current site realities—particularly in light of the expected lifespan of the planted stands. In practice, this may involve combining species with different climate sensitivities or selecting transitional species that can tolerate both current and near-future conditions.

3.2.3. Species composition

Species and seed source selection should prioritize ecological integrity by aligning with the site's potential natural vegetation and structural characteristics. References such as the European Forest Types (Portoghesi 2006) can support the identification of suitable compositions. Promoting structural diversity—through variation in canopy layers, age classes, and spatial patterns—and planning for natural successional dynamics strengthens ecosystem resilience and long-term functionality. Other important factors to consider when selecting species and seed sources include growth rate, longevity, maintenance requirements, local community preferences, and relevant legal or certification standards.

13 Available from Federal Research and Training Centre for Forests, Natural Hazards and Landscape https://seed4forest.org.

3.2.4. Planting techniques

Proper planting techniques involve a range of considerations (Figure 7), each of which can significantly affect the project's timeline and budget[14].

Figure 7:

Aspects of implementing a tree planting project

1. **Site preparation** is the first crucial step. This may include clearing weeds, digging planting pits, and adding compost or mulch where necessary to create favourable conditions for seedling survival and growth.
2. **Spacing** must be carefully planned. Distance requirements vary by tree species and should align with the ecological goals of the project—whether it's timber production, habitat restoration, or carbon sequestration. Proper spacing supports plant health, reduces competition, and allows for long-term canopy development. It also enables accurate calculation of the number of seedlings needed, which directly affects procurement, logistics, and budgeting. In addition, spacing must account for safety—maintaining appropriate distance from infrastructure such as power lines, underground pipes, roads, and buildings.
3. **Protection measures for seedlings** may be necessary depending on local risks and available resources. These can range from individual tree guards to fencing entire planting areas to safeguard against grazing, theft, trampling, or wildlife damage.
4. **Community involvement and labour planning** are key to ensuring smooth implementation. Organizing trained planting teams or mobilizing community volunteers requires early coordination, especially when working in remote areas or under tight seasonal windows. Roles and responsibilities should be clearly defined to avoid delays and ensure quality standards are met.
5. **Ongoing maintenance**—such as watering, mulching, weeding, and pest control—is (depending on the location) essential during the early years to support seedling survival and healthy growth. Maintenance efforts should be scheduled and resourced in advance, especially in areas with harsh conditions or limited natural regeneration capacity.
6. **Monitoring and adaptive management** are crucial for tracking progress and making necessary adjustments. Regular monitoring helps assess survival rates, growth performance, and potential threats like pests, disease, or vandalism. Where outcomes differ from expectations, adaptive management should be applied to revise methods or inputs. Monitoring tools such as AURORA[15] (World Resources Institute and FAO, 2022) can support to set up a system for consistent data collection and reporting.

14 FAO's Sustainable Forestry Management toolbox offers a detailed guide and training manual for tree planting: https://www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/zh/c/218089/.

15 See https://auroramonitoring.org.

3.3. Guidelines for Tree and Shrub Seedlings Production

3.3.1. Introduction

Seedling production requires a long-term perspective. Planning must account for the time it takes to grow seedlings to a suitable size for planting. The critical element for the feasibility of FLR projects is the capacity to produce the right trees (as outlined in Chapter 3.2) at the right time. The guidelines refer, on one hand, to the strategic planning process of seedling production to meet FLR strategic goals and objectives, and on the other hand, to the common operational techniques, procedures, and safety requirements related to the production of forest reproductive material (FRM) in nurseries.

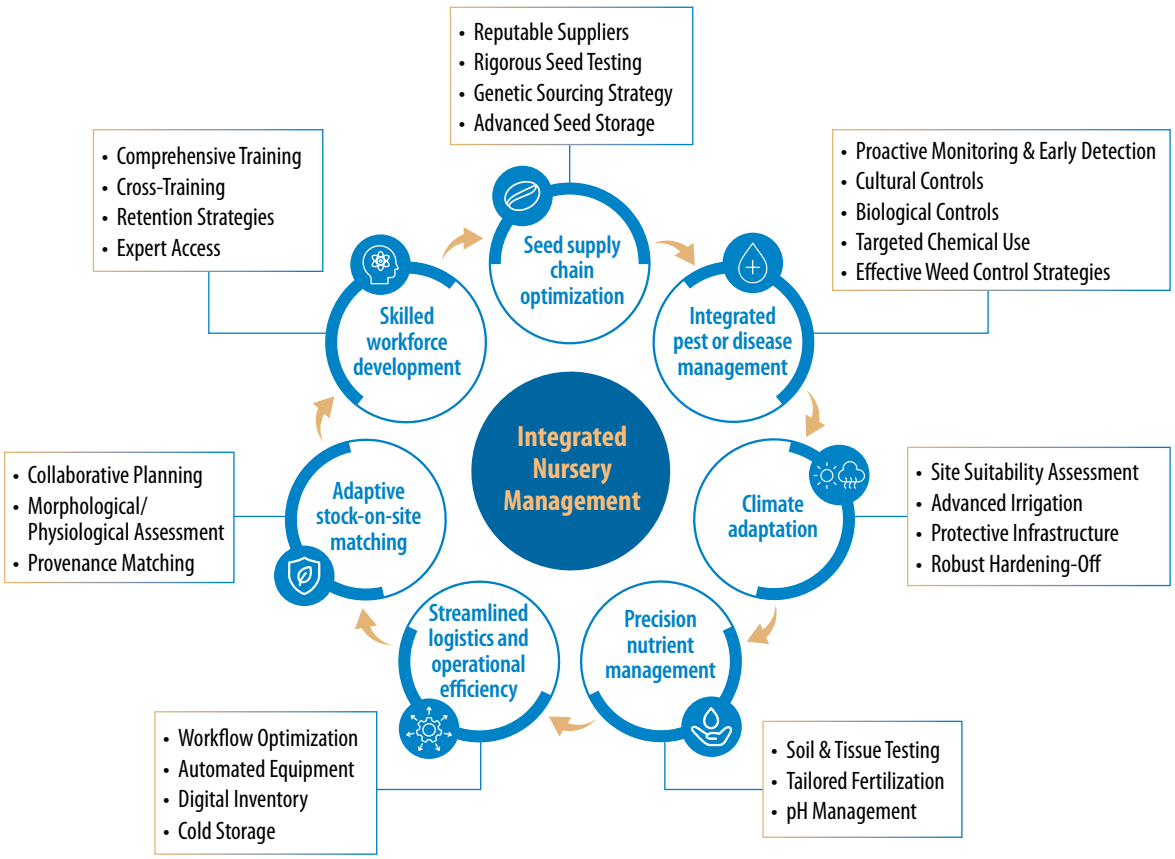
3.3.2. Strategic planning: Integrated Nursery Management

The European Forest Strategy 2030 (European Commission, 2021) underlines the general aim to be considered in the strategic planning of FRM production: planting and growing the right tree in the right place and for the right purpose. Consequently, the production of a steady supply of high-quality FRM needs to be tightly coordinated with both the need for seedlings and the capacity of forestry nurseries. FRM production is thus embedded in a set of strategic decisions that need to be considered, e.g., to set species assortments and yearly production capacities. Producing the required quantity of seedlings for each species cannot be accomplished from one year to the next, must be planned well in advance, considering not only the time required to produce the seedlings, but also the time needed to develop the necessary production capacities (nurseries).

Setting clear area targets, depending on land availability, and defining the purpose of afforestation projects (as outlined in Chapter 3.1) are essential for the species selection (Chapter 3.2) and thus for planning the FRM production, especially in a relatively short period. Strategic planning must cover the entire production chain and its main components, e.g., proper afforestation planning documents (function, species composition),

Figure 8:

Main components of the integrated nursery management



seed availability, seedling production capacity, planting capacity, and financial and technical support to producers.

Integrated Nursery Management (Figure 8), which is species- and local climate-dependent, involves selecting the right seed source with diverse genetics and proven provenance, customizing growing media, precisely managing nutrients, ensuring efficient irrigation, and implementing integrated pest management. Nursery infrastructure and equipment must be designed for efficiency and regularly maintained, while a skilled workforce is essential for implementing best practices. Rigorous quality control, careful handling, and proper transportation ensure seedlings reach their destination in optimal condition.

As indicated in Chapter 2, a strategic level steering committee is necessary for the co-development of the FLR projects that need to assess the current FRM production capacities; and plan, certify, coordinate and supervise the production of FRM. It is therefore recommended to consider the following aspects for the strategic planning of FRM production in the context of national scale FLR projects:

- Nursery infrastructure: Nurseries need adequate facilities, including land, water sources, greenhouses, and equipment. Expanding production capacity may require significant investment.
- Seed sources: Access to high-quality seed or other propagation material is essential. Ensuring genetic diversity and adaptability is also important.
- Community-Based Seed Production: Involve local communities in seed production to promote sustainable practices and ensure seed availability.

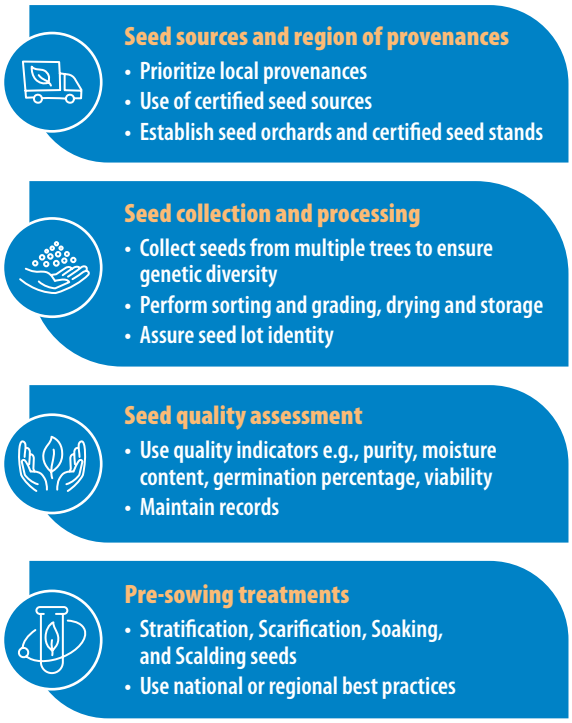
- Skilled labour: Producing high-quality seedlings requires skilled workers who understand plant propagation, pest management, and other nursery practices.
- Water availability: Modern irrigation systems for efficient water use need to be prioritized as investments, as water shortage in nurseries has proven to be a significant constraint for efficient seedling production.
- Logistics and distribution: Strategic planning can reduce the transport of seedlings to planting sites, which is time-consuming and costly, especially for large-scale projects or in remote areas.
- Climate change: Changing climate conditions can affect seedling production, making it more difficult to predict optimal growing conditions and increasing the risk of pests and diseases.

All these aspects require adequate dedicated funding to support private investors, farmers, and households in developing nursery operations for FRM production. The concentration of resources and effort as well as choosing smaller scale but well-funded and supported projects would help to improve efficiency, success, and sustainability of the undertaken measures, serving as examples and spreading good practice and knowledge.

Best local practices play a crucial role in successful seedling production. They leverage region-specific knowledge of climate, soil, and pests to ensure seedlings are well-adapted for their environment. These practices often optimize the use of local resources, making seedling production more sustainable and cost-effective. By incorporating traditional techniques for seed selection, soil preparation, water management, and pest control, local practices contribute to improved seedling quality, reduced costs, and increased community involvement. While modern techniques are valuable, integrating them with available local workforce and best local practices ensures the preservation of traditional knowledge, supports livelihood of local population and fosters environmentally sound and economically viable seedling production.

Figure 9:

Main seed management operations



3.3.3. Seed management

Seed management encompasses all activities involved in collecting, treating, and processing seeds to ensure their viability for seedlings production. Figure 9 provides general recommendations for the main seed management operations.

The geographic origin of seeds can significantly influence a tree's growth, survival, and resistance to pests and diseases. Some key recommendations can help project planner and nursery producers to assure well suited seedlings:

- Prioritize local provenances. Locally adapted trees are more likely to survive and thrive because they are already acclimated to the specific climate, soil conditions, and pest pressures of the area. Using local provenances also helps maintain the genetic integrity and resilience of local forests.
- Use of certified seed sources. Whenever possible, the use of seeds from known and documented seed sources is highly advised. It is also essential for future management and monitoring, to maintain detailed records of seed sources, including the location, elevation, and other relevant environmental data.
- Establish seed orchards and certified seed stands. Seed orchards and certified seed stands provide a reliable seed source for large-scale planting programs, and their timely establishment exemplifies long-term strategic planning for afforestation projects.
- Approach assisted migration with caution: It's important to select provenances that are predicted to have climates similar to the future climate of the planting site (see the Seed4Forest tool introduced in the previous Chapter).

High sowing quality can be ensured only with mature seeds that have been harvested in time and properly processed. Maternal tree selection generally relies on healthy and vigorous trees free from pests and diseases, exhibiting good form and growth. It is also recommended to collect seeds from multiple trees (international practices is 10–20 trees) to ensure genetic diversity and to avoid isolated trees, unless combined with seed from other local trees (EUFORGEN, 2023).

After collection, seeds undergo several crucial processing steps to ensure their viability and longevity. These steps include cleaning to remove debris and potential contaminants, sorting and grading to achieve uniformity in size and quality, and drying to reduce moisture content for safer storage, as higher moisture levels can lead to damage from heat, fungi, and insects. Additionally, maintaining a clear seed lot identity through detailed labelling is essential for tracking and managing seeds during storage, transportation, and extraction. Finally, storage conditions vary by seed type (orthodox or recalcitrant), with cool temperatures and controlled humidity being key to preserving seed viability. Assessing seed quality is an important pre-requisite of successful FRM production. There are different criteria to assess seed quality such as purity, moisture content, and germination percentage.

To encourage seeds to germinate, pre-sowing treatments recreate the natural environmental triggers that signal them to sprout. This is important because many plant and tree seeds must undergo a developmental period to overcome dormancy—internal factors that prevent germination. The specific conditions needed for this process differ widely among species; for instance, some seeds require prolonged exposure to cold and moisture, whereas others need hot, dry conditions. Depending on practical considerations like the quantity of seeds, their type, local environmental factors, and the availability of equipment, various techniques are employed to improve seed viability and accelerate germination, with stratification and scarification being the most common.

3.3.4. Bare root seedlings and containerized seedlings

Forest nursery production methods are specialized techniques used to grow tree seedlings for reforestation, afforestation, ecological restoration, and other forestry purposes. The primary goal is to produce healthy, vigorous seedlings that can survive and thrive after transplanting into often challenging forest environments. This can be done in containers, seed trays, or directly in a prepared seed bed. The choice between bare-root and containerized methods depends on factors like the tree species, planting site conditions, scale of operation, climate, budget, and desired seedling characteristics (Table 5).

Table 5:

General advantages and disadvantages of bare-root seedlings vs. containerized seedlings

Characteristics	Bare-Root Seedlings	Containerized Seedlings
Cost	• Generally lower production costs	• Higher costs: containerized seedlings require purchasing containers, specialized substrates, and often more intensive labour
Root Development	• Encourages deep, natural root systems	• The root system is largely undisturbed during transplanting vs. root binding if kept too long
Handling & Transplanting	• Requires careful handling • Limited planting window	• Easier handling • Broader time frame for planting
Storage & Transport	• Short storage life • Sensitive to drying	• Longer storage/transport periods • More robust
Establishment	• Risk of transplant shock	• Reduced transplant shock
Environmental Impact	• Lower input materials • Minimal waste	• Higher use of materials • Requires container disposal
Management Flexibility	• Less flexible, dependent on seasonal timing	• More flexible timing, can be transplanted when conditions are optimal

FLR projects involving larger-scale operations might favour bare-root seedlings due to cost and ease of handling during bulk out planting, whereas smaller-scale or urban forestry projects may benefit from the greater control offered by containerized systems. In regions with shorter growing seasons or harsher transplanting conditions, containerized seedlings might provide the extra buffer needed to ensure establishment, whereas in milder climates, the cost-effectiveness of bare-root seedlings could be more advantageous.

3.3.5. Ensuring safety in tree seedling production

Safety is crucial in tree seedling production, and international best practices emphasize comprehensive measures to protect workers. Key recommendations include thorough and regular safety training for all employees, covering equipment operation, chemical handling, and emergency procedures. A readily accessible safety manual outlining protocols and hazard communication is also essential. Facilities should maintain a well-stocked first-aid kit with trained staff, and a system for incident reporting and investigation is vital for preventing future occurrences. Regular safety inspections of equipment and facilities, coupled with strict adherence to equipment safety guidelines and preventative maintenance, are critical.

Furthermore, chemical safety is paramount, requiring careful handling, storage, and disposal of all substances, along with the use of appropriate personal protective equipment and spill response plans. Environmental safety practices should guide waste disposal and water conservation. To protect worker well-being, ergonomic practices should address repetitive tasks, while measures for sun exposure, heat stress, and dust/allergen protection are necessary for outdoor and greenhouse environments. Finally, caution with sharp objects and the use of protective gloves are always recommended. Implementing these comprehensive safety measures creates a safer work environment and minimizes risks in tree seedling production.

3.4. Pest and Disease Management for Trees and Shrubs

3.4.1. Introduction

Pests and diseases are an increasing threat to global tree and shrub health, particularly in the context of climate change and the intensification of global trade. Rising temperatures, droughts, and extreme weather events weaken the resilience of trees and shrubs, while the global movement of plant materials accelerates the spread of invasive pathogens and pests.

According to the *State of the World's Forests 2024* report by the Food and Agriculture Organization (FAO), an estimated 35 million hectares of forest are affected annually by insect pests and diseases, and around 70 million hectares are impacted by other disturbances such as wildfires and severe weather events (FAO, 2024). These figures highlight the increasing scale and frequency of forest health challenges, with climate change and global trade acting as key drivers. Invasive species, including pests and pathogens, continue to expand their range, affecting both native and commercial tree species. Just as forest fires can play a natural role in certain ecosystems, many insects and fungi are endemic components of forest dynamics. Especially in contexts where re-naturalization is the objective, pest and disease management should carefully consider the ecological function of these factors. Interventions should avoid disrupting natural processes unnecessarily and distinguish between harmful outbreaks and normal ecological interactions. A nuanced approach helps to maintain ecosystem balance while still addressing genuine threats to forest health.

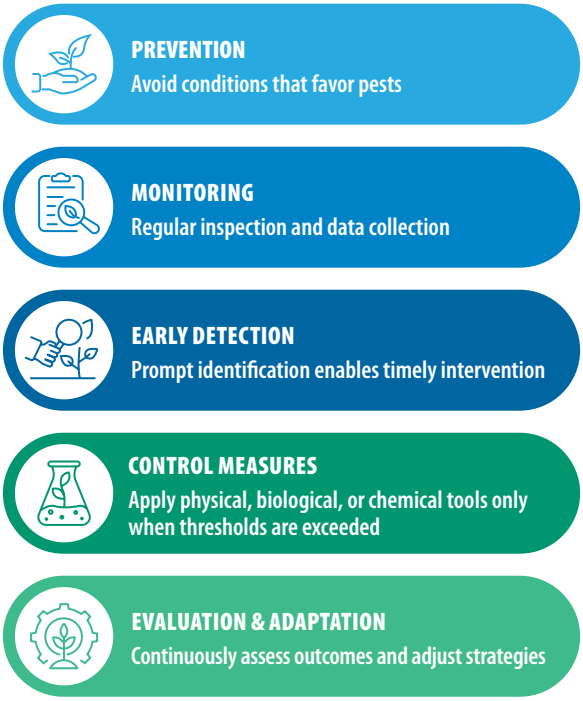
3.4.2. Guiding principle: Integrated Pest Management

In response to the increasing frequency and scale of pest and disease outbreaks, forest health strategies have evolved beyond reactive approaches. In the past, the standard response often involved aggressive application of chemical pesticides. However, it has become evident that such short-term solutions are not sustainable and can lead to long-term ecological harm.

As a result, Integrated Pest Management (IPM) has become the globally recognized standard. While not a new concept, IPM (Figure 10) represents a holistic and sustainable framework that integrates biological, physical, and, where necessary, chemical control methods to manage pests and diseases effectively. It emphasizes prevention, monitoring, and targeted intervention, aiming to minimize environmental impact while maintaining forest health and resilience.

Figure 10:

Steps in Integrated Pest Management



3.4.3. Prevention: the first line of defence

A key element of IPM is prevention. The ecological foundation established during the design, species selection, and planting phases will shape a forest's vulnerability or resilience for decades to come. Poor planning and a lack of species diversity create conditions in which pests and diseases can thrive once climate stressors or pathogens appear.

Given the uncertainty of how climate change will impact future habitats, the effective strategy must support variability—in species, genetics, and stand structure. The focus should not be limited to diversity of tree species but should be systemic and include other elements of the ecosystem—flora and fauna—which together contribute to ecological stability and natural pest regulation. A heterogeneous forest system provides a buffer against unpredictable environmental stresses and helps build long-term ecosystem resilience.

For example, silvicultural planning in Germany's state forest of Rhineland- Palatinate[16] proactively embraces species diversification to mitigate risks from climate change, pests, and diseases.

Their strategy includes promoting mixed forests, prioritizing natural regeneration of native species, and introducing carefully selected drought-resistant species to create more climate-resilient forests.

Figure 11 provides examples of how low species diversity has led to severe forest damage caused by pests and pathogens.

Figure 11:

Lessons from history in Integrated Pest Management

CASE	DESCRIPTION	LESSON
Rubber Tree Blight – Brazil	In the 1920s, over **50,000 ha of rubber plantations were destroyed by leaf blight** (*Microcyclus ulei*)	Monocultures in the native range resulted **in catastrophic loss**
Bark Beetles – North America	**104 million ha damaged by beetle outbreaks** in the temperate zone (until 2020)	Rising pest damage during climate change **highlights vulnerability of plantations**
Norway Spruce Dieback – Central Europe	Since the 2000s, over **400,000 ha of spruce forest in Germany lost to drought and bark beetles**	**Short-sighted management and poor species choice** lead to extreme vulnerability

16 https://www.wald.rlp.de/klimakrisewaldrlpde.

3.4.4. Species selection, site preparation, and nursery hygiene

Forest planners should prioritize climate-adapted and pest-resistant tree and shrub species that are well suited to the ecological conditions of the site. The use of genetically diverse and locally adapted provenances increases resilience to pests and environmental stress. Large-scale monocultures should be avoided, as they are particularly vulnerable to pest outbreaks and the spread of pathogens, unless they represent a natural forest formation (e.g., native single-species stands occurring under specific ecological conditions).

Site preparation and planting practices also play a vital role. Proper spacing, attention to soil health, and ensuring adequate drainage/watering all help reduce plant stress and the likelihood of pest establishment.

Nursery hygiene and quality assurance are critical for long-term forest health. Nurseries must be able to trace the origin of the seeds or cuttings they are working with to ensure genetic quality and phytosanitary safety. This is best guaranteed by sourcing from internationally certified nurseries—for example, those certified under the Forest Stewardship Council (FSC) or other recognized schemes—which follow robust protocols for seed handling, documentation, and pest prevention.

Together, these preventive measures lay the groundwork for healthy, pest-resilient forests and landscapes—ensuring that trees begin their life cycle with the best possible conditions for long-term survival and ecological function.

3.4.5. Monitoring and early detection

Effective surveillance is critical for IPM. Combine field inspections, remote sensing, and community involvement to ensure timely response. The sheet on Figure 12 shows an example for a forest pest and disease monitoring report.

Figure 12:

Example of a forest pest and disease monitoring report

Best Practice Example for a Forest Pest and Disease Monitoring Report

1. General Information

- Date:.....
- Inspector Name(s):.....
- Location:.....
- GPS Coordinates:.....

2. Tree Condition

- Tree Species Affected:.....
- Type of pest known: (☐ Yes / ☐ No).....
- Signs of Damage: (☐ None / ☐ Discolored Leave / ☐ Leaf Loss (%:_____) / ☐ Cracked Bark / ☐ Holes in Bark / ☐ Fungus growth)
- Other Observations:.....

3. Monitoring Actions

- Visual Inspection: (☐ Yes / ☐ No)
- Insect Traps Used?: (☐ Yes / ☐ No)
- Samples Taken for Testing?: (☐ Yes / ☐ No)
- Photos Taken?: (☐ Yes / ☐ No)

4. Risk Assessment

- Spread of Issue: (☐ Isolated / ☐ Scattered / ☐ Widespread)
- Tree Health Impact: (☐ Low / ☐ Moderate / ☐ High)
- Likelihood of Further Spread: (☐ Low / ☐ Moderate / ☐ High)

5. Next Steps

- Further Monitoring Needed?: (☐ No / ☐ Yes, Frequency: .....)
- Control Measures Recommended: (☐ None / ☐ Pruning / ☐ Chemical Treatment / ☐ Remove Infected Trees)
- Report to Authorities?: (☐ No / ☐ Yes, To: .....)

6. Notes and Next Inspection Date

- Additional Notes:.....
- Next Inspection Date: .....

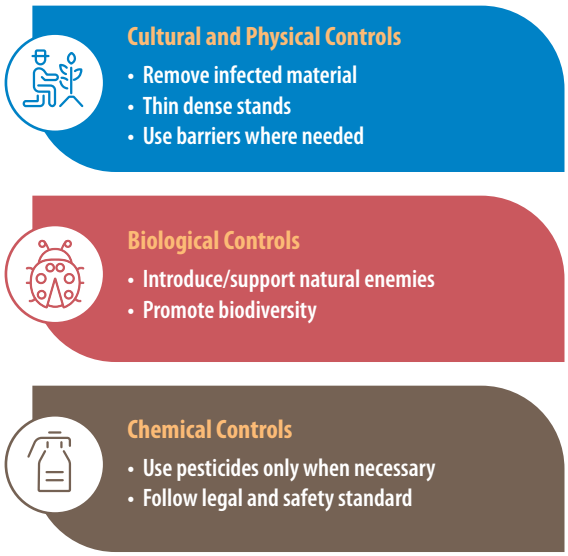
Inspector Signature :

3.4.6. Control Methods

Effective pest and disease control requires a balanced and adaptive approach. As visualized in the accompanying diagram, IPM applies a combination of physical biological, and chemical controls—each serving a distinct role in limiting outbreaks while maintaining ecosystem health (Figure 13).

Figure 13:

Classification of the main control methods in Integrated Pest Management



Physical Controls: Cultural and physical measures are the first line of intervention. These include the removal of infected plant material, thinning dense stands to improve air circulation, and the use of physical covering and barriers to prevent pest access. These practices directly reduce pest habitats and slow the spread of infections.

Biological Controls: Biological control relies on nature's own regulatory mechanisms. By introducing or supporting natural enemies such as competitive mycelium, predatory insects, or by enhancing landscape biodiversity, pest populations can be managed sustainably and without chemical inputs. Biodiverse systems are naturally more stable and less prone to large-scale outbreaks. However, such interventions must always be based on sound scientific evidence and ecological understanding to ensure their effectiveness and to avoid unintended consequences (e.g., installation invasive species).

Chemical Controls: Chemical treatments should always be considered a last resort, used only when pest levels surpass defined thresholds. When necessary, targeted pesticide application must be conducted following strict legal and safety standards to avoid unintended harm to non-target species, water sources, and human health.

By combining these strategies, control methods in IPM promote long-term forest and landscape resilience, reducing dependency on reactive measures and supporting ecological stability.

3.4.7. Evaluation and adaptation

Effective pest and disease management does not end with the implementation of control strategies—it requires continuous evaluation, adaptation, and institutional readiness. As climatic conditions evolve, and new biotic threats emerge, a dynamic response system must be in place at both regional and national levels to detect, respond, and adjust management actions accordingly (Figure 14).

When outbreaks occur, the ability to quickly train forestry staff, local authorities, and communities is critical. Governments should develop modular training programs that focus on pest and disease recognition, management techniques, and safety protocols. In addition to in-person sessions, they should establish online learning platforms and create accessible field manuals to ensure that essential knowledge can reach a wide audience rapidly. It is also essential to create emergency training teams that can be deployed to outbreak hotspots to build capacity on the ground when needed. A national forestry extension service or a dedicated pest management task force should coordinate these training efforts, ensuring consistent messaging, knowledge dissemination, and the implementation of best practices across the entire country.

Figure 14:

Establishing national and regional institutions for Integrated Pest Management

Sustainable pest disease management requires institutional capacity at multilevel levels:

Create or strengthen national pest and disease management units within forestry and environmental ministries, tasked with policy development, funding coordination, and inter-agency collaboration

Support the establishment of regional pest management centers that provide local expertise, rapid response capability, and training

Ensure legal and budgetary frameworks are in place to fund these institutions and their operations sustainably

Institutions must be well-connected with international networks such as FAO, EPPO, and IPPC

3.5. Guidelines for Transplanting Trees and Shrubs

3.5.1. Introduction

Transplanting is defined as the process of relocating plants, which involves digging up and moving a tree, shrub, or other plant from one location to another. Common situations for transplanting include: i) trees and shrubs that may be relocated due to development activities (e.g., from construction sites); ii) trees and shrubs in green spaces that may need to be relocated due to unfavourable growing conditions; iii) thinning of trees and shrubs growing in favourable but overly dense conditions. This Chapter presents the planning process, common operations, and safety requirements related to transplanting used internationally (e.g., the Hong Kong Guidelines on Tree Transplanting[17]). This information can help project planners and implementers make informed decisions and address the technical solutions envisioned for FLR programs.

3.5.2. Factors guiding transplanting decisions

The decision to retain, transplant, or remove a tree needs to be based on a balanced assessment of several factors that considers:

- **Species and conservation status of a tree, tree health and age:** It is recommended that trees of particular significance and high conservation value be prioritized for retention and transplanting if on-site preservation is not feasible. A healthy tree with no signs of disease or stress is more likely to survive transplanting. As a rule, trees with poor form/architecture, health or structure cannot be considered for transplanting under normal circumstances. Younger trees generally transplant more easily than older, larger ones. Larger trees have more extensive root systems, making them more challenging to dig up and relocate.
- **Size of tree and root ball / quality of root system:** It is recommended that the size of trees considered for relocation be carefully assessed in light of logistical feasibility and available resources. Digging a tree for transplanting can remove as much as 90 percent of the absorbing roots which causes transplant shock to the tree. Larger trees need bigger root ball to encompass more roots to ensure adequate re-growth, as well as anchorage and stability. Transplanting may not be recommendable for situation where a reasonable root ball size cannot be achieved. Larger root balls are generally recommended for mature trees to improve post-transplant recovery. It is recommended that trees growing on slopes, retaining walls, or in areas where forming a reasonably sized root ball is impractical be considered unsuitable for transplanting.
- **Availability and suitability of a receptor site:** Prior to transplanting, a permanent receptor site of suitable conditions for a transplanted tree, either within or outside the project area, needs to be identified. If the new site is unavailable immediately, the trees have to be properly maintained in a temporary nursery until the new site is ready.
- **Site access and transportation logistics:** The potential need for large transplanting machinery necessitates careful consideration of site accessibility, including equipment movement, setup, and the manoeuvrability of machinery and transport vehicles. It is recommended that a comprehensive assessment of all relevant factors be conducted, including evaluating site accessibility for removing and accommodating the tree, the topography of the proposed route, any engineering limitations, and other site constraints. Lifting the tree onto a vehicle and limitations on vehicle size or transport safety should also be factored into the planning process. Significant pruning to facilitate transport is not recommended.
- **Cost effectiveness:** Given the significant time, effort, and expense associated with tree transplanting, and the inherent challenges the tree faces in regeneration, it is essential to evaluate whether the tree's anticipated post-transplant contribution justifies the investment. Moreover, the lifespan and health of the trees after transplanting have to be considered before transplanting to assess the cost effectiveness of the operation. Nevertheless, coordination and proper planning, choosing to transplant younger trees, native and adapted species that require less post-transplanting care, avoiding transplantation in extreme weather, minimizing the transport distance, and using the proper machineries are key conditions to assure cost-efficient tree plantation.

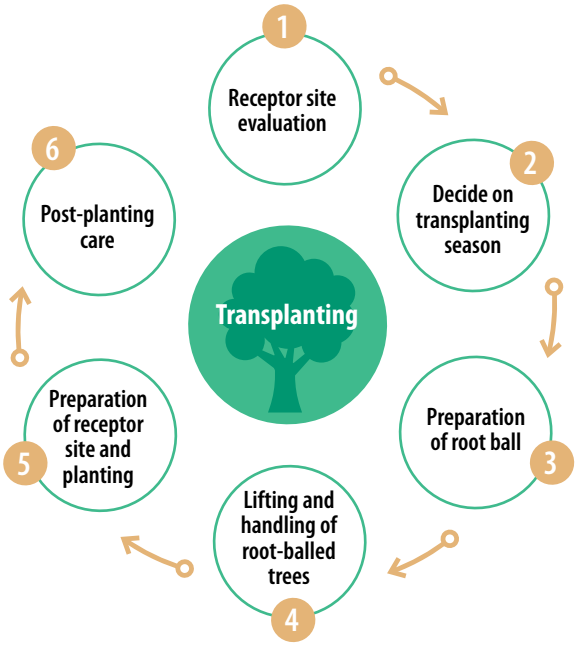
17 https://www.greening.gov.hk/filemanager/greening/en/content_28/Guidelines_on_Tree_Transplanting_e.pdf.

3.5.3. Transplanting activities

When a decision on the feasibility to transplant trees and shrubs has been taken, the execution phase involves several recommended activities (Figure 15).

Figure 15:

Main transplanting operations



Receptor site evaluation: The suitability of the new planting site is evaluated by checking the growing conditions, including light levels, soil pH and salinity, drainage, and water scarcity. This helps to decide if the new conditions at the site meet the growing requirements of the species/trees/shrubs that are relocated. Avoid sites with excessive heat reflection (e.g., next to buildings or pavement) that could stress the tree. It is also important to ensure sufficient root zone and canopy space for future growth. Planting near aggressive turfgrass, vines, or large-rooted trees that compete for water and nutrients has to be avoided. An assessment for pest infestations that could weaken transplanted trees is also advised. When planting in a new place, the geographic directions of crown growth should be maintained, i.e., east of the crown plant in the east direction in the new place.

Transplanting season: The optimal periods for transplanting generally align with the tree's dormant seasons, as this minimizes stress and promotes root development before active growth resumes. Aligning transplanting activities with the tree's dormant periods—late fall after leaf drop or early spring before bud break—offers the best chance for successful transplantation. However, it's crucial to avoid transplanting when the ground is frozen, as this can damage roots and hinder the tree's ability to settle into its new location. Deciduous trees are best transplanted during their dormant phase; international standards recommend early spring (before growth begins) and fall (after leaf drop) as ideal times for transplanting deciduous trees. For evergreen trees the recommended time for transplanting is when the soil is beginning to warm up, allowing roots to reestablish quickly. Generally, summer is not a preferred season for transplanting due to elevated evapotranspiration rates, which can subject transplanted trees to significant stress.

Preparation of root ball: Woodland or open-grown trees typically possess extensive root systems. Transplanting these trees without prior root ball preparation will likely leave a significant portion of the root system behind, leading to potential crown dieback or, in severe cases, tree death due to an inability to recover. Thus, pre-transplant crown and root pruning is sometimes necessary. The tree should be prepared with appropriate cuts to reduce the crown, then the root system should be properly prepared. For older trees, preparatory work should be undertaken at least 2-3 years before the planned replanting. The work could require digging up the root ball in several stages. The following root ball sizing considerations are recommended:

- Optimal root ball size varies by species, habit, location, and specific tree attributes.
- The root ball should be as large as practicable to maximize survival potential during and after transplanting.
- This must be balanced with logistical and cost concerns.
- Site-specific conditions (e.g., proximity to structures/utilities) may limit regular or recommended root ball size.
- Consultation with a tree specialist is essential to determine optimal dimensions.

Lifting and handling of root-balled trees: Optimizing tree lifting and transplanting operations involves the following considerations:

- Timing and site readiness: lifting operations be carefully timed to allow for immediate transport to the designated receptor site. Transplanting operations may not begin until either the receptor

site or a holding nursery is fully prepared to receive the trees. Uprooted trees must be transplanted and thoroughly watered on the same day they are lifted. Pre-lifting watering is also recommended.

- Root system integrity and stability: careful assessment is crucial when considering root system removal, as it can compromise a tree's natural form, balance, and stability, increasing its risk of failure. If a tree's stability is compromised, provide temporary support (e.g., guying, propping) before moving it. Where appropriate, robust protective fencing may be required to enclose the area around a tree undergoing staged root pruning. Regular inspections of physical supports and tree stability are essential, especially after inclement weather.
- Proper lifting techniques: use a machine of appropriate capacity with a direct lift method and padded protection for the tree. The lifting mechanism should be connected to the support structure around the root ball and not to any other part of the tree. Lifting by the trunk is strictly discouraged, as this can cause serious injury. Unprotected root balls are prone to collapse during transplanting due to their own weight. Trees in containers are more resistant to root damage during transportation.
- Approach crown pruning carefully: while pruning the crown might seem helpful, it can actually reduce the tree's ability to store nutrients. Too much pruning can also harm the tree's natural shape and lower its photosynthesis. However, crown cleaning can be performed to remove unhealthy, damaged, diseased, dead, and crossed branches, which helps minimize susceptibility to pests and diseases.

Preparation of receptor site and planting: The width and the final depth of a planting hole are determined by the depth and firmness of the root ball and other characteristics of the site. The soil directly beneath the root ball should be undistributed or prepared to prevent settling. Planting holes should generally be no deeper than the root ball with scarified sides. In general, the planting hole width should follow international practice at a minimum of 1.5 times the diameter of the root ball to suit the location.

There are several recommendations for additional support for trees/trunks after transplanting, as their root systems are often compromised and need time to reestablish. For small trees, single or double staking provides adequate support. Larger trees need a more robust approach.

Guying is the recommended technique in these instances. In cases of pre-existing lean or compromised root ball stability, supplemental propping may be necessary. This involves the placement of a rigid support, such as a timber beam, against the trunk to provide temporary reinforcement.

Post-planting care: Newly planted trees experience stress until their root systems are fully established. The stress of a tree can be observed immediately after transplanting or gradually after a period of time. Proper care after transplanting will help to assure survival and minimise stress and ensure a higher successful rate. Watering, fertilizing, and monitoring the pest and diseases after transplanting are important to assure the post-planting care, as recommended bellow:

- Mulch offers several benefits, including soil moisture conservation, temperature buffering, weed suppression, and the replenishment of soil organic matter and nutrients. A properly applied mulch layer can retain more water than the soil itself without compromising soil aeration. However, it is important to keep mulch away from the tree trunk and root collar.
- Adequate and appropriate watering is crucial for healthy root development. Provisions for watering, during the whole accommodation period, should ensure complete saturation of the root zone to minimize stress and maximize the tree's chances of survival.
- Fertilization is generally unnecessary unless a nutrient deficiency is confirmed. The slow release of nutrients from decomposing mulch and organic

matter incorporated into the backfill is often sufficient during the initial establishment phase. Fertilizer burn, characterized by insufficient water in the plant coupled with over-application of fertilizer, is a clear indication of improper fertilization practices.

- Regular monitoring of the transplanted tree is essential for early detection of any issues. This includes checking for wilting, leaf drop, branch dieback, and signs of disease or pest infestation. Maintenance activities, such as pruning dead or damaged branches, may be required.

3.5.4. General safety requirements

Prioritization of safety in transplanting is paramount, necessitating the use of appropriate tools, personal protective equipment, and specific trainings at all times. Personnel involved in tree transplanting must receive thorough instruction and supervision covering technical procedures and the safe handling of tools and equipment, including proper digging, lifting, and root ball transportation techniques, along with the importance of maintaining soil moisture. To minimize injury risk, all personnel must wear appropriate personal protective equipment, such as goggles, hearing protection, helmets, safety boots, gloves, and reflective vests when needed. Furthermore, all tools and equipment must be task-appropriate and prepared beforehand, with digging and root pruning tools kept sharp and clean to ensure precise cuts. Mechanical equipment, lifting cables, chains, straps, and slings must always be operated and inspected according to manufacturer instructions and specifications.

For complex or extensive transplanting projects, consultation with a certified specialist is strongly recommended.

3.6. Guidelines for Tree and Shrub Pruning

3.6.1. Introduction

Pruning is defined as the practice of cutting away unwanted or dead parts of a plant, such as branches or buds, in order to, for example, improve plant health, increase fruit production, reduce the risk of damage, or control its growth. This Chapter presents the common techniques, procedures, and safety requirements related to tree pruning with the aim of preserving the integrity of trees. The Chapter presents common fundamental practices used internationally (e.g., the European Tree Pruning Standard, 2024).

3.6.2. Factors guiding pruning decisions

Pruning should only be undertaken when absolutely necessary, after careful consideration of the specific tree, site conditions, and the intended purpose. It is important to acknowledge that trees, especially when tree species were selected and planted adequately to expected functions, generally do not need pruning. Trees have inherent growth patterns and forms that are optimized for their species and environment. Pruning can disrupt these natural processes and lead to long-term structural weakness or other problems. Allowing trees to grow naturally often results in stronger, healthier trees. In urban environments, the challenges of pruning are amplified by limited space, pollution, and the proximity of trees to buildings and infrastructure. For certain objectives, such as creating specific visual effects or managing woodlands, planting schemes that encourage self-pruning need to be considered. As with transplanting trees, the goal should be to avoid unnecessary intervention and prioritize the health and natural development of the tree and its surrounding environment.

Before conducting tree pruning work, it is highly recommended that a thorough risk assessment for all pruning work is conducted by the responsible planner (Figure 16).

Figure 16:

Factors guiding pruning decisions

Site Conditions Affecting Tree Stability

- Soil erosion
- Stability of adjacent stonewalls or retaining structures
- Recent site changes due to construction
- Grade changes around the site
- Assess site clearing prior to pruning operations

Potential Hazards at Pruning Site

- Electrical hazards (overhead cables, underground utilities)
- High pedestrian/vehicle activity areas (streets, parks, expressways, railways)
- Construction sites and car parks
- Need for pedestrian traffic control and safety measures

Biodiversity Considerations

- Assess risks to rare/protected animals and plants
- Avoid disturbance to active nesting, breeding, roosting
- Identify presence of birds, bats, squirrels in trees/ground
- Prevent interference with natural habitats

3.6.3. Defining pruning objectives

When pruning is needed, developing clear pruning objectives is a first prerequisite in choosing the proper technical solutions. Most pruning is done for general objectives that relate either to enhance the vitality of the trees (e.g., prevention and management of pests/diseases, adapting the individual tree's structure, and increased survival rate in arid zone) or to human needs (increasing the aesthetic value, for safety of people and traffic and for minimizing conflict between trees or parts of trees and adjacent structures) (Table 6).

Combining these objectives with knowledge of pruning techniques and plant responses will maximize the value of pruning efforts. Therefore, it is highly recommended that, unless pruning is required to address existing problems like disease or damage, a well-defined pruning strategy should be developed from the very beginning of the plant's life and consistently followed throughout its growth. This proactive approach, rather than reactive pruning, will lead to healthier, more structurally sound plants and ultimately achieve the desired long-term form and productivity.

Table 6:

Overview of the general and specific objectives that can be achieved for pruning activities

Prevention and management of pests/diseases	Increasing the aesthetic value and safety	Adapting the individual tree's structure	Management of trees in arid zones
Improved tree health: removing dead, diseased, or infested branches helps prevent insect and pest colonies from establishing as well as the spread of pests and diseases to healthy parts of the plant	**Aesthetic management:** maintaining the desired shape and size of plants improves the overall landscape design and functionality	**Reducing competition and increased sunlight penetration:** pruning helps manage tree density, ensuring adequate sunlight, water and nutrient availability for each plant promoting healthy growth	**Water conservation:** reducing foliage and unnecessary branches minimizes water loss through transpiration
Enhanced air circulation: thinning dense canopies improves airflow, reducing humidity buildup that can lead to fungal infections	**Controlling size and growth direction:** managing plant size and directing growth prevents overcrowding and ensures proper space utilization for aesthetic or safety of people and traffic	**Rejuvenating old or overgrown plants:** revitalizing aging plants encourages fresh growth and prolongs their lifespan	**Encouraging deep root growth:** reducing excess branches can shift the tree's energy toward root development, enhancing drought resistance
Encouraging balance growth: Prevents branches from rubbing against each other, reducing wounds that can invite pests or infections	**Safety and hazard reduction:** removing low-hanging or weak branches prevents potential hazards, especially near roads, buildings, or power lines	**Structural strength:** eliminating weak or poorly attached branches reduces the risk of breakage, especially during strong winds or storms	**Fire risk reduction:** removing dry, dead branches lowers the risk of wildfires, which are common in arid regions

3.6.4. Overview of main pruning operations

In practice, the following pruning operations can be applied that integrate the tree condition and the objectives for pruning activities (Table 7).

Table 7:

Overview of the main pruning operations and their specific objectives

Pruning operation	Type of interventions – points for consideration	Specific objectives for intervention
Structural pruning	• Intervention in the crown structure and shape of the tree to establish and maintain its desired, stable structure • Change of tree height or substantial change of crown shape is not recommended	• Establish a single dominant stem • Suppress of overgrown secondary shoots • Removal/reduction of unstable damaged or decayed branches • Removal/reduction of branches colonized by pests or diseases • Establish good branch distribution • Deadwood management
Lateral crown reduction (directional pruning)	• Intervention on the side or lower parts of the crown • Lateral crown reductions will often have to be repeated periodically to manage the regrowth of the tree • Excessive crown lifting can cause problems with the stability of the tree	• Eliminating conflict with surrounding structures, which cannot be removed (branches vs. power lines, building facades or windows etc.) • Improving tree stability (i.e., correcting reduction of top-heavy crowns, correcting destabilised branches etc.) • Maintaining clearance for traffic
Upper crown reduction	• Reduction of the apical, upper part of the crown • It is not advisable to combine an upper crown reduction with simultaneous removal of branches in the lower crown	• Keep trees at a specific height by repetitive pruning • Mechanically stabilise the whole tree or to follow natural crown retrenchment
Crown shaping	• Shaping a tree (trimming, pollarding etc.) that irreversibly alter the tree's natural crown architecture	• Establish a fixed, artificial form for amenity (aesthetic) reasons
Restorative pruning	• Interventions are done in stages over several years to avoid shocking the plant	• Restore the crown of trees, which have been substantially affected in their physiological and mechanical functions

Effective tree pruning requires a thorough understanding of appropriate branch removal techniques to ensure tree health and achieve desired outcomes. The main branch removal methods are presented in Table 8. In addition, pruning must be meticulously timed and executed with careful consideration for wound size by using appropriate pruning tools. Some general recommendations are presented below.

Pruning season: The optimal pruning season is determined by the aims of minimizing physiological stress and supporting natural wound reactions and/or regrowth of trees. Pruning is not recommended to be performed in i) post-dormancy (spring) – period between bud breaking and full development of leaves; ii) pre-dormancy (autumn) – period when leaves start to colour until they are shed or fully dysfunctional; and it is advised to always avoid pruning during long periods of drought. Pruning during the growing season is preferred for structural and lateral crown reduction. For crown shaping pruning is generally done during the dormant period while trimming (i.e., removing or reducing annual shoots) can be done during the growing season. For restorative pruning, the growing season is preferred for interventions.

Size of pruning: to minimize wound size, pruning should remove the smallest necessary portion of the crown to achieve specific goals. It is often preferable to perform multiple small cuts further away from the trunk than a small number of large cuts lower in the crown or directly on the stem, except when pruning in the temporary crown of young trees. Wound sizes can differ between tree species with weak and good compartmentalization.

Table 8:

Overview of the main branch removal methods and type of interventions *(based on European Tree Pruning Standard, 2024)*

Branch removal method	Type of interventions – points for consideration
Target pruning	• Removal of a side (lateral) branch just beyond the branch collar (which belongs to stem tissues) without damaging the branch collar • If branch collar is visible, the final cut should be made just outside the edge of branch collar • If a branch collar is not clearly visible, the cut must be positioned outside of the branch bark ridge without damaging it
Removing a co-dominant leader	• The cut must be positioned outside of the bark ridge without damaging it, as close as possible to the shoot that is left
Dead branches	• The collar must not be damaged when removing dead branches, even if this means cutting at a distance from the main stem • Leaving the base of the dead branches (stubs) can give a more natural appearance to the tree (especially if they are removed by breaking the branch) and support biodiversity
Pruning to a lateral	• The removal of the main axis (leader) of the branch/limb, leaving a living side (lateral) branch to sustain the remaining branch
Trimming	• It is used to shape trees formally and maintain hedges • It involves removing or reducing annual shoots, typically with hedge shears, trimmers, or similar tools. For an optimal cut, the tool should be used perpendicular to the shoot's axis, resulting in a small, smooth wound
Rip cutting (controlled breakage)	• A branch removal technique where a branch is intentionally broken off • The goal is to create a tear that imitates how branches naturally break and shed, ultimately supporting biodiversity and mimicking nature's aesthetic

Pruning tools: Choosing the right pruning tools means focusing on three key qualities: clean, sharp, and appropriate. Pruning tools should be kept clean, should be sharp and suited to the task being performed. To reduce the risk of transmitting pests and diseases, cleaning tools and other equipment must be part of daily maintenance. These qualities all contribute to making smooth, clean cuts.

3.6.5. General safety requirements

Pruning operations inherently carry significant risks, including falls, cuts, and electrical hazards, making stringent safety measures crucial for everyone involved. To minimize injury, all personnel must consistently wear appropriate personal protective equipment (PPE); this includes goggles, hearing protection, helmets, safety boots, and gloves, with chainsaw operators requiring additional protective clothing, and climbers needing safety harnesses with secure anchor points. Beyond PPE, comprehensive training and emergency preparedness are vital; workers should be instructed on proper pruning techniques, tool operation, and hazard recognition before starting any work. Furthermore, a well-equipped first aid kit must always be accessible on-site, and all workers must be fully aware of emergency contacts and established procedures for responding to injuries, falls, or electrical accidents.

3.7. Model Time and Productivity Norms for Forestry Activities

3.7.1. Introduction – a global best practice framework for sustainable forestry

Time and productivity norms are fundamental tools in modern forest management. They provide a science-based framework for estimating labour requirements, operational costs, and timelines across a wide range of forestry activities. In an era marked by climate change, biodiversity loss, and the urgent need for large-scale restoration, productivity models enable planners, policymakers, and practitioners to allocate resources effectively, improve efficiency, and ensure the long-term viability of afforestation and reforestation projects.

Traditionally, productivity norms were documented in static manuals, often based on limited data and outdated practices. While these references offered initial guidance for basic planning, they lack the adaptability, precision, and contextual relevance required for today's complex forestry operations. Modern productivity models, by contrast, offer a dynamic, data-driven alternative. They empower forestry professionals to make informed decisions tailored to specific environmental, social, and economic conditions, thereby optimizing both ecological outcomes and financial sustainability.

3.7.2. Developing context-specific productivity norms

The development of productivity norms must be rooted in local realities. Building an effective forestry productivity model begins with the collection of detailed, site-specific data. This involves recording time, labour, and cost inputs for various forestry activities under real working conditions. Factors such as species composition, terrain type, accessibility, available machinery, and local climate conditions must all be considered. By aligning productivity norms with ecological contexts and socio-economic conditions, forestry operations become more transparent, predictable, and financially viable.

A well-designed productivity model enables practitioners to forecast labour requirements, accurately estimate costs for planting, maintenance, and harvesting, plan resources based on terrain and species characteristics, and adapt operations to changing environmental conditions. This integrative approach is crucial for achieving sustainability in both economic and ecological terms (Figure 17).

Figure 17:

Advantages of productivity models

3.7.3. Biological rationalization: reducing costs through natural processes

An essential strategy for sustainable forestry is biological rationalization—the strategic use of natural processes to reduce human intervention and operational costs. Productivity models can assess when and where natural regeneration is a viable alternative to planting, based on factors such as seed availability, soil conditions, grazing pressures, and species-specific regeneration potential. Identifying areas where natural regeneration can succeed allows planners to reduce costs while promoting genetic diversity, ecosystem stability, and long-term resilience (see Section 3.1).

For example, in semi-arid regions native species with high natural regeneration potential may establish themselves successfully if protected from overgrazing, trampling, or invasive species pressure. Reducing reliance on labour-intensive planting not only cuts costs but also supports biodiversity and aligns forestry efforts with ecological principles.

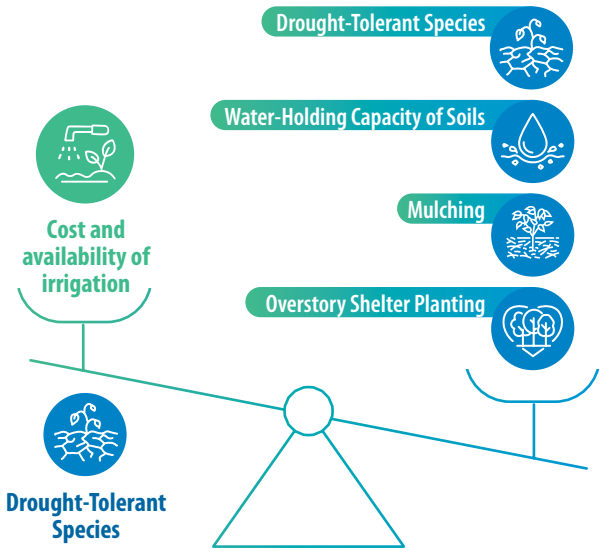
3.7.4. Water resource management in forestry productivity

Effective water resource management is a critical element of productivity planning. A comprehensive approach must balance the costs and availability of irrigation—both short-term expenses for installation and long-term costs for maintenance, water supply, and system deinstallation—with alternative, nature-based solutions. While irrigation may be necessary in some contexts, it is often costly and resource-intensive.

Enhancing the natural water-holding capacity of soils is a key strategy to reduce irrigation needs. This can be achieved by integrating humus and biochar into the soil matrix, improving structure, porosity, and moisture retention. Selecting drought-tolerant species adapted to local climate conditions is another critical step in reducing water demand (Figure 18).

Figure 18:

Balancing water resource management



Additionally, techniques such as mulching—which shades the soil, reduces evaporation, and regulates temperature—and ground cover planting can effectively conserve moisture while providing added ecological benefits. Ground cover species can protect the soil, prevent erosion, suppress weeds, and support other land uses such as beekeeping or livestock fodder production. Overstory shelter planting—using fast-growing species to create a protective canopy—can further enhance microclimate conditions, reduce wind stress, and support the establishment of target species, while also providing economic benefits through timber, fuelwood, or non-timber products.

By integrating these factors into productivity models, planners can assign an economic value to water as a finite and often costly resource. This allows for a more holistic assessment of the financial sustainability of forestry projects, optimizes their cost and promotes the adoption of water-efficient strategies.

3.7.5. Economic and ecological cost-benefit analysis

A comprehensive productivity model enables a comparative analysis of different forestry strategies, helping planners balance economic and ecological objectives. By quantifying trade-offs, decision-makers can design forestry programs that align with both restoration goals and financial realities. For example, models can compare the long-term outcomes of native versus non-native species plantations, assess the benefits of timber-focused versus conservation-driven projects, and evaluate the costs and benefits of intensive planting versus natural regeneration. This analytical approach supports evidence-based decision-making and fosters the development of forestry systems that are both sustainable and economically viable.

3.7.6. Social compliance: protecting workers in forestry

Productivity models must not only reflect technical and ecological realities but also ensure that forestry operations uphold fair labour standards. Forestry work is physically demanding, often carried out in challenging environments, and must be governed by principles of safety, fairness, and human dignity. A socially responsible productivity model must ensure fair wages that comply with national and international standards, prevent exploitation through unrealistic piece-rate systems, set reasonable working hours to avoid fatigue and injury, provide safety training and protective equipment, and offer access to medical care. Moreover, workers must be meaningfully included in norm-setting processes and have access to channels for grievances and feedback (Figure 19). Integrating social compliance into productivity models is essential for promoting equitable and ethical forestry practices globally.

Figure 19:

Labour standards for workers in forestry

3.7.7. The Swiss WSL model: a global benchmark

A strong example of an effective productivity model is the suite of tools developed by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). The WSL models[18] (Holm *et al*. 2020) are based on systematic field data collection, incorporating real-world insights from diverse forestry operations, such as site preparation, planting, tending, and maintenance. By combining scientific research with practical experience, the models provide reliable forecasts for labour requirements, costs, and timelines across a wide range of forestry activities.

One of the key strengths of the WSL models is their adaptability. They are dynamic tools, continuously updated to reflect new data, technological innovations, and changing environmental conditions. This makes them particularly valuable in the context of climate change, where flexibility and responsiveness are essential for effective forest management.

Another important aspect is that the WSL models are freely available to practitioners and institutions worldwide (Holm et al., 2023). This openness allows forestry professionals in different countries and contexts to explore and adapt the models to their own specific needs. By studying the WSL approach and tailoring it to local conditions, countries can accelerate the development of their own productivity models—saving time, avoiding costly mistakes, and benefiting from an existing framework that has been tested in practice.

The WSL models demonstrate how a science-based, transparent, and collaborative approach can improve forestry planning and operational efficiency. They serve as a valuable reference for countries seeking to establish or refine their own productivity norms, offering inspiration and a practical foundation for building customized solutions suited to local challenges and objectives.

In conclusion, model time and productivity norms are essential tools for modern, efficient, and socially responsible forestry. The example set by the WSL productivity models demonstrate the value of a science-based, adaptive, and comprehensive framework for forestry planning. By developing localized, data-driven productivity models that integrate environmental, economic, and social considerations, forestry practitioners can improve planning, reduce costs, protect ecosystems, and ensure fair labour practices.

18 https://www.waldwissen.net/en/technique-and-planning/forest-technology/calculation-tools/calculation-of-harvesting-operations.

4. References and Photo Credits

References

Chakraborty, D., Móricz, N., Rasztovits, E., Dobor, L., & Schueler, S. (2021). Provisioning forest and conservation science with high-resolution maps of potential distribution of major European tree species under climate change. Annals of Forest Science, 78(2), 26. Retrieved from: https://doi.org/10.1007/s13595-021-01029-4.

Convention on Biological Diversity (2010). Decision X/2. The Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. Adopted by the Conference of the Parties to the Convention on Biological Diversity at its tenth meeting, Nagoya, 18-29 October 2010. Montreal: Secretariat of the Convention on Biological Diversity. Retrieved from https://www.cbd.int/cop/.

Corbett, J. (2009). Good practices in participatory mapping: A review prepared for the International Fund for Agricultural Development (IFAD). Rome, Italy.

EUFORGEN (2023). Seed harvesting, processing, storage, and nursery practices: How management practices can affect or influence genetic diversity of forest reproductive materials. Focus on Forest Genetic Diversity, Theme 5. European Forest Institute.

European Commission, Joint Research Centre (n.d.). EU Forest Observatory: Global Forest Mapping and Monitoring. Retrieved from https://forest-observatory.ec.europa.eu/.

European Commission (2021). New EU Forest Strategy for 2030 [COM(2021) 572 final]. Brussels: European Commission. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0572.

European Tree Pruning Standard (2024). EAS 01:2024. European Arboricultural Standards (EAS), European Arboricultural Council. Retrieved from: https://www.europeanarboriculturalstandards.eu/etps.

Evans, K., de Jong, W., Cronkleton, P., Sheil, D., Lynam, T., Kusumanto, T., & Colfer, C. J. P. (2006). Guide to participatory tools for forest communities. Center for International Forestry Research (CIFOR).

Evans, K., & Guariguata, M. R. (2019). A diagnostic for collaborative monitoring in forest landscape restoration (Vol. 193). Center for International Forestry Research (CIFOR): Bogor, Indonesia.

FAO (1993). Planting trees: An illustrated technical guide and training manual. Food and Agriculture Organization of the United Nations. Rome, Italy.

FAO (2015). Template for Global Forest Resources Assessment 2015 Country Report (FRA). Food and Agriculture Organization of the United Nations. Rome, Italy. 51p.

FAO (2024). The State of the World's Forests 2024 – Forest-sector innovations towards a more sustainable future. Food and Agriculture Organization of the United Nations. Rome, Italy. https://doi.org/10.4060/cd1211en.

FAO (2024). Guide to implementation of phytosanitary standards in forestry, Food and Agriculture Organization of the United Nations, Rome, Italy.

Federal Research and Training Centre for Forests, Natural Hazards and Landscape. "Seed4Forest" (n.d.). Retrieved from: https://seed4forest.org. Accessed 26 July 2025.

Greening, Landscape and Tree Management Section Development Bureau Hong Kong, 2014. Guidelines on Tree Transplanting, Hong Kong. 36p, Retrieved from: https://www.greening.gov.hk/filemanager/greening/en/content_28/Guidelines_on_Tree_Transplanting_e.pdf.

Holm, S., Werder, M., Thees, O., Lemm, R., & Schweier, J. (2023). JuWaPfl: A decision support tool to estimate times and costs of processes related to young-forest maintenance. *SoftwareX*, *24*, 101581.

Holm, S., Frutig, F., Lemm, R., Thees, O., Schweier, J. (2020) HeProMo: A decision support tool to estimate wood harvesting productivities. PLoS ONE 15(12): e0244289. Retrieved from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0244289.

IUCN (2020). Bonn Challenge 2020 progress report. Impact and potential of forest landscape restoration. Gland, Switzerland: IUCN. Retrieved from: www.bonnchallenge.org/sites/default/files/resources/files/%5Bnode%3Anid%5D/Bonn%20Challenge%20Report.pdf.

Landesforsten Rheinland-Pfalz (n.d.). Wald in der Klimakrise – Helfen wir ihm! Retrieved from https://www.wald.rlp.de/klimakrisewaldrlpde.

Mintzberg, H. (1978) Patterns in Strategy Formation. Management Science, 24, 934-948.

Portoghesi, L. (2006). European Forest Types. Categories and types for sustainable forest management reporting and policy. Forest@-Journal of Silviculture and Forest Ecology, 3(4), 462.

Rizzeti, D., Swaans, K., Holden, J, Brunner, J., Le, T., Nguyen. T. (2018). Assessing Opportunities in Forest Landscape Restoration in Quang Tri, Viet Nam: Viet Nam: IUCN. 46pp.

Team Technologies, Middleburg, Virginia. (2005). The logframe handbook: a logical framework approach to project cycle management. Washington, DC, USA: World Bank.

UNECE (2022). National policy guiding principles for forest landscape restoration. ECE/TIM/2022/7; Retrieved from https://unece.org/sites/default/files/2022-09/ECE_TIM_2022_7_en.pdf.

UNGA (2019). United Nations Decade on Ecosystem Restoration (2021-2030). United Nations General Assembly Resolution A/73/L.76.

UNGA (2025). United Nations Decade for Afforestation and Reforestation in line with Sustainable Forest Management (2027-2036). United Nations General Assembly Resolution A/79/283.

United Nations Framework Convention on Climate Change (n.d.). Nationally Determined Contributions Registry. Retrieved from https://unfccc.int/NDCREG.

World Resources Institute (WRI) & Food and Agriculture Organization of the United Nations (FAO) (2022). AURORA: Assessment, Understanding and Reporting of Restoration Actions [Web application]. Retrieved from https://auroramonitoring.org/.

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National forest landscape restoration strategies

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This manual is a comprehensive guide designed to empower decision-makers and field managers in the development and implementation of national Forest Landscape Restoration (FLR) strategies. It provides a dual-focused approach to ensure both strategic vision and on-the-ground success.

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Website: http://www.unece.org

ISBN 978-92-1-159185-9

Designed and Printed at United Nations, Geneva – 2516408 **(E)** – March 2026 – 65 – **ECE/TIM/SP/64**