# FOREST LANDSCAPE RESTORATION, BIODIVERSITY AND ECOSYSTEM SERVICES

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**Resumo**

A deflorestação e a degradação florestal são desafios globais que afectam a biodiversidade e os serviços dos ecossistemas. O 'Restauro Florestal à escala da paisagem' poderá contribuir para responder a estes desafios, recuperar os ecossistemas florestais, a biodiversidade e os serviços de ecossistema e contribuir para os Objectivos Millennium de Desenvolvimento Sustentável. O restauro da paisagem florestal pode criar oportunidades para a conservação da biodiversidade, produção de alimento e de produtos florestais lenhosos e não-lenhosos. Actualmente os projectos de restauro florestal caracterizam-se por uma ampla variedade de abordagens, sendo essencial avaliar como estas abordagens são implementadas ao nível global. Em particular é importante identificar: localização geográfica dos projectos, principais objectivos e metodologias usadas, e acções para a conservação da biodiversidade e serviços de ecossistemas, incluindo potenciais benefícios para a segurança alimentar.

Este trabalho visou caracterizar as práticas de restauro da paisagem florestal em todo o mundo. Para isso realizaram-se inquéritos on-line, direccionados a gestores de projectos de restauro florestal. Obtiveram-se respostas relativas a 47 projectos de restauro. Concluiu-se que a maioria destes projectos se concentram nas regiões tropicais, tendo como objectivos mais frequentes o aumento da cobertura vegetal e a conservação da biodiversidade. Cerca de 60% dos projectos investigados usaram simultaneamente técnicas de regeneração artificial e natural. Baseado nas respostas ao inquérito, verificou-se que na maioria dos projectos (75%), 100% das espécies plantadas eram nativas da área do projecto. No entanto, o número de espécies plantadas variou entre 1 a 3 espécies diferentes por hectare. De um total de 131 espécies de árvores plantadas 17% eram espécies classificadas como ameaçadas. Na maioria dos casos, os projectos de FLR não usaram espécies arbóreas com valor nutricional. Verificou-se também que os gestores dos projectos, assim como as comunidades locais, homens e mulheres, participaram na selecção de espécies para restauro florestal.

**Palavras-chave:** Restauro Florestal, Espécies arbóreas, Biodiversidade, Serviços do ecossistema, Nutrição

**Abstract**

Deforestation and forest degradation are global challenges that negatively affect forests, ecosystem services and biodiversity. The concept of 'Forest Landscape Restoration' has emerged as a contribution to address these challenges and recover forests, restore biodiversity, improve ecosystem services and human well-being, thus contributing to the Sustainable Development Goals. Forest landscape restoration may create opportunities for biodiversity conservation, reduction of erosion, water regulation, and supply of food and wood products. Today, Forest Landscape Restoration projects are applied with a wide variety of approaches. However, there is still a need to assess how this concept is being put into practice by different initiatives. This includes getting information on project locations, project main objectives, methods, implications on biodiversity and ecosystem services, nutritional benefits of trees, and evaluate how the selection of tree species is done.

In order to provide a complete picture of forest landscape restoration practices around the world, this research focused on obtaining information from various projects through an online survey aimed at practitioners of forest restoration worldwide. Responses from 47 FLR projects showed that most restoration activities targeted are currently undergoing in the tropics. Increasing vegetation cover and recovering biodiversity were the most common objectives. About 60% of the projects used a mixture of artificial and natural regeneration. According to the responses, in most of the projects (75%), 100% of the planted species were native to the project site. The diversity of planted species was on average of 1 to 3 species per hectare. From the total list of 141 responses, 131 planted tree species were derived, threatened species covered a small proportion of 17%. In general, FLR projects did not plant any edible tree species. It was also found that project managers and local communities are often involved in species selection, in most cases both men and women.

**Keywords:** Forest Landscape Restoration, Tree species, Biodiversity, Ecosystem services, Nutrition

**Resumo alargado**

As florestas desempenham um papel essencial na conservação da biodiversidade e dos serviços dos ecossistemas, albergando mais de 80% das espécies terrestres e gerando serviços de ecossistemas que contribuem para a subsistência de mais de 1,6 mil milhões de pessoas em todo o mundo. Por biodiversidade entende-se a "variabilidade da vida" a várias escalas, desde os genes aos ecossistemas, enquanto por "serviços dos ecossistemas" se entende serem os 'benefícios' que os ecossistemas geram para o bem-estar humano. Os serviços dos ecossistemas são usualmente classificados em: serviços de suporte (ex: ciclo de nutrientes, produção primária), serviços de aprovisionamento (ex: alimentos, combustível, madeira e produtos florestais não madeireiros), serviços de regulação (ex: sequestro de carbono, regulação ciclo da água) e serviços culturais (ex: recreio, turismo, valores estéticos e espirituais). Actualmente sabe-se que existe uma relação positiva entre biodiversidade (ex: número de espécies) e a capacidade dos ecossistemas de gerar serviços.

A deflorestação e a degradação florestal, no entanto, ameaçam a biodiversidade florestal e os serviços dos ecossistemas, nomeadamente devido à fragmentação e perda de habitat, com impactos negativos na capacidade dos ecossistemas para mitigar eventos extremos (e.g. secas, incêndios) ou proporcionarem segurança alimentar.

O conceito de restauro florestal à escala da paisagem visa reverter a deflorestação e a degradação florestal, conservando a diversidade biológica, e os serviços dos ecossistemas, contribuindo também para os objectivos do Desenvolvimento Sustentável (SDG) do Millennium. O termo 'Restauro florestal à escala da paisagem' é definido como "*um processo planeado que aponta para a recuperação da integridade ecológica e o melhoramento do bem-estar humano em paisagens desflorestadas ou degradadas*". Embora o restauro florestal inclua abordagens e metodologias diferentes, todas as actividades que visam restaurar áreas desflorestadas e degradadas podem ser consideradas como restauro florestal.

Os projectos de restauro florestal encontram-se enquadrados por uma variedade de abordagens e politicas globais. Tratados e acordos como, por exemplo: "Aichi Targets Declaration", a "Bonn Challenge", A "New York Declaration on Forests", ou a "Land Degradation Neutrality" impõem metas e objectivos concretos para acções de restauro florestal. É todavia essencial compreender como se distribuem e são implementados os projectos de restauro florestal a nível global. O objectivo deste trabalho foi pois o de analisar uma amostra de projectos de restauro da paisagem florestal, ao nível global, procurando identificar: localização geográfica do projecto, objectivos principais, métodos usados, relação com a conservação da biodiversidade e dos serviços dos ecossistemas. No âmbito dos serviços dos ecossistemas considerou-se em particular de que maneira o restauro florestal pode contribuir para a segurança alimentar das populações locais, nomeadamente identificando eventuais benefícios nutricionais das árvores usadas no restauro florestal.

Na literatura sobre restauro florestal, raramente os aspectos acima referidos são analisados em conjunto, impedindo uma visão completa e sobre as implicações do restauro florestal. O presente trabalho visou obter informação sobre vários aspectos de projectos de restauro florestal através de inquéritos on-line, globais, dirigidos aos profissionais do sector.

Para este efeito, elaborou-se um inquérito em plataforma digital, online, no qual se colocaram as seguintes questões: (1) Onde estão a decorrer os projectos, quais ecossistemas florestais alvo e principais objectivos dos projetos em curso no mundo? (2) Quais são os principais métodos (ex: regeneração natural, regeneração assistida, regeneração artificial) utilizados nestes projectos? (3) Como varia a diversidade de espécies e estatuto de conservação (ex: espécies nativas, espécies endémicas, espécies ameaçadas) utilizadas nos projectos de restauro? (4) Que factores e serviços do ecossistema, incluindo potenciais benefícios nutricionais, são considerados durante o processo de selecção das espécies? E finalmente (5) Que actores (ex técnicos, populações locais, percentagem de homens ou mulheres) estão envolvidos na selecção das espécies usadas nos projectos de restauro?

O inquérito foi distribuido através do programa SurveyMonkey, uma ferramenta para elaboração de inquéritos *on-line*. Os inquéritos foram enviados para várias organizações na área do restauro florestal, nomeadamente organizações não governamentais de ambiente e agências de investigação, com a solicitação de que fossem redistribuídos por outras entidades relevantes, de forma a alcançar o maior número possível de organizações e projectos. Como o número de respostas foi relativamente baixa nesta primeira fase, foi ainda realizada uma segunda distribuição de inquéritos, dirigida a um maior número de organizações do sector.

Foram recebidas 55 respostas, das quais 47 foram validadas para análise. Os resultados mostraram que a maioria das actividades de restauro ocorrem nas regiões tropicais. Nas respostas analisadas África, Ásia e América do Sulcobrem quase 80% dos projectos de restauro em todo o mundo. Aumentar a cobertura vegetal e promover a conservação da biodiversidade são os objectivos mais frequentes listados nos projectos analisados. São também mencionados outros objectivos como, por exemplo, a educação ambiental ou a certificação florestal. Cerca de 60% dos projectos utilizaram uma mistura de regeneração artificial e natural. Baseado nas respostas ao inquérito, verificou-se que na maioria dos projetos (75%), 100% das espécies plantadas eram nativas na área do projecto. O número de espécies plantadas variou em média entre 1 a 3 espécies por hectare. Do total de 141 espécies de árvores plantadas 23 espécies tinham estatuto de espécie ameaçada. Na maioria dos casos, os projectos de FLR não usaram espécies arbóreas com valor nutricional. Verificou-se também que os gestores de projectos e as comunidades locais, quer homens quer mulheres, são envolvidos na selecção de espécies.

Tendo em conta que estes resultados se baseiam na amostra analisada e possam não ser absolutamente representativos das actividades globais de FLR , mesmo assim conclui-se que:

Cada projecto de restauro uma dinâmica própria.Analisar a variedade de práticas adoptadas nos projectos de FLR é crucial para diagnosticar a diversidade de abordagens e os objectivos globais do restauro florestal.

Conclui-se também que a regeneração natural e artificial são frequentemente usados simultaneamente no restauro florestal. Adicionalmente a FLR tem objectivos diversos, incluindo a conservação da biodiversidade e a promoção de alguns serviços do ecossistema. Plantar uma maior diversidade de espécies arbóreas e espécies ameaçadas pode favorecer a conservação da biodiversidade nos projectos FLR. Quanto ao envolvimento das populações locais, é necessário integrar aspectos sociais e relativos ao bem-estar humano nos projectos FLR. O aumento da segurança alimentar, por exemplo, pode desempenhar um papel importante para mostrar o potencial das árvores em nutrição para abordar a segurança alimentar das pessoas locais e motivá-las para a manutenção das práticas de FLR.

A presente tese revelou também que os projectos de restauro se localizam principalmente em áreas tropicais húmidas. Um maior esforço de restauro em regiões áridas poderá aumentar o potencial da FLR em mitigar a insegurança alimentar e a pobreza das pessoas que vivem nessas áreas, e também, o desenvolvimento sustentável.

Esta tese reconhece que a FLR como uma ferramenta que pode contribuir para o desenvolvimento sustentável, compilando informação global sobre práticas de FLR que visam atingir as metas globais de restauro florestal, e contribuir simultaneamente para a integridade ecológica e o bem-estar humano.

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**List of Abbreviations**

AFR100 – African Forest Landscape Restoration Initiative

AFRP – Atlantic Forest Restoration Pact

APAFRI – Asia Pacific Association of Forestry Research Institutions

APFORGEN – Asia Pacific Forest Genetic Resources Programme

BGCI – Botanic Gardens Conservation International

CBD – Convention on Biological Diversity

CGIAR – Consultative Group on International Agricultural Research

CER – Certified Emission Reduction

CDM – Clean Development Mechanism

COP – Conference of the Parties

D&D – Forest Degradation and Deforestation

ES – Ecosystem services

EUFORGEN – European Forest Genetic Resources Programme

FAO – Food and Agriculture Organization

FLR – Forest Landscape Restoration

GBIF – Global Biodiversity Information Facility

GPFLR – Global Partnership on Forest and Landscape Restoration

GRN – Global Restoration Network

IISD – International Institute for Sustainable Development

IMFN – International Model Forest Network

IPAM – The Amazon Environmental Research Institute

IUCN – International Union for Conservation of Nature

IUFRO – International Union of Forest Research Organization

LAFORGEN – Latin American Forest Genetic Resources Network (LAFORGEN)

NGO – Non-Governmental Organization

NTFP – Non-Timber Forest Products

PES – Payment for Ecosystem Services

PFAF – Plants For A Future

REDD+ – UNFCCC-Reducing Emissions from Deforestation and Forest Degradation

UN-CCD – United Nations Convention to Combat Desertification

UNFCCC – United Nations Framework Convention on Climate Change

SAFORGEN – Sub-Saharan African Forest Genetic Resources

SDGs – United Nations Sustainable Development Goals

SER – Society of Ecological Restoration

WWF – World Wide Fund for Nature

WRI – World Resources Institute

# 1. INTRODUCTION

The term “forest” stands for a minimum of 0.5 hectares of land, with trees higher than 5 meters at maturity and at least 10% of tree crown cover (FAO, 2010). Forest ecosystems are crucial reservoirs of biodiversity that host more than 80% of entire species living on land (Aerts & Honnay, 2011; United Nations, 2011), and generate ecosystem services that contribute to livelihoods of more than 1.6 billion people worldwide (Chao, 2012; The World Bank, 2004). Biodiversity is the variability of living organisms in all types of ecosystems (Groot et al., 2012). Biodiversity is positively related to the ecological functions that promote the provision of ecosystem services (ES) (Benayas, Newton, Diaz, & Bullock, 2009; Brockerhoff et al., 2017). ES are defined by Millennium Ecosystem Assessment as the benefits ecosystems provide to humankind, and can be classified into: supporting services (e.g. nutrient cycling, primary production, maintenance of habitats and genetic diversity) provisioning services (e.g. food, fuel, timber and non-timber forest products); regulating services (e.g. climate and disease control, carbon sequestration, water treatment, moderation of extreme climatic events); and cultural services (e.g. recreation, tourism and spiritual values) (Brockerhoff et al., 2017; Millennium Ecosystem Assessment, 2005) .

## 1.1. Global Threats to Forests

Deforestation and forest degradation are the biggest threats to forests worldwide (IUCN, https://www.iucn.org/resources/issues-briefs/deforestation-and-forest-degradation).
Deforestation is the extensive removal of vegetation to less than 10% crown cover (Hobley, 2010), whilst forest degradation is the reduction of the capability of a forest to provide goods and services (Lamb, Stanturf, & Madsen, 2012). Effects of forest deforestation and degradation (D&D) induce habitat fragmentation, biodiversity reduction and loss of ES (Duguma et al., 2019), and ultimately generate food insecurity and intensify the effects of climate change. Livelihoods of millions of forest-dependent people may be affected by D&D. Some authors indicate that at least 3.2 billion people may be affected (Besseau, Graham, S., & Christophersen, T., 2018), with negative repercussions on societies and economies (Cunningham et al., 2015).

Direct drivers of deforestation include conversion of forest to other land uses. Agriculture is estimated to be the most intense driver by leading to around 80% of deforestation worldwide. 2/3 of the total deforestation is caused by commercial agriculture practices, including livestock agriculture in Latin America. Meanwhile, in Africa and (sub)tropical Asia, commercial and subsistence agriculture each causes 1/3 of deforestation, leaving the other 1/3 for mining, urban area expansion, and infrastructure. Overall, commercial agriculture of answering international demand for cattle, soybean and palm oil is a stronger driver than subsistence agriculture in the last 30 years. In terms of forest degradation, 70% of total degradation in Latin

America and (sub)tropical Asia is caused by commercial timber extraction and logging, while in Africa fuelwood collection is the main driver (Kissinger, Herold, & De Sy, 2012). Indirect drivers of D&D are complex interplays in the social, economic, political and cultural environments at global, regional and local levels, such as local subsistence and poverty, prices at international markets, national policies and governance (Sabogal, Besacier, & McGuire, 2015). Recent forest fires that occurred in the Amazon rainforest in 2019 demonstrate that the threats of D&D are yet to be mitigated. According to the current report of The Amazon Environmental Research Institute (IPAM), the fires that occurred in the summer of 2019, a non-dry year, in municipalities which were already highly deforested are intentional and mostly caused by clearing of forest areas (Silvério, Silva, Alencar, & Moutinho, 2019), which according to the international media is taking place to expand logging and agricultural activities (Andrade, 2019).

As a result of both direct and indirect factors, the estimated total extent of global deforestation since 1990 is 129 million hectares - nearly the size of South Africa - (Besseau et al., 2018; FAO, 2016), with a global deforestation rate of  about 13 million hectares per year (Bremer & Farley, 2010). About 850 million hectares of forests worldwide are classified as degraded (Mansourian & Vallauri, 2014). Considering that the total human population is expected to increase up to 9.8 billion by 2050 (United Nations, DESA, Population Division, 2017), an increase in the demand and overexploitation of forest resources is inevitable. Recent efforts of sustainable management and the establishment of protected areas reduced the rate of net forest loss, however, D&D remains a major global challenge in the 21$^{st}$ century (Vallauri, Aronson, Dudley, & Vallejo, 2010).

### 1.2. Forest Landscape Restoration

The Forest Landscape Restoration (FLR) concept has emerged as a solution to the consequences of D&D. “Forest Landscape Restoration” was defined by specialists as a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes (Dudley, Mansourian, & Vallauri, 2010; Newton & Tejedor, 2011; Stanturf, Mansourian, & Kleine, 2017). By definition, ecological integrity refers to adequate levels of biodiversity, as well as ecosystem stability, resilience, sustainability, and naturalness (Mansourian, Stanturf, Derkyi, & Engel, 2017). Generally, Forest Landscape Restoration aims to enhance biological diversity, provide  ES and create a win-win outcome to achieve biodiversity conservation and socio-economic development (Benayas et al., 2009). The FLR concept goes beyond planting trees individual sites or re-creating past ecosystems. FLR includes a landscape approach that considers mosaics of interacting land uses such as agriculture, agroforestry and improved fallow systems, ecological corridors, areas of forests and woodlands, and river or lakeside plantings to protect waterways (Bonn Challenge, http://www.bonnchallenge.org/content/forest-landscape-restoration). The rationale for this approach is that ecological, economic and social needs can be balanced by creating self-sustainable forests that benefit both people and biodiversity (Janishevski, Santamaria, Gidda, Cooper, & Brancalion, 2015). Consequently, FLR is an interdisciplinary concept implying not only forestry and biodiversity conservation but also socio-economic issues (Sayer, 2010) as D&D results mostly from human use of the lands. Therefore, long-term engagement of people to take part in restoration is essential. If all actors (e.g. public administrations, private corporations, NGOs, civil society organizations, local communities) are committed to FLR, they will fulfill their responsibilities on restoration and protection of natural resources. There is not a uniform method to apply in all cases to ensure that commitments from different actors are respected, especially considering the pressure to address multiple, and occasionally competing, needs and demands of this wide range of interest groups. Each situation and place is unique with different dynamics, different types of environment, different D&D drivers and different stakeholders. As a result, each FLR activity is distinctive and one definite application does not exist. Nevertheless, a participative implementation of FLR initiatives is assumed to be more sustainable, politically more acceptable and long-lasting although more complex (Lamb et al., 2012).

### 1.3. Forest Landscape Restoration on the International Agenda

FLR became a significant item on the international and national political agenda and in conservation strategies (Mansourian & Vallauri, 2014). Today, many governments, companies and non-governmental organizations (NGOs) are committing to forest restoration and to the promotion of FLR (Mansourian et al., 2017). The FLR approaches set in place can differ substantially based on the final objectives. Ecological restoration assists the recovery of an ecosystem that has been degraded, damaged or destroyed to ensure it returns to a condition very similar to the initial state, before disturbance (Society for Ecological Restoration, 2004). Other approaches are afforestation, reforestation, reclamation. Afforestation refers to the establishment of a forest on degraded land that had no forest cover before, while reforestation is the re-establishment of a forest cover on degraded land that was previously a forest. Reclamation is an approach that ensures the return of a vegetation cover on sites usually highly degraded as a result of mining or other forms of industrial exploitation (Mansourian, 2018). These various approaches and terminologies may cause ambiguity. As suggested by Mansourian et al., (2017) there is a need for consistent and clear terminology. Forest Landscape Restoration is a broad approach that includes others and refers to different types of ecosystems and land uses (Romijn et al., 2019). In this study, all types of efforts that aim to recover degraded and deforested land, either naturally or through human activities, and either performed in a large or small scale are included under the term “Forest Landscape Restoration”. The terms “restoration project” or “FLR project” will be used here to refer to a project that applies a range of approaches (as described above), depending on the environmental context and objectives of restoration activities.

Various international programs and agreements are associated with the implementation of FLR at a global level. Some examples include; The Aichi Targets, Bonn Challenge, Land Degradation Neutrality and the New York Declaration on Forests. Each of these international agreements was defined under a specific platform. The Aichi Targets were defined by the Convention on Biological Diversity (CBD). Aichi target 14 determines restoration as essential for the provision of ES (Ockendon et al., 2018), while Aichi target 15 sets a global goal of restoration of at least 15% of degraded ecosystems (Janishevski et al., 2015). In 2011, The International Union for Conservation of Nature (IUCN) and the Government of Germany launched the Bonn Challenge and invited governments, the private sector, and civil society to accomplish the goal to restore 150 million hectares by 2020 worldwide. Under the Bonn Challenge, 63 countries have committed to restoration so far. The Bonn Challenge is an actualization of many existing commitments such as the United Nations Framework Convention on Climate Change Reducing Emissions from Deforestation and Forest Degradation goal (UNFCC REDD+), and Rio 20+ Land Degradation Neutrality Goal (Bonn Challenge, http://www.bonnchallenge.org/content/challenge). The goals of REDD+ integrated with FLR practices can contribute to decrease greenhouse gas emissions and to store carbon in forest ecosystems while supplying benefits to humans (Alexander et al., 2011). Land Degradation Neutrality, set by the United Nations Convention to Combat Desertification (UNCCD) in 2012, aims to reverse land degradation to achieve a net-zero loss of healthy and productive land (UNCCD, https://knowledge.unccd.int/topics/land-degradation-neutrality). In 2014, during the United Nations Climate Summit, the Bonn Challenge was included in the New York Declaration on Forests and the goal of Bonn Challenge was extended to restore about 350 million hectares by 2030.

There are 4 large-scale regional initiatives that promote restoration and support the Bonn Challenge: 20x20 initiative for Latin America, AFR100 for Africa, the Agadir commitment for the Mediterranean and the Action Plan for FLR for the Asia-Pacific region (http://www.fao.org/in-action/forest-landscape-restoration-mechanism/resources/detail/en/c/1152305/, FAO). The 20x20 initiative was launched in December 2014 by the UNFCC Conference of the Parties (COP) with the aim to restore 20 million hectares of degraded land in Latin America and the Caribbean by 2020 (Laestadius, Buckingham, Maginnis, & Saint-Laurent, 2015). The African Forest Landscape Restoration Initiative (AFR100), initiated with the involvement of the World Resources Institute (WRI), targets 100 million hectares by 2030 in Africa (Stanturf et al., 2017). The Agadir Commitment aims to restore a minimum of 8 million hectares in the Mediterranean region by 2030 (http://www.fao.org/forestry/silva-mediterranea/93061/en/, FAO). The Regional Strategy and Action Plan for Forest and Landscape Restoration in the Asia-Pacific promotes and accelerates FLR in degraded and deforested landscapes in the region (FAO and APFNet, 2018).

In general, FLR is considered as an approach to achieve the United Nations Sustainable Development Goals (SDGs) (Mansourian, 2018). The SDGs are 17 different goals, determined by the United Nations and acknowledged by 193 countries, set to achieve global sustainable development (United Nations, accessed on 7 May 2019). Depending on its specific objectives, FLR can contribute to SDGs in various ways, such as; SDG 1 – no poverty by improving livelihoods; SDG 2 – Zero Hunger and SDG 3 – Good Health and Well-being by increasing food provision and water quality; SDG – 5 Gender Equality through gender-responsiveness; SDG 13 – Climate Action by carbon sequestration and SDG 15 – Life on Land through the recovery of biodiversity.

Although the FLR concept has gained momentum at a global scale, according to Chazdon et al. (2015) there is a knowledge gap in how to operationalize and implement restoration at different scales, considering different local demands and needs. Therefore, there is also a need to assess where and how FLR projects are implemented.

### 1.4. Objectives of Forest Landscape Restoration

By restoring degraded and deforested areas that have lost the capacity to provide goods and services; FLR improves ES, such as maintenance of biodiversity and therefore the well-being of humans (FAO, 2011a; Janishevski et al., 2015). Furthermore, by enhancing the biological richness, FLR also contributes to the diversification and improvement of ES, and therefore to the resilience of the environment and local communities (Beatty, Cox, & Kuzee, 2018). According to Benayas et al.,(2009), provisioning ES, including biodiversity are significantly improved in restored ecosystems compared to degraded lands. FLR can target the improvement of a single ES or aim, (e.g. biodiversity conservation or climate change adaptation/mitigation) or multiple ES (Sabogal et al., 2015). Examples of FLR objectives can be:

- Forest biodiversity conservation or recovery (Beatty et al., 2018),
- Improving food security and nutrition by diversification of food resources derived from plants (Kumar, C., Saint-Laurent, C., Begeladze, & Calmon, M., 2015),
- Improvement of forest ES provision that determines the livelihoods and quality of lives of people such as food, timber, fuel, and medicines (Besseau et al., 2018).
- Increase productivity of agriculture and agroforestry through improved fertility of soils and diversification of crops (Mansourian & Vallauri, 2014)
- Biomass production and climate change mitigation/adaptation (Ciccarese, Mattsson, & Pettenella, 2012),
- Aesthetics, recreation, educational and cultural values (Lamb, 2018; Mansourian & Vallauri, 2014),
- Increasing vegetation cover (Romijn et al., 2019),

Through a global analysis, Hallett et al. (2013) focused on assessing the objectives of different FLR projects implemented and recorded that most projects focus on bio-physical targets while socio-economic objectives were not as frequently adopted. There is a need to understand if the ongoing FLR projects tend to favor (through planting) tree species that have the potential to meet some of the needs of local communities.

### 1.5. Methodologies for Forest Landscape Restoration

There are different methods for restoration namely: natural regeneration, assisted regeneration and artificial regeneration. These methods can also be applied simultaneously by mixing them in appropriate conditions. Natural regeneration is based on enabling natural succession processes and minimizing human intervention, by usually isolating the area being restored to allow native vegetation to regenerate naturally (Nunes, Soares-Filho, Rajão, & Merry, 2017). This method is also called 'passive' due to the minimum human interference. Natural regeneration is appealing because it enables to restore of many ES at lower cost, without the need to address the issue of seed sourcing and species selection (Lamb, 2018). Due to its naturalness, affordability, and simplicity, natural regeneration is an attractive strategy for restoration. However, it highly depends on the climate, soil, disturbances, former land use and dispersal of seeds and sprouts (Chazdon & Guariguata, 2016; Nunes et al., 2017). In some cases, soil conditions are unfavorable for tree establishment due to continual burning, grazing activities or competition with herbaceous vegetation. Assisted regeneration can be used to help trees regenerate in these conditions by removal or reduction of barriers to natural regeneration such as prevention of fire, grazing, wood harvesting and protection of mother trees (FAO, http://www.fao.org/forestry/anr/en/). Natural regeneration and assisted regeneration methods do not require as much financial sources as active restoration methods. Consequently, they are preferred at large-scale. Although natural regeneration method comes as the first preference, if the ecosystem is significantly altered or the biodiversity is under high-risk, then active restoration may play a major role (Mansourian & Dudley, 2010). Active restoration can help to control floristic diversity in the initial phases and can be particularly helpful to achieve more rapid recovery of endangered species (Chazdon & Guariguata, 2016). Conditions such as compaction of soil, high level of fragmentation and species invasion are examples of profound changes in the ecosystem structure that require active interventions that can be achieved through planting nursery-grown seedlings or by direct seeding to support forest regeneration. Although financially it is a more demanding method (Nunes et al., 2017), in certain circumstance active restoration may provide certain environmental benefits more rapidly than waiting for natural regeneration to get established. In particular, artificial regeneration can favor a faster recovery of soil fertility and of soil physical properties. It can also attract wildlife to the site and may create conditions that enable native species to get established later on in the succession, when the conditions of the sites have improved (Cunningham et al., 2015).

Natural and artificial regeneration can be also mixed (Nunes et al., 2017). A combination of methods requires considerations of the conditions of different plots, to apply the appropriate method according to their characteristics.

Choosing the most appropriate method for restoration requires a local diagnosis. Site conditions, landscape contexts, management goals and available financial resources.

### 1.6. Biodiversity Concerns: Species Diversity, Nativeness and Conservation Status

FLR can contribute to biodiversity at different levels: genetic diversity, species diversity, and ecosystem diversity. Genetic diversity refers to within-species diversity and is at the base of species adaptation to local conditions and future environmental conditions (EUFORGEN, http://www.euforgen.org/forest-genetic-resources/why-do-they-matter/). FLR approaches imply decisions on tree species diversity to be used (e.g., monospecific or mixed-species tree stands), sometimes with considerations on what the species selected can contribute at the landscape level (Beatty et al., 2018).

Restoration methods that include plantation (artificial regeneration and a mixture of artificial and natural regeneration) influence the genetic diversity of the future stand depending on how seed sourcing is organized. The monoculture plantation is the practice of planting a low diversity of species, usually with an industrial perspective to answer the demand for provisioning ES such as timber production, or other ES that can enhance financial benefits such as carbon sequestration. Although monospecific plantations may not support biodiversity, if well planned and integrated at the landscape scale, they may contribute to enhance local livelihoods (Chazdon & Guariguata, 2016). Multi-species plantation (mixed-species plantation) method refers to the plantation of a wide diversity of tree species that can assist biodiversity and generate a wide range of ES as compared to monocultures.

FLR also contributes to the reintroduction and conservation of threatened tree species by providing suitable habitat for them (Beatty et al., 2018). Based on the views of many authors (Benayas et al., 2009; Bremer & Farley, 2010; Hall, Ashton, Garen, & Jose, 2011; Hartley, 2002); use of native tree species is preferable. Native species can assist in genetic diversity preservation and provide an ideal habitat for local wildlife. According to Suárez et al. (2012), when properly managed, FLR done with native species can provide diversified goods, be more sustainable and resistant to pests and diseases. Nevertheless, this is also dependent on the objectives of intervention. It is important to review what choices regarding tree diversity are made in ongoing FLR activities and to assess to what extent FLR projects contribute to conservation of biodiversity.

### 1.7. Drivers of tree species selection

If the restoration project is based on tree planting, selection of tree species and seed sources require careful consideration since the future achievement of restoration goals is directly related to these initial choices (Thomas et al., 2017). Species should be planted ensuring a balance of socioeconomic goals and biodiversity objectives in the landscape (Montagnini, 2010).

FLR practices that aim to support food security should focus on increasing the density of trees that provide edible products and support livelihoods, through income generation. Besides, trees can increase resilience for shocks caused by changes in the market or climatic conditions (Kumar, C. et al., 2015; Reed et al., 2017). In the case that FLR initiative focuses on climate change mitigation, species that produce extensive biomass and enhance carbon sequestration are chosen. Considering regulating ES, tree species that have deep, extensive fibrous roots and provide soil protection from water erosion are targeted. Soil protection from wind erosion requires tolerant species, especially the trees in the windbreaking zone may have roots that expand laterally. Restoring soil fertility is possible by planting nitrogen-fixing tree species to improve soil nitrogen. In general, the species with deep roots can adapt to infertile soil and enhance soil properties. In order to achieve pollination of agricultural crops, a diversity of tree species is necessary to provide habitat, pollen, and nectar for pollinators (Lamb, 2018). To ensure provision of cultural ES, species preferred by local communities based on traditional knowledge, (usually multipurpose trees) are favored or species with aesthetical/recreational value (e.g., species with particular leaf shapes and colours). If those cases where FLR practitioners are more concerned with ecological conservation or restoring the habitat for wildlife through planting, then project tends to plant a wide diversity of native species (Lamb et al., 2012). Besides the socio-economic and ecological objectives, selection of tree species in FLR also depends on the availability of proper seeds and seedlings (Jalonen et al., 2014; Jalonen, Valette, Boshier, Duminil, & Thomas, 2017).

### 1.8. Food Provision in Forest Landscape Restoration

Forests are vital for nutrition in various ways: They provide edible products and supply also certain ES which help to stabilize food systems such as habitats for biodiversity, pollination, water and climate regulation, soil protection, nutrient cycling (Jamnadass & McMullin, 2015; Millennium Ecosystem Assessment, 2005). They assist the quality of agrarian landscapes by restoring soil fertility, they provide shade and protect agricultural crops from extreme temperatures. Forests also reduce soil water loss by evaporation and transpiration, prevent wind erosion and keep the topsoil in dry areas contributing to ameliorate conditions for the cultivation of other species with nutrition aims. In the upper steep areas with strong rainfalls, trees decrease the risk of erosion by stabilizing the soil and keeping nutrients; and consequently assisting agriculture and food security (FAO, 2011b). In addition to regulating services, forests enhance nutrition by supplying fuelwood for cooking and providing food from trees.

Those trees that have edible parts can contribute to the diversity of people's diets and help them intake significant nutrients (Vira et al., 2015). Through planting a variety of tree species that reflect nutritional diversity for humans, FLR can significantly contribute to complement agricultural commodities and to achieve more nutritious diets (Vinceti et al., 2013), enhancing food and nutritional security (Jamnadass & McMullin, 2015). Food from the forests is derived from certain tree species that yield edible parts with nutritional value for people. These parts can be fruits, seeds, nuts, edible oils and leaves that answer nutritional demands of humans. Although forest foods are not a solution to combat global hunger, they help filling nutrient gaps, widening choices for food consumption and contributing to food supply especially in vulnerable times due to lean seasons or disturbances. Edible products from trees in particular enhance nutritional quality of the diet as they are a source of significant micronutrients such as iron, vitamin A, vitamin C, vitamin B9 and calcium (Asher & Shattuck, 2017).

This brings up the question of how different FLR initiatives are tackling food provisioning around the world.

## 1.9. Tree species selection: who decides?

There are plenty of approaches to support the species selection process. Restool (http://www.restool.org/en/) is an example of a tool developed for the restoration of tropical dry forests in Colombia. The tool assists in selecting tree species for planting and provides the best combination of tree species, depending on the conditions of the planting site, restoration goals, and species' traits that match the needs and favor adaptation to the site (Thomas et al., 2017). Other approaches for species selection can be based on plant functional traits (e.g. legume species to increase N fixation), that is, a consideration of linkages between certain species, their roles in the ecosystem and generation of ES (Charles, 2018). Another option is a selection based on genetic diversity focusing on characteristics associated with different tree provenances (Janishevski et al., 2015). The Framework Species Method suggests a mixture of indigenous tree species with high survival rate, rapid growth, shade provision for other plants and attraction of wildlife (Wangpakapattanawong, Tiansawat, & Sharp, 2016). However, the species selection process is not only technical. It is also crucial to consider cultural perceptions, social benefits, and approval of local stakeholders. Local people are essential to be a part of the species selection process (Meli, Martínez-Ramos, Rey-Benayas, Carabias, & Ewald, 2014), because they are the primary witnesses of their forest area degradation and those who may identify potential benefits of restored ecosystems and livelihood possibilities derived from trees (Basnett, Elias, Ihalainen, & Valencia, 2017). In addition, only if local people are given voice on the implementations of an FLR, they would support the restoration efforts and natural resources sustainably (Galabuzi et al., 2014), sharing their local knowledge; which would lead to improved livelihoods and improvement of local economies (Besseau et al., 2018). An example has been provided by Sayer (2010): a government-initiated restoration project faced opposition by local people in Vietnam since tree species planted were not meeting the needs of local people who were not be committed to the project efforts in the long term. Therefore, participatory approaches are necessary also during species selection (Sacande & Berrahmouni, 2016) to involve local knowledge, experience and wisdom on the management and use of natural resources (He, Ho, & Xu, 2015; Maradiaga & FAO Guatemala, 2015; Florencia Montagnini, Suárez Islas, & Santana, 2008). In order to ensure engagement of local communities, FLR needs to consider a wide range of local socio-economic demands such as contributing to poverty alleviation by creating livelihood opportunities or enhancing food security through planting tree species that supply edible products to improve diets of local people.

The information about who takes the decision on tree species selection is critical for the long-term acceptance and engagement of local communities in restoration projects.

There may be more vulnerable subgroups within the communities that are marginalized due to age, ethnicity, religion, social classes, and mostly gender. Due to legal and cultural barriers, the rights of women on the land and trees are often limited. These barriers cause inequalities and discriminations that continue damaging global sustainable development. This issue is also considered by SDG 5 – Gender Equality, for women and their rights for equal participation in decision making and equal rights on resources (Basnett et al., 2017). Therefore, even if local communities are given a voice for the FLR decisions, it is necessary that gender aspects are addressed at the same time. According to Broeckhoven & Cliquet (2015), gender aspects are vital in restoration for two main reasons: firstly for enhancement of human rights and gender equality, secondly for improvement of effectiveness and efficiency of restoration. A restoration project should be gender-responsive by not only improving the women voice in decision-making but also enhancing their livelihoods and access to resources and services equally by men and women, ensuring an adequate identification of stakeholders and maintenance of equality in the landscape (IUCN, 2017) and taking into account interests and knowledge of both men and women and distributing the restoration benefits equally (Basnett et al., 2017).

The involvement of women during the species selection process has been mentioned in different studies. In the example of Suárez et al. (2012), within the local community involved in species selection, the ratio of women participation was limited to 20%. A larger-scale analysis would be necessary to understand how gender issues are addressed in FLR projects and derive guidelines from cases that follow best practices.

### 1.10. Forest Landscape Restoration Practices

There are reports on FLR practices made at various levels: from the local level to global meta-analysis. Local-level studies usually analyze FLR focusing on one or a few locations. For example, Shaw (2019) addressed biodiversity, namely tree species diversity, native and threatened species used in FLR in southern Brazil. Similarly, Lu et al., (2017) focused on the evaluation of native tree species by describing their common names and uses for addressing restorations efforts in southwest China. An FLR project in central Veracruz, Mexico (Suárez et al., 2012) analyzed local people’s preferences and perceptions during tree species selection. Additionally, there are several studies focusing on restoration practices at the regional level. For instance, Romijn et al., (2019) focused on objectives, restoration methods and scales of restoration projects in Latin America and the Caribbean region through databases gathered from NGOs and governmental bodies and interviews. Appanah (2016) examined Asian case studies from China, Indonesia, Myanmar, Nepal, Thailand, the Philippines, and Viet Nam. Furthermore, Kumar, C. et al. (2015) compiled FLR experiences from seven countries including Brazil, Burkina Faso, Ethiopia, Ghana, Guatemala, the Philippines, and Viet Nam looking in particular to the nutritional benefits of the projects to humans. A WWF report provided information on characteristics of projects in Bulgaria, Armenia, Azerbaijan and Georgia, China, Madagascar; Malaysia, New Caledonia, Paraguay, Portugal, Tanzania and Viet Nam, in terms of geography, main goals of projects and involved actors (Mansourian & Vallauri, 2014). Global-scale analyses were made on the relationship between restoration and biodiversity (Bremer & Farley, 2010), (Benayas et al.,2009), and there were also global reviews on goals adopted (Hallett et al., 2013) and main methodologies used in FLR (Meli et al., 2017).

Overall, the aspects examined in these studies are presented in the table below. This list is a sample example of the different experience documented in the literature, that aims to give a sense of the range of themes addressed.

**Table 1: Existing studies that analyzed FLR practices**

| Author | Approach | Area | Topics covered by each study |
|---|---|---|---|
| (Romijn et al., 2019) | Project documents | Regional | Project goals, restoration methods, carbon storage, climate change mitigation |
| (Shaw, 2019) | Survey/Interview | Local | Tree species diversity, seed production in nurseries |
| (Jalonen et al., 2017) | Online Survey | Global | Project goals, native trees, seed availability and seed sourcing |
| (Paula Meli et al., 2017) | Meta-analysis | Global | Restoration methods and comparison of them |
| (Lu et al., 2017) | Case Study | Local | Selection of native trees, survival and growth of tree species |
| (Appanah, 2016) | Case studies | Various countries | Selection of native trees, actors involved actors and their roles |
| (Kumar, C. et al., 2015) | Case Studies | Various countries | Food provided from trees, economic valuation of benefits |
| (Mansourian & Vallauri, 2014) | Case studies | Various countries | Native tree species, lessons learnt from past restoration experiences |
| (Hallett et al., 2013) | Meta-analysis | Global | Classification of restoration goals |
| (Suárez et al., 2012) | Case Study | Local | Local people in species selection, cultural importance and scarcity |

| | | | |
|---|---|---|---|
| (Bremer & Farley, 2010) | Meta-analysis | Global | Diversity of native species, biodiversity in different land types |
| (Benayas et al., 2009) | Meta-analysis | Global | FLR effects on and ES, biodiversity in different land-uses |

These studies can help understanding how FLR activities can be distinctive depending on local dynamics. Nevertheless, the studies listed do not include a complete picture of native and threatened species, their nutritional uses and species selection processes. There is a dearth of studies addressing the nutritional benefits of FLR at the global level.

### 1.11. Research Questions of the Thesis

Some of the gaps emerging from the literature have become the focus of the research questions addressed in this study:

1: Where are restoration projects located, which forest ecosystems are targeted and what are the main objectives of restoration projects globally?

2: Which restoration methods are adopted by the restoration projects around the world?

3: How do the diversity, nativeness and conservation status of planted tree species vary within restoration projects?

4: Which ES are considered during the species selection process? How do FLR projects address nutritional benefits?

5: Which actors are involved in species selection? To what extent do restoration projects include local women during tree species selection?

## 2. METHODOLOGY

### 2.1. Questionnaire

To answer the research questions, a survey on FLR practices was undertaken. A questionnaire was prepared and made available on a platform called SurveyMonkey, a cloud-based platform for online survey development. The questionnaire was directed to different FLR stakeholders: managers, coordinators, NGOs and research agencies relating to FLR, through a link sent via e-mail. A link to the survey past distributed via email to a roster of forest restoration practitioners. The e-mail was drafted with a brief summary of the objectives of the study and the organizations (see Appendix-1 for e-mail template) responsible for it, the University of Lisbon, Bioversity International, and Associação Natureza Portugal / WWF. The respondents were informed about the duration of the questionnaire and about the deadline for submission.

The respondents were informed that their participation to reply to the questionnaire was voluntary. They were also informed that all their answers would be analyzed anonymously. Participants were also given an option to receive the final report of the study. In case of a positive answer to this last question, they would have to leave behind their contact details. to receive the final report.

There were different types of questions: 1) closed questions (if the answer was yes, clicking to the related box, if the answer was no, leaving the box unticked), 2) questions with multiple choices (predefined) and 3) questions with open text box for specific responses (e.g. country of the project). Multiple-choice questions were those that respondent needed to choose only one valid reply among various options. Check-box questions were those questions that more than 1 option could be chosen as valid answers. Multiple-choice and checkbox questions included an option entitled ‘other’ for the respondents to fill in any specific information when necessary.

The questionnaire was divided into 5 main groups of questions: The 1$^{st}$ section asked information about the characteristics of each project: location, width, life span, dominant climate and vegetation, owner of the land and project funding source, causes of D&D and main objectives. The 2$^{nd}$ section asked restoration methods applied. The 3$^{rd}$ asked the number of tree species planted by the project, by hectare and in total. The 4$^{th}$ section was about species names of planted tree species, their nativeness and edible parts. The 5$^{th}$ section asked about the tree species selection process in terms of participation of different actors (see Appendix-2 for a copy of the questionnaire).

For open questions with pre-defined answers, the various options for responses were adapted from the terminology used by Beatty et al., (2018); Mansourian & Vallauri (2014) and Romijn and Coppus (2018). Based on the respondents' answer to the question asking about the approach used for forest regeneration, if they indicated the options 'natural regeneration' or 'assisted regeneration', they would be excluded from filling the questions on tree planting and they would be redirected to contact details question at the end of the survey.

The questionnaire had to be as short as possible and the questions should be clear and encouraging for the respondent to continue answering all questions in the survey.

### 2.2. Pilot Survey

Before distributing the survey to a large group of contacts, a pilot test was conducted to check the questionnaire's level of feasibility and clarity to the respondent and the time needed to complete it. Four extra questions were included only for the pilot survey, asking the respondents feedback on the questionnaire, asking if the length of the questionnaire was fair or too long, how much time it took them to fill it and if the questions were easy to understand and practical to fill or not. The last question was a comment box question asking respondents their comments on the points that could be improved. The pilot survey was available only in English.

Publicly available e-mail contact information of five active projects from different countries was found through Google searches. The pilot survey was sent to the e-mail of forest restoration practitioners found online with a request to kindly contribute to the study by filling the attached online form. It was explained how their e-mail contacts were found. The pilot test was conducted on Monday 15th of April 2019 and closed on the 21st of April, at 21:00 (CET+1) hours.

### 2.3. Data Collection

After the pilot survey, some parts of the questionnaire were improved as follow: the 3rd group of questions was turned into a filter to redirect respondents according to their answers to the question about the total number of tree species planted by the project:

- If the number of tree species planted was between 1-3, the respondents would see 3 questions on tree species names and their nutritional uses, 1 of them was compulsory.
- If the number of tree species planted was between 4-6, the respondents would see 4 questions on tree species names and their nutritional uses, 2 of them were compulsory.
- If the number of tree species planted was between 7-9, the respondents would see 5 questions on species names and their nutritional uses, 3 of them were compulsory.
- If the number of tree species planted was more than 10 species, the respondents would see 10 questions on tree species names and their nutritional uses; 4 of them were compulsory.

The main objective of this setup was simply not to expose respondents with a low number of tree species to a long list of questions. The mandatory modality for some fields was introduced to reduce the risk of null replies. Furthermore, the English questionnaire was translated to French, Spanish and Portuguese to facilitate access by FLR managers in various countries. Target populations were FLR practitioners at management level. Neither the number of respondents nor their contacts were directly known to send the questionnaire. Therefore, the survey was sent to a roster of NGOs, networks, large-scale regional programs and they were asked for assistance in spreading the survey among their local contacts, therefore the number of actual candidate respondents was not known. The survey was shared on the 24th April 2019 the following initiatives:

- Asia Pacific Association of Forestry Research Institutions (APAFRI)
- Consultative Group on International Agricultural Research (CGIAR) Research Programme on Forests, Trees, and Agroforestry
- Regional forest genetic resources networks in Asia, Latin America and Sub-Saharan Africa (APFORGEN, LAFORGEN, and SAFORGEN)
- Global Trees Campaign
- International Institute for Sustainable Development (IISD)
- International Model Forest Network (IMFN)
- International Union of Forestry Research Organizations (IUFRO)
- the Secretariat of the Convention on Biological Diversity (CBD)

Between 24th April and 30th April, the number of replies obtained was not sufficient to conduct an analysis, therefore a second launch of the survey took place.

### 2.4. The second stage of data collection

Further efforts were applied to disseminate the survey to a larger network and by using different channels. Additional contacts were found by looking at accessible documents of the World Bank, Global Environment Facility (GEF), United Nations Framework Convention on Climate Change that helped to identify stakeholders. When contact information was publicly available in these documents, they were used to send the survey. The survey was also distributed to international and regional initiatives related to forests, conservation, carbon sequestration and certification (e.g UNCCD, Bonn Challenge, UN-REDD, UNFCCC Clean Development Mechanism and Forest Stewardship Council). The database created by Romijn and Coppus (2018) was used to derive information on focal points responsible for forest restoration projects conducted in Latin America. Moreover, further organizations related to FLR were identified through Google searches. Many combinations of keywords were used in the search engine, some examples are: ‘forest restoration’, ‘forest landscape restoration’, ‘forest restoration NGO’, ‘forest restoration projects’, ‘forest restoration initiatives’, ‘tree-planting organizations’. This research yielded details from many projects and organizations (e.g WRI, Botanic Gardens Conservation International, Fruit Tree Planting Foundation and projects of WWF). They were contacted through openly available e-mail addresses and they were kindly asked reply to the questions if the survey was pertinent and related to their activities. These initial contacts were also asked to further distribute the survey to their contacts in the field of FLR. As an additional method to e-mailing, fora related to FLR were used to reach professionals in the restoration sector. The International Institute for Sustainable Development (IISD) maintain different online fora on biodiversity, forests, and climate; these were targeted to spread the news about the survey (see Appendix-3 for the full list of organizations and platforms contacted). Mostly, multiple e-mails were sent to an organization’s various departments related to FLR. In total, approximately 200 e-mails of relevant contact were gathered and targeted. The e-mails addressed to the identified contacts included links to the survey in different languages sent from the e-mail address forest.restoration.global@gmail.com. The emails were sent on Tuesday 30th of April 2019. The deadline was responding was set on Friday 30thof May Friday 09:00 PM (GMT+1) hours.

### 2.5. Double-checking the quality of the obtained responses about tree species

The replies to the survey received were organized in a dataset and checked for quality. The first objective of the analysis was to observe the robustness of the responses about tree native ranges and edible parts of the trees consumed by comparing the responses with the information available in other openly accessible databases (e.g. Global Biodiversity Information Facility (GBIF), World Agroforestry Centre). Secondly, the names of the tree species planted were searched in the IUCN Red List of Threatened species to determine their conservation status. These analyses were done only for the species names and did not include the responses in which the name of the tree species included only a specification of the genus and not of the species. The second objective of the quality check of responses was based on a comparison of the information obtained through the survey on tree species native range and edible parts consumed, and the information available in openly accessible online databases to verify the alignment of the responses with other accessible sources. Some degree of misalignment was expected as on the types of use of a certain tree species are context-specific and may vary from place to place. Cross-checks of native ranges were done through the databases of Global Biodiversity Information Facility (GBIF) and the database of Botanic Gardens Conservation International (BGCI) (https://tools.bgci.org/global_tree_search.php).

For what concerns the information about edible uses of tree species, the data derived from the survey were double-checked with the databases of the World Agroforestry Centre (http://db.worldagroforestry.org//species) and of the Plants For A Future (PFAF) (https://pfaf.org/user/Default.aspx) initiative.

### 2.5.1. Identification of conservation status of planted tree species through IUCN Red List of Threatened Species

The survey did not include a direct question on the conservation status of the tree species reported. Therefore, an analysis of the conservation status of tree species planted by FLR projects was conducted by searching the names of these species in the IUCN database of threatened species, the IUCN Red List of Threatened Species (https://www.iucnredlist.org/about/background-history).

The IUCN Red List of Threatened Species is a tool to access information concerning the global extinction risk of plant, animal and fungi species, by dividing species into 9 categories (Table 1) Each tree species was attributed to a category based on the categories identified by IUCN.

**Table 2: Definitions of categories in the IUCN Red List of Threatened Species**

| | |
|---|---|
| Data Deficient | Lack of information on abundance and/or distribution |
| Least Concern | Widespread and abundant species |
| Near Threatened | Possibility to go under the threatened category in the future |
| Vulnerable | High risk of extinction in the wild |
| Endangered | Very high risk of extinction in the wild |
| Critically endangered | Facing extreme risk of extinction in the wild |
| Extinct in the wild | Survival in cultivation, captivity or as a naturalized population outside its range |
| Extinct | The last individual of the species has died |

Derived from (IUCN, 2012).

Critically endangered, endangered and vulnerable species are called ‘threatened’. The categorization for critically endangered, endangered and vulnerable are made through certain criteria defined by IUCN, such as reduction of population size, geographical range and extinction risk within 10 years or three generations (IUCN, 2012).

## 3. RESULTS

In total 55 responses were received: 38 replies from the English questionnaire, seven replies from the Spanish version, six replies from the Portuguese version, two from the French version, two from the pilot survey (two responses were fully completed in the test phase so they were included in the analysis).

Responses were downloaded from SurveyMonkey into Excel. Afterward, all data were translated into English and merged into one file. Eight responses were largely incomplete, so they were excluded, and this brought the total number of valid responses to 47, each from a different FLR project. Although well diversified with regard to location, scale, forest type and project objectives, the 47 responses may not be sufficiently representative at the global scale, therefore results were treated without generalizing on the global scale. The information collected on projects' characteristics was gathered and summarized into most frequent 4 replies per question as well as their frequency by Table 3. The responses that can be utilized to answer the research questions of the thesis will be discussed further.

**Table 3: Most selected 4 replies on the main characteristics of the FLR projects analyzed and the number of projects falling in a different type**

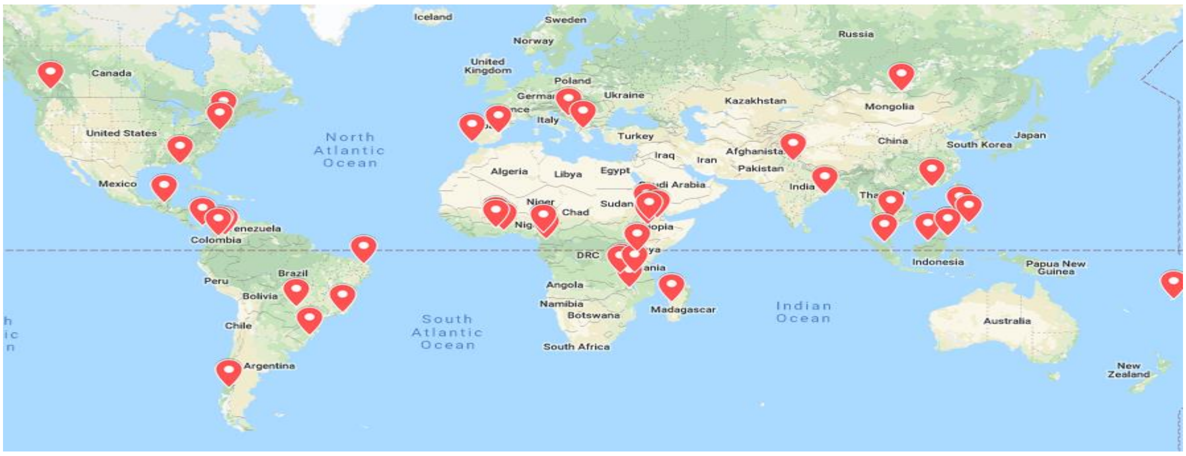
| | | | | | **Total number of most cited 4 options** |
|---|---|---|---|---|---|
| **Geographic characteristics** | Mountain (14) | Plain (10) | Hill (6) | Plateaux, Valley (5 each) | 40/47 |
| **Dominant climate** | Tropical (30) | Temperate (7) | Arid (3) | Mediterranean (3) | 43/47 |
| **Area/ Scale** | 10-100 ha (13) | 100-1000 ha (8) | 20000 - 100000 ha (5) | <5 ha<br>1000- 5000 ha<br>5000- 20000ha<br>>100000 ha<br>(4 each) | 42/47 |
| **Project age** | >10 years (18) | 1-3 years (9) | 3-5 years<br>7-10 years<br>(5 each) | <1 year (4) | 41/47 |
| **Timespan Envisaged duration of the project** | >15 years (12) | 5-10 years (9) | <5 years (6) | 10-15 years (3) | 30/47 |

| | | | | | |
|---|---|---|---|---|---|
| **Ownership of the restored land** | Public (23) | Community (13) | Private, smallholders (10) | Private, large landowners<br>Private, leased (5 each) | 56/47 Multiple answers |
| **Source of funding** | Governmental/ Public administration (16) | International Organization or Initiative (14) | Non-Governmental Organization, Company (10 each) | Private Forest Owner (7) | 57/47 multiple answers |
| **D&D factors** | Unsustainable agriculture practices (12) | Logging for timber (8) | Other (8) | Fire (4) | 32/47 |

**Question 1: Where are restoration projects located, which forest ecosystems are targeted and what are the main objectives of restoration projects globally?**

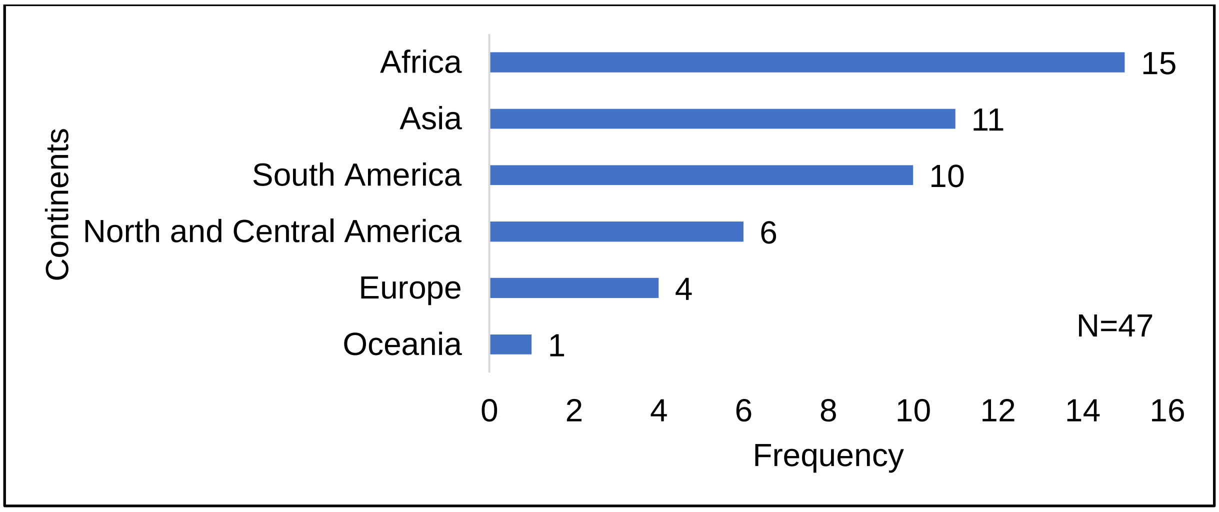
Figure 1 shows the geographical distribution of the projects described in the 47 survey responses. They are located in 27 countries, spreaded in all continents, mainly in tropical countries. The map was created based on responses that specified countries, regions and municipalities. Some respondents indicated that the project took place in various municipalities. In that case, only information about the region was used to mark the project on the world map. Although the majority of replies were from the tropical zone in Africa, Asia, South and Central America, also temperate regions were covered (e.g. Canada, northern parts of the United States of America). Both hemispheres were represented.

**Figure 1: Geographic distribution of the FLR projects from which responses to the survey were obtained**



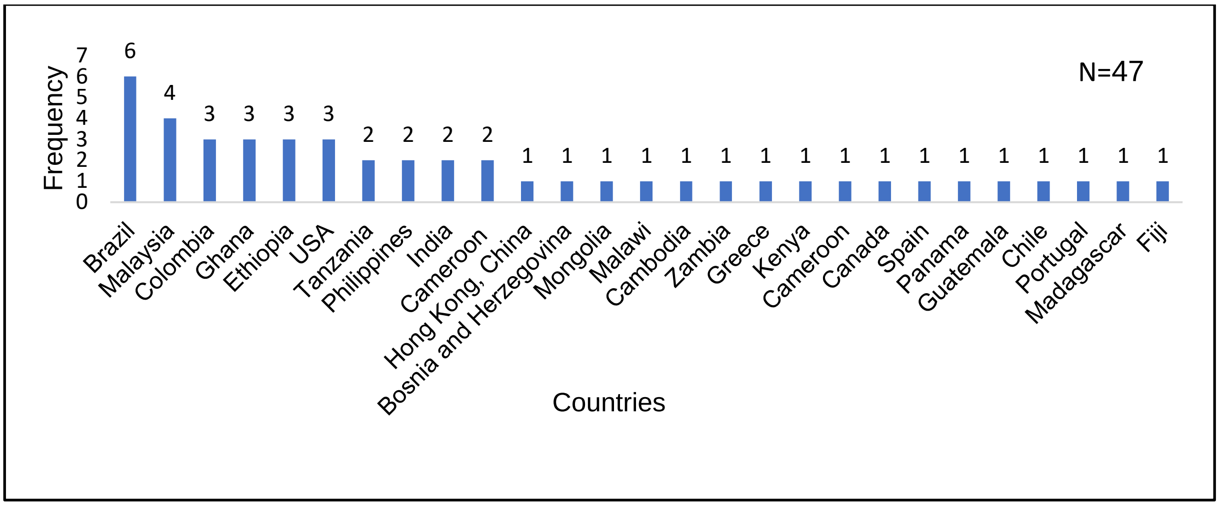

The majority of FLR projects were located in Africa (15 replies; 32% of total responses), followed by Asia (11 replies; 24%) and South America (10 replies; 23%). The remaining 11 replies were from other continents: 6 projects were located in North and Central America, 4 in Europe and 1 project in Oceania. and Oceania (Figure 2).

**Figure 2: Number of survey responses in each continent**



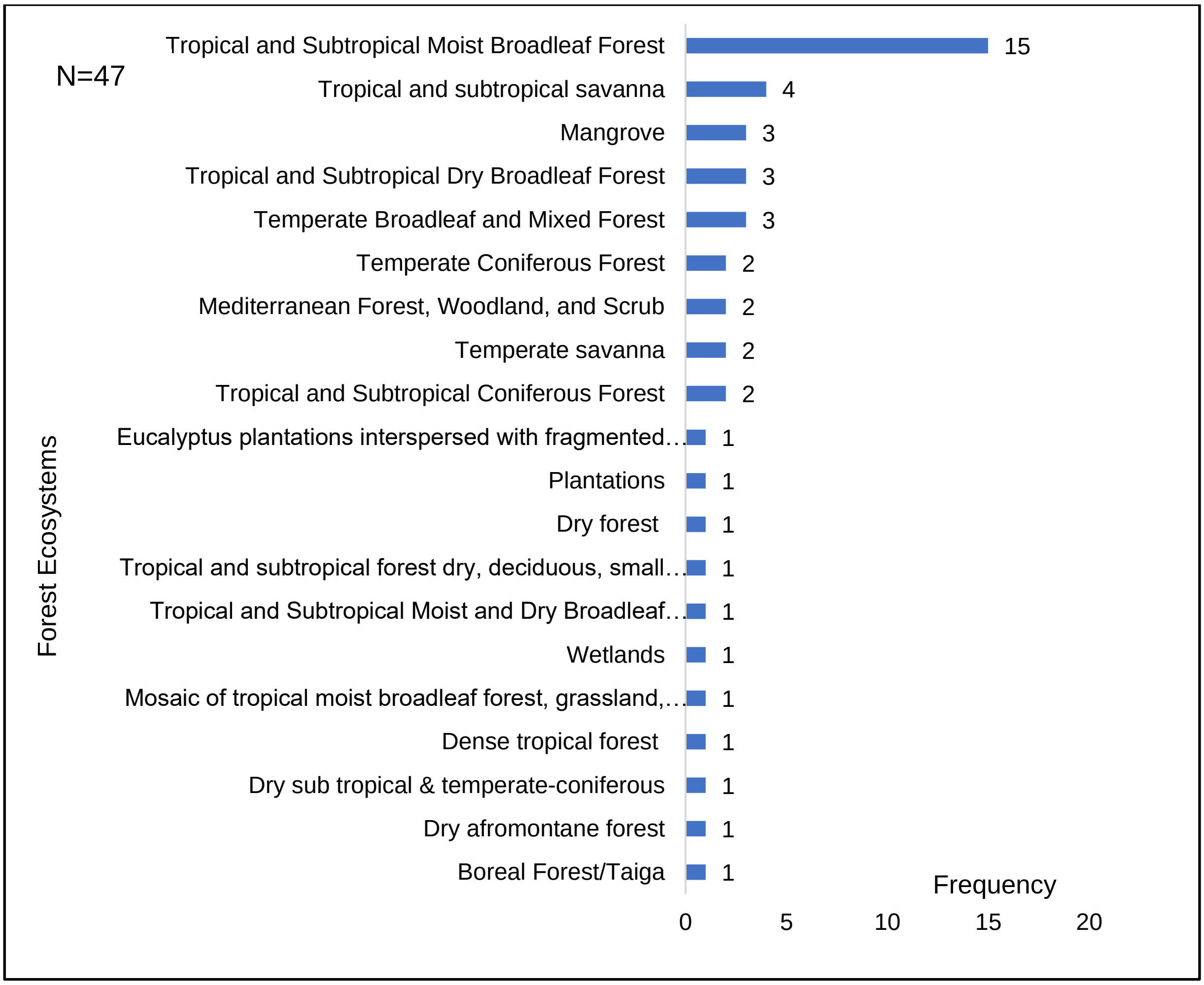

Responses were well distributed across countries. Very few countries were represented by multiple responses (Figure 3). The highest number of multiple responses were from Brazil (6), followed by Malaysia (4). All other countries included had fewer responses (17 countries with a single response).

**Figure 3: Number of responses received from FLR projects in different countries**



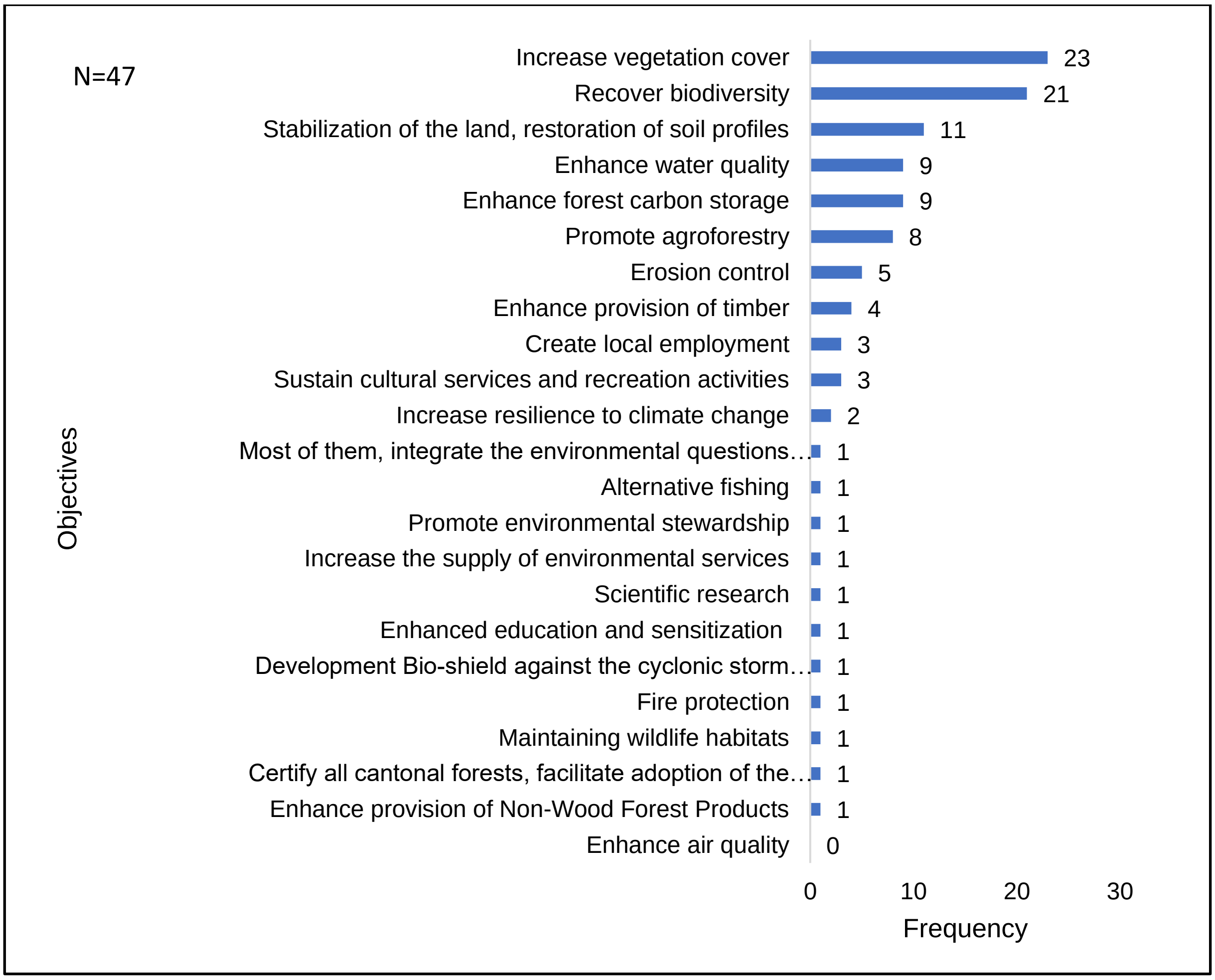

In terms of ecosystem types, responses from 47 projects were received. The majority of FLR projects reached (15) were implemented in tropical and subtropical moist broadleaf forests. The second most frequent ecosystem type was tropical and subtropical savanna, with 4 replies. Mangroves, tropical and subtropical dry broadleaf forests, and temperate broadleaf and mixed forests were covered by 3 projects each. All other forest types represented had fewer responses, several ones only 1 response. Some of the responses were written specifically in the ‘other’ category by respondents. Therefore, these ecosystems are mostly corresponding to 1 reply (Figure 4).

**Figure 4: Types of forest ecosystems and the number of FLR projects aimed at restoring them**




With regard to the main objectives of the FLR projects reached, 109 responses were received (multiple responses per each of the 47 FLR projects were provided) (Figure 5). "Increasing vegetation cover" was the most selected response, followed by "Recovering biodiversity". Improvement of soil, water quality and carbon sequestration were the following most considered objectives. Timber provision, generation of local employment and recreational activities were adopted less frequently. Some examples of the replies that respondents added under the 'other' category are; certification and developing FSC standards, awareness and education, scientific research, enhanced education and sensitization, and promoting environmental stewardship. This category also included responses showing that some projects focused on climate change effects, such as 'development of bio-shield against the cyclonic storm for coastal communities close to sea mouth' or 'increase resilience to climate change and fire protection'.

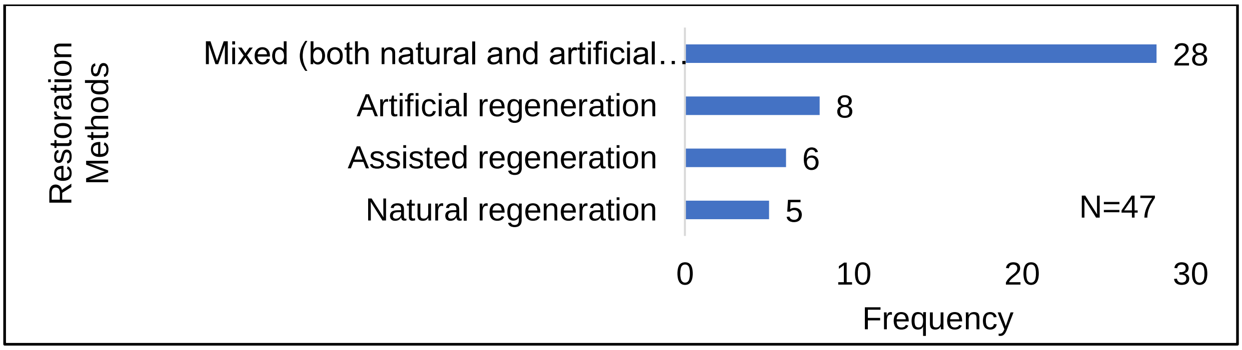
**Figure 5: Most commonly adopted goals of FLR projects and number of projects that apply them**




**Question 2: Which restoration methods are adopted by FLR projects around the world?**

From a total of 47 projects, the majority (28 projects; 59%) apply a mixture of artificial and natural regeneration. The second most selected response was ‘artificial regeneration (8 replies (Figure 6).

**Figure 6: Number of FLR projects that applied different restoration methods**

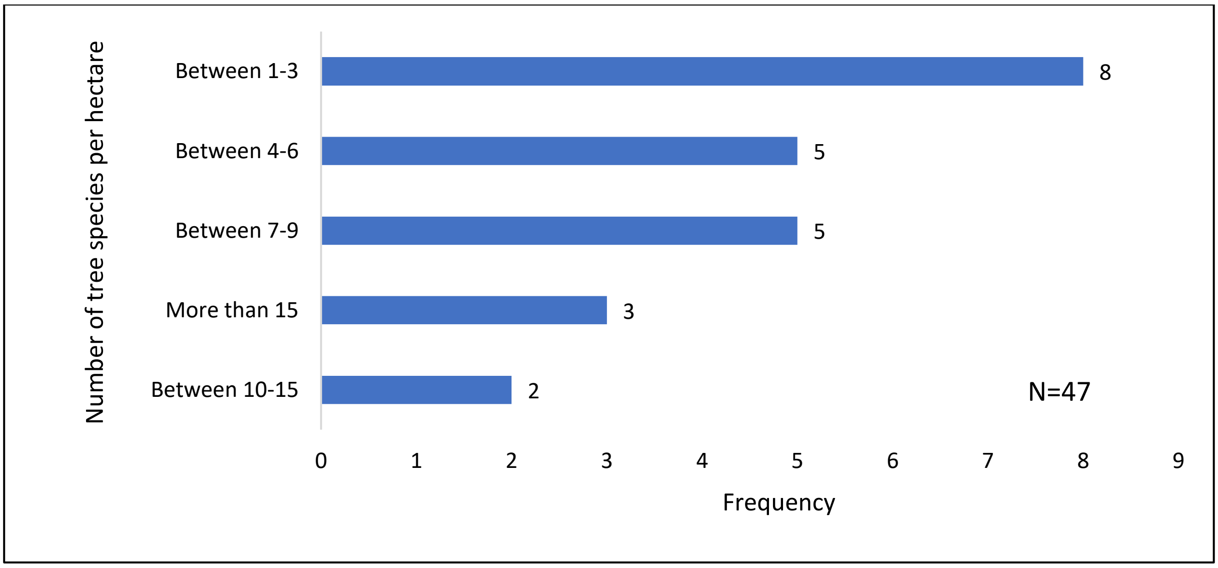


**Question 3: How do the diversity, nativeness and conservation status of planted tree species vary within restoration projects?**

There were 144 replies from 24 projects reporting tree species used in FLR projects. Some of these responses were not tree species (e.g rose flower, bamboo and Dodonaea viscosa) therefore they were excluded in the analysis, so the actual list of tree species planted includes 141 tree species. For the analysis of native tree percentage and nutritional benefits, the total number of 141 was considered. For some of the 141 tree species in the list, only the genus is reported and not the full species name (e.g., *Guibourtia spp., Cassia spp., Vitex spp., Eucalyptus spp., Jacaranda spp. Hibiscus spp., Myrcianthes spp., Moringa spp., Dipterocarpus spp., Albizzia spp.*) so the tree species with full scientific name reported are 131 (see Appendix-4 for the full list of tree species and genera names). For the analysis of conservation status, only the 131 tree species of full scientific names were compared with the IUCN Red List of Threatened Species.

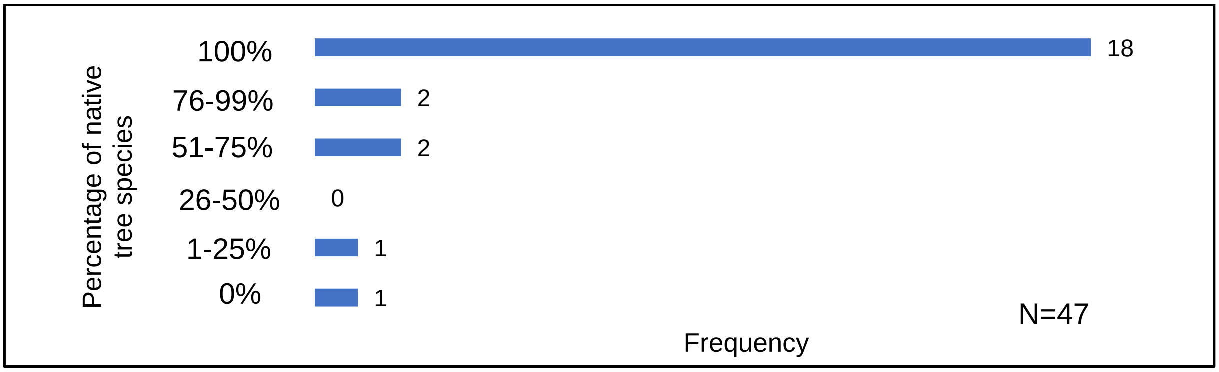
In order to make a comparison of species diversity consideration among projects, the number of species planted by the project per hectare was considered since the scales of the projects varied and it was more appropriate to group projects according to a common measure. From 36 projects that involve tree planting, only 23 projects provided valid replies to this question. According to their answers, between 1-3 species plantation was most frequently applied. An increasing number of tree species planted was associated with a decreasing number of projects (Figure 7).

**Figure 7: Number of species planted per hectare and associated FLR projects**



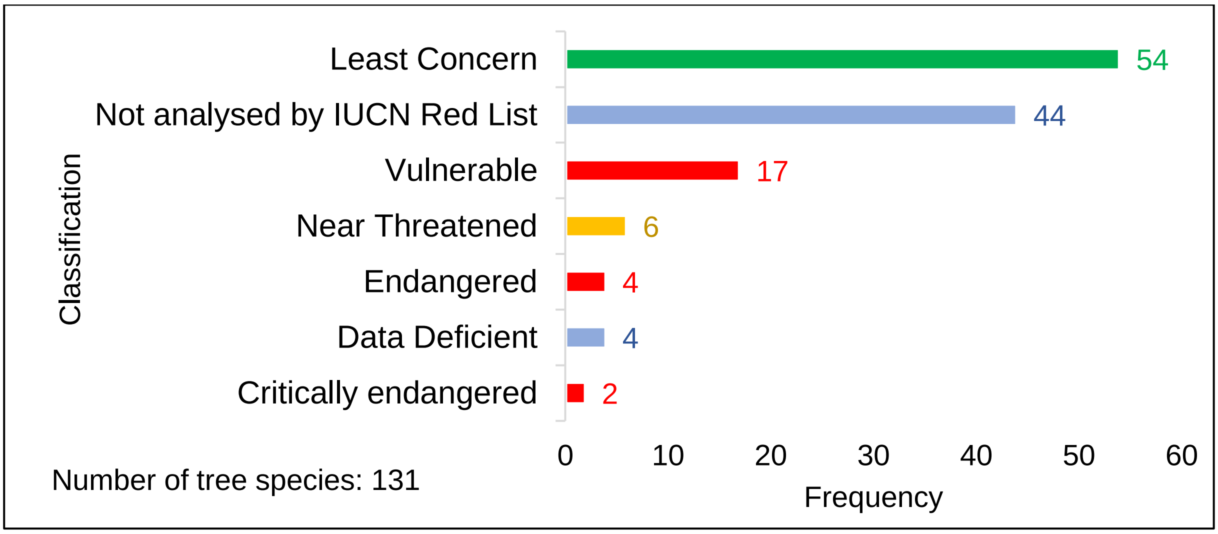
According to the statements of the respondents, out of 141 items in the list of species and genus planted, 127 of them (90%) were native in the country where the FLR project took place, while 14 (10%) were exotics. The degree of inclusion of native tree species on the total of tree species planted was converted in percentage intervals (Figure 8). From the total 47 projects, 24 valid replies were received. A total of 18 projects provided a list of species that were all native in the project area. Four projects indicated a list of species that were consisting of natives but the ratio of them was more than 50%. Only 2 projects planted less than 50% ratio of native species, one of them provided a species list consisted of solely exotic species (Figure 8). This result is based on the main tree species listed by the respondents during the survey, and in most cases, the species list they provided was not the complete portfolio of the project (the survey recorded only the 10 most planted tree species; in addition it is possible some respondents did not fill the list due to lack of time or information).

**Figure 8: Different percentages of native trees and the number of projects planting those**




The majority of tree species planted in FLR projects (54 species) were categorized as Least Concern whilst 23 species (17% of the 131 total species planted) were classified as threatened, consisting of Critically Endangered (2), Endangered (4) and Vulnerable (17) (Figure 9). Conservation status of 48 species could not be identified, 4 species were marked as Data Deficient in the IUCN database and 44 species were not analyzed by the Red List.

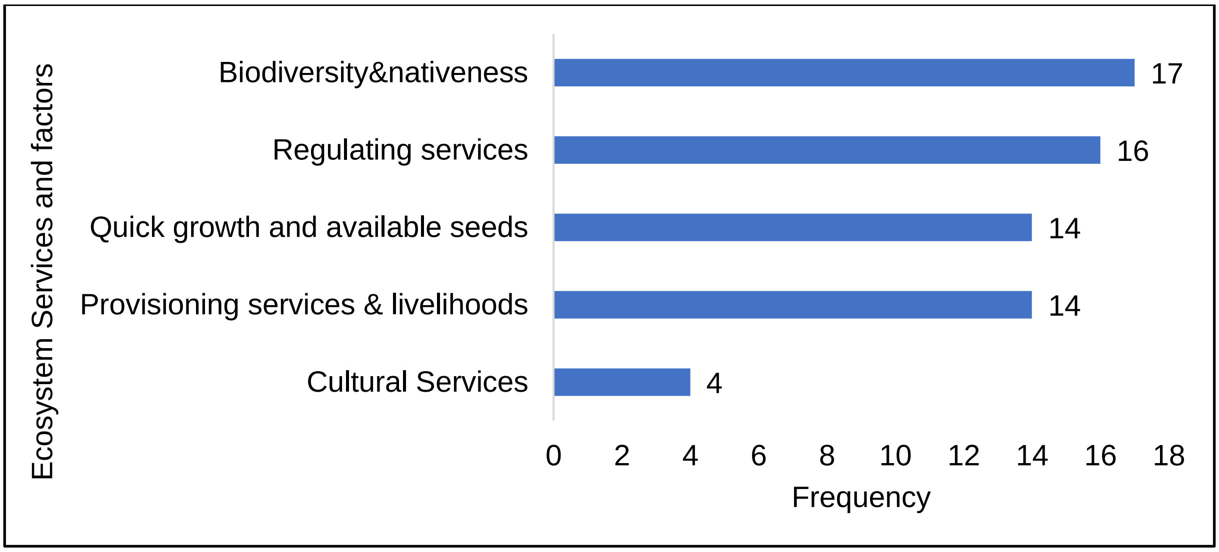
**Figure 9: Classifications of tree species in IUCN Red List Threatened species and number of tree species in each category**




**Question 4: Which ES and factors are considered during the species selection process? How do FLR projects address nutritional benefits at the global level?**

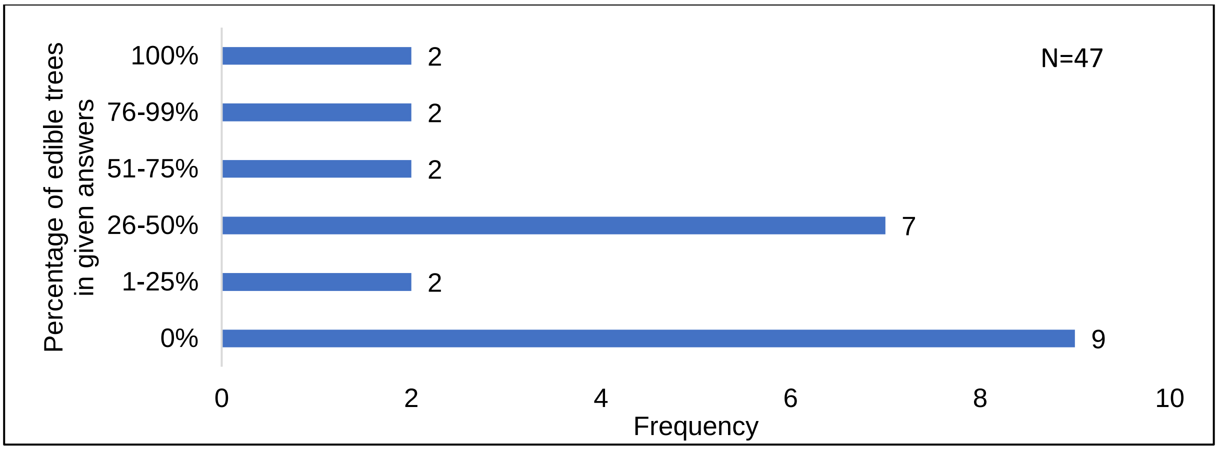
A total of 65 replies were received regarding the factors considered during the selection of the indicated tree species (Figure 10). Enhancing biodiversity and being native in the project country were the most selected reasons to select tree species to plant. The second most selected reason was the provision of regulating services, including soil and water protection, climate control, carbon sequestration and pollination. Quick growth and availability of seeds; as well as provisioning services such as timber and food were the following factors. Cultural services, including aesthetic value, cultural importance and knowledge for local people were less frequently considered in the species selection process.

**Figure 10: Factors and ES considered during the species selection process**



To examine the potential role of FLR projects to nutrition security, an analysis was carried out to assess how many planted tree species supplied edible parts. According to the information received from respondents, from the total of 141 planted tree species, 43 species provided edible products and 5 additional tree genera for which detail at the level of species was not available in the answers. When the percentages of edible tree species planted in each project were assessed it was observed that majority of the projects did not plant any nutritious tree and within the projects that planted edible trees, the proportion of them remained low (Figure 11). These results were based on survey responses and may not be exhaustive but provide a sense of proportions.

**Figure 11: Percentage of edible tree species in a project and the corresponding number of projects**




These 43 tree species and 5 genera planted supply different edible products (such as fruits, leaves, seeds, nuts and oil), fruits are the most commonly consumed edible part (supplied by 22 trees from this subset of tree species). Some tree species provide more than one edible products. For example, *Irvingia gabonensis* (known as wild mango, African mango) provides both edible fruits and nuts and *Parkia biglobosa* provides both fruits and nuts. Seven species provide only leaves and 6 provide only oil. A total of 10 species supply nuts, 6 species provide edible seeds (Table 12). Although the species can not be extracted from this information, the names of genera are: *Eucalyptus spp., Hibiscus spp., Jacaranda spp. Moringa spp.* and *Vitex spp.*

**Table 4**: **Information obtained from the survey on edible tree species, their native range and uses**

| Scientific names of Tree Species and Genus | Project Country | Native? | Fruits | Leaves | Seeds | Nuts | Oil |
|---|---|---|---|---|---|---|---|
| Tree Species | | | | | | | |
| *Acacia mangium* | Philippines | | | Yes | | | |
| *Acer saccharum* | USA | Yes | | | | | Yes |
| *Annona muricata* | Philippines | Yes | Yes | | | | |
| *Arbutus Unedo* | Portugal | Yes | Yes | | | | |
| *Arbutus unedo* | Spain | Yes | Yes | | | | |
| *Artocarpus heterophyllus* | Philippines | Yes | Yes | | | | |
| *Azadirachta indica* | Cameroon | | | | | | Yes |
| *Bauhinia variegata* | India | Yes | Yes | | | | |
| *Brosimum alicastrum* (Ramón maya nut) | Guatemala | Yes | | | Yes | | |
| *Carya ovata* | USA | Yes | Yes | | | Yes | |
| *Castanea sativa* | Portugal | Yes | | | | Yes | |
| *Castanopsis carlesii* | Hong Kong, China | Yes | | | | Yes | |
| *Castanopsis concinna* | Hong Kong, China | Yes | | | | Yes | |
| *Cedrela odorata* | Tanzania | | | | | | Yes |
| *Dacryodes edulis* | Cameroon | Yes | Yes | | | | |
| *Durio zybethinus* | Malaysia | Yes | Yes | | | | |
| *Gnetum africanum (Eru)* | Cameroon | | | | Yes | | |
| *Eucalyptus maidenee* | Tanzania | | | Yes | | | |
| *Euterpe edulis* | Brazil | Yes | Yes | | | | |
| *Grivelia robusta* | Tanzania | | | Yes | | | |
| *Inga edulis* | Brazil | Yes | Yes | | | | |
| *Milicia excelsa* (Iroko) | Cameroon | | | Yes | | | |
| *Irvingia gabonensis* | Cameroon | Yes | Yes | | | Yes | |
| *Laurus nobilis* | Portugal | Yes | | Yes | | | |
| *Mangifera indica* | Philippines | Yes | Yes | | | | |
| *Mangifera indica* | Cameroon | Yes | Yes | | | | |
| *Parkia biglobosa* | Ghana | Yes | Yes | | Yes | | |
| *Parkia speciosa* | Malaysia | Yes | Yes | | | | |
| *Pentaspodon motleyii* | Malaysia | Yes | | | Yes | | |
| *Phyllanthus emblica* | India | Yes | Yes | | | | |
| *Pimienta gorda maya allspice* | Guatemala | Yes | | | Yes | | |
| *Pinus patula* | Tanzania | | | | | Yes | |
| *Prunus africana* | Cameroon | Yes | Yes | | | | |
| *Quercus alba* | USA | Yes | | | | Yes | |
| *Quercus bambusifolia* | Hong Kong, China | Yes | | | | Yes | |
| *Quercus edithiae* | Hong Kong, China | Yes | | | | Yes | |
| *Quercus rubra* | USA | Yes | | | | Yes | |
| *Shorea macrophylla* | Malaysia | Yes | | | | | Yes |

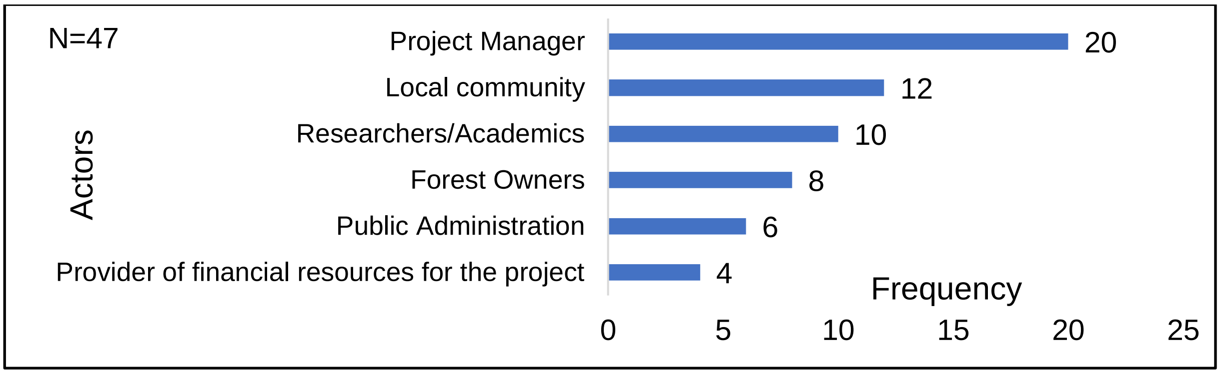
| | | | | | | |
|---|---|---|---|---|---|---|
| *Sonneratia apetala* | India | Yes | Yes | | | |
| *Tapirira guianensis* | Brazil | Yes | Yes | | | |
| *Terminalia belerica* | India | Yes | Yes | | | |
| *Terminalia chebula* | India | Yes | Yes | | | |
| *Vitellaria paradoxa* | Cameroon | | | | | Yes |
| Genus | | | | | | |
| *Eucalyptus spp.* | Malawi | Yes | | | | Yes |
| *Hibiscus spp.* | Cameroon | | | | Yes | |
| *Jacaranda spp.* | Tanzania | | | Yes | | |
| *Moringa spp.* | Cameroon | | | Yes | | |
| *Vitex spp.* | Cameroon | Yes | Yes | | | |

The cell "Yes" under the column of "Native where planted" means the respondent marked this species as native in the project site, while empty cells indicate cases where the respondent did not choose the option "native". Similarly, for the columns of edible parts, respondents selected the species that have edible products and indicated for each the edible parts. If the cell under edible certain parts is empty, the species are not marked as providers of those edible parts.

**Question 5: Which local stakeholders are involved in species selection? To what extent do restoration projects involve local women in the identification of tree species to be planted?**

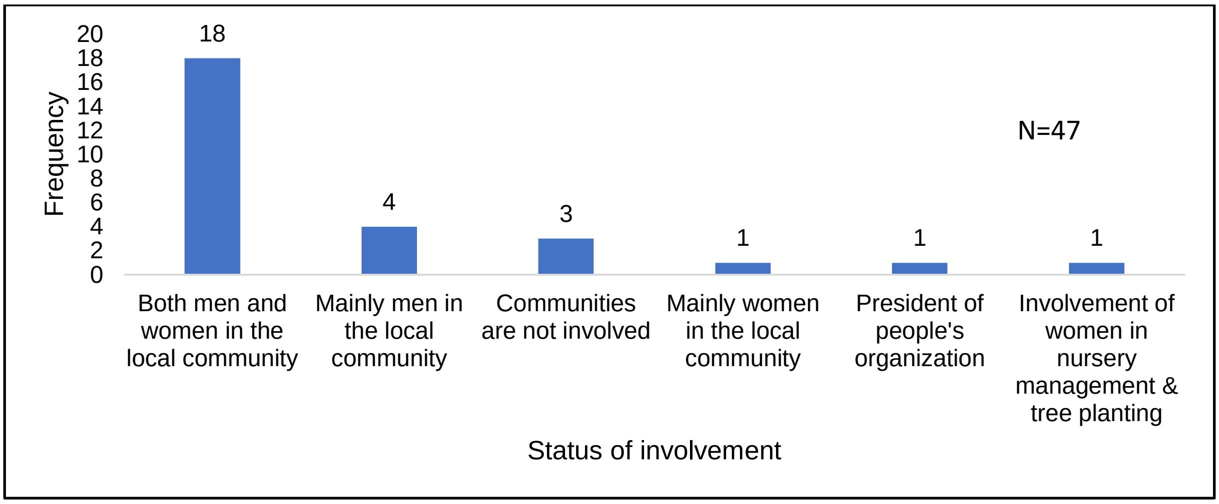
Since some projects provided multiple answers to this question, 60 survey replies were provided regarding local stakeholders involved in tree species selection. In the most frequent case, tree species selection was the responsibility of the project manager, followed by the local community and researchers/academics. The least selected actor was the provider of financial sources of the project (Figure 12).

**Figure 12: Different actors and the number of projects that included them in species selection**



From 28 valid answers received on the local community involvement, in 18 projects both men and women were involved in tree species selection. In the case of two replies falling in the category 'other' women were increasingly involved in nursery management and tree planting and 'species selection was made by the president of peoples' organization' (Figure 13).

**Figure 13: Status of men and women involvement in local communities and the number of projects apply each option**



## 4. DISCUSSION

**Question 1: Where are restoration projects located, which forest ecosystems are targeted and what are the main objectives of restoration projects globally?**

Based on the sample analyzed the present study suggests that FLR projects are mainly concentrated in tropical countries. This may be an expected result considering the critical levels of forest fragmentation (e.g. 130 million fragments, Taubert et al., 2018), deforestation (e.g. 5.9 million hectares/year between 2000 and 2010, Achard et al., 2014) and biodiversity decline (Bradshaw, Sodhi, & Brook, 2009) in the tropics. Other research findings indicate that FLR is mostly practiced in humid areas as compared, for example to drylands (Romijn et al., 2019).

Results also show that a high proportion of FLR projects address restoration of tropical and subtropical moist broadleaf forests but focusing on a wide range of different ecosystem services (e.g. climate control, carbon sequestration, timber, and food provisioning) and that most of the projects addressed multiple goals such as enhancing biodiversity, creation of local employment and promotion of agroforestry, as recorded also by other studies (e.g. Meli et al., 2017). Increasing vegetation cover and improvement of biodiversity were the most common objectives at the global scale in this study as observed by Romijn et al., 2019 in Latin America and the Caribbeans. There are links between FLR and the Sustainable Development Goals (SDGs). Most selected objectives can be linked with SDG 15 – Life on Land (Mansourian, 2018) on protecting and restoring the ecosystems while halting biodiversity loss. Other FLR objectives included: improvement of land and soil, enhancing water quality, forest carbon storage and promotion of agroforestry. Improvement of land and soil and agroforestry can be linked with SDG 2 – Zero Hunger, since by assuring these objectives, FLR may improve food security and ameliorate livelihoods. Improvement of water quality links with SDG 6 – Clean Water and Sanitation, while carbon storage relates to SDG 13 – Climate Action. Additionally, timber and NWFP provision and creation of local employment may reflect SDG 1 – No Poverty and SDG 8 – Decent Work and Economic Growth.

A meta-analysis by Hallett et al., 2013 has shown a majority of FLR projects addressed ecological concerns (e.g. presence of native species), including ecosystem functioning (e.g presence of different or specific functional groups). However, these authors contend that few projects addressed ecosystem stability (e.g elimination of threats, resilience). This confirms the main thesis findings on that goals frequently adopted by FLR were related to ecological improvements. As a different approach to Hallett et al., 2013, this study showed that regulating ES (e.g. improving soil and water quality, erosion control) are frequently pursued during FLR.

Conversely, social goals were less frequently addressed: the creation of local employment, sustaining cultural services or recreation were selected by fewer projects. Additionally, economic goals such as the provision of timber and promotion of agroforestry are more frequent (but still not the majority), in agreement with the suggestion of Hallett et al., 2013 that social goals need to be more integrated into FLR plans.

Meli et al., 2017 and Hallett et al., 2013 highlighted the importance of defining targets in restoration to assess whether projects have achieved their objectives; however, restoration successes are not easy to evaluate (Vallauri et al., 2010). In the present thesis aspects of monitoring and evaluation were not addressed. However, the data collected through the survey showed that examples of measurable goals on biodiversity could include biodiversity indices such as tree survival rates whilst provisioning of ES may be assessed using indicators of timber, food and NTFPs productivity. The most commonly referred goal ('increasing vegetation cover') could be monitored more easily than other targets. The relation between tree species and project goals is also an important aspect to evaluate.

**Question 2: Which restoration methods are adopted by the restoration projects around the world?**

The decision on which restoration method to use requires an understanding of ecological processed such as forest regeneration (Williams-Linera et al., 2011). According to the findings from this study, the majority (59%) of FLR initiatives used a mix of natural regeneration and artificial regeneration. This is in agreement with Reid, et al. (2018), who suggested that natural regeneration (passive restoration) and active restoration are not competing methods. Instead, a mixture of approaches can be used according to different local needs and availability of resources. A combination of natural and artificial regeneration can also balance the cost of tree planting. Depending on the conditions of the land aimed to be restored, plantations may be needed in highly degraded patches without sufficient natural regeneration, while the remaining area may be naturally regenerated (Brancalion et al., 2016; Nunes et al., 2017). The present thesis found out that in practice, 76% of the projects involve tree planting. This finding is not surprising considering that tree planting enables to select appropriate species to deliver specific ES (Lamb, Erskine, & Parrotta, 2005).

Practices that involve planting trees raise costs and consequently the need to generate financial incentives and develop cost-benefit analyses. There are different international mechanisms that can fund restoration activities. The Clean Development Mechanism (CDM) is an example (Benayas et al., 2009). CDM was developed under the Kyoto Protocol to support projects that reduce carbon emissions in developing countries. These projects earn certified emission reduction (CER) credits, 1 credit per tonne of $CO_2$, that can be traded or bought by industrialized countries to contribute their targets of reduction of $CO_2$ emissions (UNFCCC, https://cdm.unfccc.int/about/index.html). Another international mechanism that finances restoration projects is Global Environment Facility (GEF), an international partnership consisting of international institutions, civil society organizations and private actors from 183 countries that aim to address global environmental issues such as land degradation. The World Bank and Forest Investment Fund are other international financial source providers. On the national and local scale; governments, local governments and local NGOs can provide funds for restoration projects. These types of mechanisms complement approaches such as Payment for Ecosystem Services that may contribute to promote recovery or maintenance of ES (Brancalion et al., 2012; Bugalho & Silva, 2014; Bugalho et al., 2016). Considering the current results showing that almost 80% of the projects surveyed involved tree planting, there is a need to properly consider costs and funding implications as a possible constraining factor for future FLR projects. In addition to financial considerations, limits in tree seed supply of high quality and in sufficient quantities, setting up a nursery sector that can sustain large scale operations are also important issues that FLR projects may face.

**Question 3: How do the diversity, nativeness and conservation status of planted tree species vary within restoration projects?**

It has been observed that plantations may contribute to biodiversity if established on degraded lands but will negatively affect biodiversity if replacing native forests (Benayas et al., 2009; Bremer & Farley, 2010).

According to Lamb et al., (2005), restoration practices based on planting mostly use tree species from three genera: *Pinus spp, Eucalypts spp, and Acacia spp.* Also, Hartley (2002) and Davis et al (2012) state that restoration activities globally have been limited to only a small number of species. The findings in this thesis showed that several other tree species are planted in the FLR projects surveyed. However, the thesis concords with Lamb et al (2005) in pointing to the fact that the diversity of tree species planted per hectare is low (1-3 tree species). The number of projects that plant high diversity of tree species per hectare is limited.

Results in this study show that the majority of projects have a high ratio of planted native to exotic tree species, in contrast to other authors (Davis, Jacobs, & Dumroese, 2012; F Montagnini, 2001) who state that restoration practices promote exotic species. Considering that a mixture of native trees improves biodiversity (Bremer & Farley, 2010; Cunningham et al., 2015), results indicate that biodiversity recovery is being addressed by analyzed restoration projects. Meanwhile, according to survey responses, 2 projects reported to planted high ratio of exotic to native species. This may be explained by factors such as lack of markets, unavailability of seeds, the need for seeds to be collected or uncertainty of plant growth rates (Florencia Montagnini, 2010).

A high number of tree species names derived from the survey were not in the IUCN List of Threatened Species database. Since these species are not yet included in the database, their conservation status could not be identified. This is expected, considering only about 2.5% of the world's estimated 1.8 million species have been assessed by the IUCN Red List so far (Vié et al., 2008). According to questionnaire responses, the majority of the species planted by FLR projects are not endangered while 23 species out of the total of 141 (131 tree species and 10 genera) planted were classified as threatened. Planting threatened tree species is an effort towards the conservation of biodiversity. However, the proportion of threatened species used in FLR seems to remain low, as found by Volis, 2019, who states that most restoration activities include goals addressing human needs (e.g. improvement of soil quality, erosion control), rather than threatened species.

As a result of the cross-checks of received responses through the databases of GBIF and BGCI, it was observed that some survey replies on the native range did not match with the information available in databases. For example, one reply by an FLR project in the Philippines on *Acacia auriculiformis* states that this species is native in Philipines, while according to BGCI, it is native to Oceania. Another example of mismatch was detected for *Inga uruguensis* Hook. & Arn, which according to the response is native to Brazil, although BGCI reported its native range as Argentina and Paraguay. In total, 25 species were found as exotics according to the databases, in contrast to the number of 14 exotic species gathered by the responses.

**Question 4: Which factors and ES are considered during the species selection process? are FLR projects addressing nutritional benefits?**

Species selection is a multi-faceted key decision during FLR depending on project goals (Reubens et al., 2011). Improving biodiversity and the use of native species was the most considered factor during species selection suggesting that improvement of biodiversity was a common FLR objective. Regulating ecosystem services was the second most important element addressed during species selection. Seed availability and rapid growth was the third most selected determinant during tree species selection decision. Jalonen et al., 2014 found that availability of forest reproductive material (e.g. seeds, seedlings) were the most important reasons for species selection and a more robust driver rather than species functional characteristics or conservation status of the species. Thesis results reveal that seed availability is a frequent concern when considering species selection for FLR projects overcoming goals such as provisioning or cultural services provided by trees. Rapid tree growth is also an important factor considered during species selection (Cunningham et al., 2015) together with eventual financial gains through quicker provision of timber (He et al., 2015) or carbon sequestration.

Only a low number of projects addressed nutritious trees in FLR, with the ratio of trees that provide nutrition to non-nutritious trees remaining very low. FLR may enhance food provisioning for local people, contribute to a supply of tree products during lean season and diversify nutritious intake (Kumar, C. et al., 2015). There is indeed a high diversity of trees providing edible products in Africa, Asia and Latin America (Dawson et al., 2014) that could potentially be used in FLR projects contributing to increase food security.

Thesis results show that the nutritional value of FLR trees come mostly from fruits. This is an expected finding, considering about 50 percent of the fruit consumed worldwide is coming from trees (Powell et al., 2013). Chiwona-Karltun et al., (2017) highlight the role of wild fruits value as vital forest products both for nutrition and income generation when local people can collect, consume and sell them. Fruits are sources of nutrition to intake micronutrients and vitamins, as well as a source of livelihoods and income generation for local people which help to access other food types.

When double-checked through online databases, however, some inconsistencies were observed between these resources and the information stated by the respondents. For example, a reply on *Artocarpus heterophyllus*, also known as jackfruit, states that only nuts are edible. However, according to the World Agroforestry database, the pulp of young fruit is cooked as a vegetable and the pulp of ripe fruit is eaten fresh or can be added into local dishes in Indonesia. According to this source, the seeds of this species can also be eaten after boiling or roasting, dried and salted as nuts, or they can de be grounded to make flour for baking. The seeds are sources of vitamin A, sulfur, calcium and phosphorus. Another example of a discrepancy of replies and databases on edible parts is observed with *Brosimum alicastrum*, known as the breadnut. According to the response received, this species provides edible seeds, whereas, the data in the Useful Tropical Plants Database (http://tropical.theferns.info/) shows that in addition to seeds, also its fruit has a sweet, thin edible flesh surrounding the large seed. Also, when the trunk is cut, the milky latex resembles cream, and when diluted with water, it can be used as a substitute for cow's milk. These kinds of incoherencies are expected since many species can be consumed as edible ingredients in some food or condiments in one site and not in others, according to local customs. The cases where no confirmation found with the responses were collected through the whole list, and in total 34 species were found as nutritious according to the databases, in contrast to the number of 43 edible species gathered by the responses and the distribution of edible parts showed some differences.

**Question 5: Which actors are involved in species selection? To what extent do restoration projects include local women during tree species?**

Suárez et al., (2012) state that species selection is often made by project managers or technicians and that their decisions rely on scientific literature or own experiences. This may exclude the involvement of local people and their traditional knowledge for tree species selection ultimately leading to a lack of support from local communities to FLR projects. The current study did not cross-check with the local communities on their involvement in species selection since reaching them at the global scale was not feasible. Nevertheless, the anonymous analysis was made in order to reflect realistic replies. Findings of current investigation both match and mismatch with this statement: according to the results of this thesis, project manager does cover the highest proportion in species selection, however, the second-highest group that is involved in the decision are the local communities.

Despite indications of some authors (e.g. Broeckhoven & Cliquet, 2015) that gender equality is not properly addressed in restoration practices and most of the restoration projects are gender blind, thesis findings show that a majority of projects involved local communities ( both men and women) during the species selection process. Nevertheless, four projects did not involve women, which may potentially cause future negative impacts as species may not be appropriate for all forest users (WWF UK, 2012) and benefits may not be adequately distributed among men and women (IUCN, accessed on 10 June 2019). Despite these few examples, it can be stated that FLR activities comply with SDG 5 (Gender equality) in the species selection process.

## 5. CONCLUSIONS

Every forest restoration effort has its own unique dynamics without a single defined path for implementation. Therefore, learning from a wide variety of management practices adopted by FLR projects worldwide is crucial to diagnose the diversity of potential restoration approaches and how these approaches may meet global restoration goals.

The current analysis revealed that restoration projects are applied to recover degraded ecosystems and are mostly found in tropical and subtropical moist broadleaf forests in tropical areas. Considering the pressures that dryland biomes are exposed to (e.g. desertification, climate change effects and biodiversity loss) (FAO, 2015), increasing FLR efforts in those dry regions has the potential to contribute to mitigating food insecurity and poverty for people living in those areas, and therefore to sustainable development.

The results of this study also support that the majority of restoration projects use a combination of natural and artificial regeneration.

Results also show that FLR target a wide range of objectives including biodiversity conservation. However, to better address biodiversity conservation, the use of a higher tree species diversity and threatened tree species in FLR projects that are based entirely or partially on artificial regeneration could be considered.

For engaging local people, results also suggest the need to integrate social aspects and human well-being in FLR. Increasing nutrition security, for example, may play an important role in this aspect. FLR efforts showing the potential of trees in nutrition can contribute to addressing local people's food security and play a motivation role in local people's perception of forest restoration practices.

Results also show that the involvement of local communities to include local knowledge on species and support for the maintenance of restoration initiative could possibly be increased.

The long-term success of FLR projects depends on various implications during different stages. The current study focused on goals and implementations in terms of biodiversity and ES however, it did not include performance assessments. These topics are important and can be explored further in future research projects. Also, efforts should be made to increase the sample and the global database of FLR projects to provide more representative information.

Besides the suggestions derived from the results, the data generated by this study on the tree species, their native areas and edible uses could benefit the species selection process of the future projects as it provides a glance of which species have been planted in various locations.

This information on tree species is also shared with the local communities during species selection and depending on their preferences, this data can help increase awareness of the nutritional value of different trees and therefore increase demand for plantation of nutritious trees.  This thesis also aimed at increasing awareness that FLR, by planting edible trees, can complement agricultural commodities by providing edible products and diversifying diets.

Hopefully, the present study may contribute to a better acknowledgment of FLR as a tool for sustainable development and provide information to better the use of FLR practices addressing global forest restoration goals as well as human well-being and ecological integrity.

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# Appendix-1

**Survey on Forest Restoration Practices**

Dear Mr./Miss. …..,

We have found your contact information through the website of ……. and we are contacting you to ask your collaboration in distributing/ filling an online survey. The survey is on forest restoration practices at a global scale.

We are sending to you the link to an online survey as part of a project that involves the University of Lisbon, School of Agriculture (http://www.isa.ulisboa.pt/) in Portugal and is conducted in collaboration with Bioversity International (https://www.bioversityinternational.org/) and the Associação Natureza Portugal (ANP), the representative of the World Wide Fund for Nature (WWF) in Portugal (https://www.natureza-portugal.org/).

The results of this survey will contribute to a Master thesis focused on assessing some management practices adopted in forest restoration projects globally.

We are kindly asking if you could forward this e-mail to your contacts as widely as possible and help us reaching a large group of forest landscape restoration managers and forestry professionals within your network, or if you have managed a restoration project, we kindly ask you to answer to the questionnaire.

The questionnaire will take approximately 20 minutes to fill in and it is available in different languages. The deadline to respond has been extended to the 15th of May Wednesday 9:00 PM (GMT+1).

English version: https://www.surveymonkey.com/r/Forest_Restoration_En

French version: https://fr.surveymonkey.com/r/Forest_Restoration_Fr

Spanish version: https://es.surveymonkey.com/r/Forest_Restoration_Es

Portuguese version: https://pt.surveymonkey.com/r/Forest_Restoration_Pt

Thank you for your kind contribution in this study!

Best Regards,

Carol Kohen

# Appendix-2

## Survey On Forest Restoration Practices

### 1. General Information

**The survey**

**This online survey is part of a project that involves the University of Lisbon, School of Agriculture (http://www.isa.ulisboa.pt/) in Portugal and is conducted in collaboration with Bioversity International (https://www.bioversityinternational.org/) and the Associação Natureza Portugal (ANP), the representative of the World Wide Fund for Nature (WWF) in Portugal (https://www.natureza-portugal.org/).**

**The results of this survey will contribute to a Master thesis focused on assessing some management practices adopted in forest restoration projects globally.**

**The questionnaire will take approximately 20 minutes to fill in.**

**Participation and Privacy**

**The participation in this survey is voluntary and responses to the questionnaire are anonymous. However, if you wish to receive the key results of the survey, please insert your email address in the optional field "Email Address".**

**Please note that if you supply us with your email address it will be used exclusively to share with you the final results of the survey and upon the completion of this project, on 30th of September, your contact information will be deleted from our records.**

**Thanks for your collaboration in this project.**

**Best regards,**

**Carol Kohen, MSc student, University of Lisbon.**

## Survey On Forest Restoration Practices

### 2. Project characteristics

**Please focus on a forest restoration project in which you are involved and provide the information requested in the questionnaire.**

**In this survey we target both 'forest restoration' and 'forest landscape restoration' projects and we use the definition of 'forest landscape restoration' developed by WWF and IUCN: "a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes".**

* In which country is the project taking place?

* Region/province

* Municipality

* How long ago did the project start?

- <1 year
- 1-3 years
- 3-5 years
- 5-7 years
- 7-10 years
- >10 years
- Other (please specify)

* What is the total expected duration of the project?

- <5 years
- 5-10 years
- 10-15 years
- >15 years
- Other (please specify)

* What is the number of hectares that the project covers?

- <5 hectares
- 5-10 hectares
- 10- 100 ha
- 100- 1000 ha
- 1000 - 5000 ha
- 5000 - 20000 ha
- 20000 - 100000 ha
- >100000 ha
- Other (please specify)

## Survey On Forest Restoration Practices

### 3. Project characteristics

* What is the dominant climate in the project area?

- Temperate
- Arid
- Tropical
- Mediterranean
- Other (please specify)

* What is the dominant vegetation in the project area?

- Tropical and Subtropical Moist Broadleaf Forest
- Tropical and Subtropical Dry Broadleaf Forest
- Tropical and Subtropical Coniferous Forest
- Temperate Broadleaf and Mixed Forest
- Temperate Coniferous Forest
- Boreal Forest/Taiga
- Tropical and subtropical savanna
- Temperate savanna
- Mediterranean Forest, Woodland, and Scrub
- Mangrove
- I do not know
- Other (please specify)

* What are the geographic/orographic characteristics of the project area?

- ◯ Valley
- ◯ Plateaux
- ◯ Mountain
- ◯ Plain
- ◯ Hill
- ◯ I do not know
- ◯ Other (please specify)

* Who is the owner of the land? (Please choose more than 1 option if they apply)

- ☐ Private, smallholders
- ☐ Private, large land owners
- ☐ Private, company
- ☐ Private, leased
- ☐ Public
- ☐ Community
- ☐ Other (please specify)

## Survey On Forest Restoration Practices

### 4. Project characteristics

* What source of funding supports the project? (Please choose more than 1 option if they apply)

- ☐ International Organization or Initiative
- ☐ Governmental/ Public administration
- ☐ Non-Governmental Organization
- ☐ Company
- ☐ Private forest owner
- ☐ Community association
- ☐ Other (please specify)

* What was the main driver of degradation or deforestation in the site to be restored? (Please choose 1 option only)

- ○ Unsustainable agriculture practices
- ○ Logging for timber
- ○ Mining
- ○ Fuelwood collection
- ○ Grazing
- ○ Charcoal production
- ○ Fire
- ○ Climate related pressures (storm, wind, drought, flood)
- ○ Expansion of urban area
- ○ Abandoned land
- ○ I do not know
- ○ Other (please specify)

* What is the main objective of the project? (Select the most important objectives, up to 3 main options)

- [ ] Increase vegetation cover
- [ ] Recover biodiversity
- [ ] Enhance forest carbon storage
- [ ] Enhance provision of timber
- [ ] Enhance provision of Non-Wood Forest Products
- [ ] Promote agroforestry
- [ ] Enhance water quality
- [ ] Enhance air quality
- [ ] Sustain cultural services and recreation activities
- [ ] Create local employment
- [ ] Stabilization of the land, restoration of soil profiles
- [ ] Erosion control
- [ ] Fertilization
- [ ] Remove toxicity from soil or water
- [ ] Other (please specify)

* Please select the approach used for forest restoration

- ○ Natural regeneration
- ○ Assisted Natural Regeneration
- ○ Artificial regeneration
- ○ Mixed (both natural and artificial regeneration)

## Survey On Forest Restoration Practices

### 5. Tree species planted

* How many different tree species are PLANTED in total by the project, in the area?

◯ Between 1-3 ◯ Between 4-6 ◯ Between 7-9 ◯ Between 10-15 ◯ More than 15

* How many tree species are PLANTED on average in by project per hectar?

◯ Between 1-3 ◯ Between 4-6 ◯ Between 7-9 ◯ Between 10-15 ◯ More than 15

◯ Other (please specify)

Survey On Forest Restoration Practices

## 9. Tree species characteristics

**If forest restoration is carried out by planting trees, please indicate in the next section <u>up to 10 most planted tree species</u>, starting from the most planted trees.** For each species, please provide the scientific name and click on the most relevant characteristics. (Please note that with *edible* we mean that it can be eaten by humans).

* **Tree species 1** (please provide its scientific name)

* Please select relevant characteristics (Please note that with edible we mean that it can be eaten by humans)

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 1 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

* **Tree species 2** (please provide its scientific name)

* Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 2 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

* **Tree species 3** (please provide its scientific name)

* Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 3 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

* **Tree species 4** (please provide its scientific name)

* Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 4 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tree species 5** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 5 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Survey On Forest Restoration Practices

## 10. Tree species characteristics

**Tree species 6** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 6 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tree species 7** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 7 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tree species 8** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 8 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tree species 9** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 9 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**Tree species 10** (please provide its scientific name)

Please select relevant characteristics

| | Is the species native to the area? | Does this tree give edible fruits for humans? | Does it give edible leaves for humans? | Edible seeds for humans? | Edible nuts/kernel for humans? | Does it produce edible oil for humans? |
|---|---|---|---|---|---|---|
| Tree species 10 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## Survey On Forest Restoration Practices

### 11. Tree species characteristics

* What was the main motivation to select for planting the tree species listed above? (Please choose the 3 most relevant options below)

- ☐ Seeds are available
- ☐ Grow quickly
- ☐ Provide food
- ☐ Provide timber
- ☐ Provide pollination
- ☐ Aesthetic value
- ☐ Culturally important
- ☐ Climate control
- ☐ Carbon sequestration
- ☐ Soil protection
- ☐ Water protection
- ☐ Enhance biodiversity
- ☐ Provide livelihoods for local people
- ☐ Other (please specify)

## Survey On Forest Restoration Practices

### 12. Selection process

* Who is involved in tree species selection? (Choose up to 3 most relevant options)

- [ ] Project Manager
- [ ] Provider of financial resources for the project
- [ ] Public Administration
- [ ] Researchers/Academics
- [ ] Local community
- [ ] Forest Owners
- [ ] Other (please specify)

## Survey On Forest Restoration Practices

### 13. Selection process

* If local communities are involved in tree selection for planting, please indicate which of the options below is relevant.

Selection of the tree species to be planted is done by:

- ○ Mainly men in the local community
- ○ Mainly women in the local community
- ○ Both men and women in the local community
- ○ Other (please specify)

## Survey On Forest Restoration Practices

### 14. Contact information (*optional*)

Contact Information

**Name**

**Institution**

**Email address**

**Thank you for your participation**

## Appendix-3

AFR 100 initiative

African Union Development Agency (AUDA-NEPAD)

African Wildlife Foundation

Apremavi - Associação de Preservação do Meio Ambiente e da Vida

Atlantic Forest Restoration Pact

Botanic Gardens Conservation International

Collaborative Partnership on Forests

Community Road Empowerment Kenya

Dedicated Grant Mechanism for Indigenous Peoples and Local Communities (DGM)

Department of Soil Science Brazil

Eden Projects

FAO

FAO - Action Against Desertification

Forest Research Institute Malaysia (FRIM)

Forest Stewardship Council

Fruit Tree Planting Foundation

Global Biodiversity Information Facility

Global Environment Facility (GEF)

Global Trees

International Institute for Sustainable Development (IISD) forums of biodiversity, forests, and climate

International Model Forest Network

International Union of Forest Research Organizations (IUFRO)

La Fundación Al Verde Vivo- Colombia

Lastrop- Laboratório De Silvicultura Tropical

Lerf - Laboratório de Ecologia e Restauração Florestal

Nigerian Conservation Foundation (NCF)

Nitidae

Secretariat of Bonn Challenge

Secretariat of  UN- Convention on Biological Diversity

Society For Ecological Restoration

SOS Mata Atlantica

Sosma Brasil

The Brazilian Agricultural Research Corporation

The Ibero-American Model Forest Network (RIABM)

The Nature Conservancy

Turkish Foundation for Combating Soil Erosion, for Reforestation and the Protection of Natural Habitats (TEMA)

UN- Convention to Combat Desertification

United Nations Framework Convention on Climate Change Clean Development Mechanism (CDM)

University of Hohenheim

UN-REDD Programme

WeForest

World Bank - Documents and Reports

World Resources Institute

WWF Argentina

WWF Brazil

WWF Chile

WWF India

WWF Indonesia

WWF Madagascar

WWF Nepal

WWF Peru

WWF Philippines

WWF Singapore

WWF Thailand

# Appendix-4

| Scientific names of Tree Species and Genus | Project Country | Native? |
|---|---|---|
| Tree Species | | |
| *Abatía parviflora* | Colombia | Yes |
| *Acacia auriculiformis* | Philippines | Yes |
| *Acacia mangium* | Philippines | |
| *Acer saccharum* | USA | Yes |
| *Albezia lebbeck* | Malawi | Yes |
| *Alnus acuminata kunth* | Colombia | Yes |
| *Alnus Glutinosa* | Portugal | Yes |
| *Altingia chinensis* | Hong Kong, China | Yes |
| *Aniba perutilis* | Colombia | Yes |
| *Annona muricata* | Philippines | Yes |
| *Apeiba tibourbou Aubl.* | Brazil | Yes |
| *Aphloia theiformis* | Tanzania | Yes |
| *Arbutus Unedo* | Portugal | Yes |
| *Arbutus unedo* | Spain | Yes |
| *Artocarpus heterophylla* | Philippines | Yes |
| *Avicennia marina* | India | Yes |
| *Azadirachta indica* | Cameroon | |
| *Baccharus macrantha kunth* | Colombia | Yes |
| *Bauhinia variegata* | India | Yes |
| *Bridelia micrantha* | Tanzania | Yes |
| *Bruguiera gymnorrhiza* | India | Yes |
| *Calophyllum Braziliense* | Brazil | Yes |
| *Cariniana estrellensis (Raddi) Kuntze* | Brazil | Yes |
| *Cariniana legalis (Mart.) Kuntze* | Brazil | Yes |
| *Cariniana pyriformis* | Colombia | Yes |
| *Carya ovata* | USA | Yes |
| *Castanea sativa* | Portugal | Yes |
| *Castanopsis carlesii* | Hong Kong, China | Yes |
| *Castanopsis concinna* | Hong Kong, China | Yes |
| *Cecropia pachystachya Trécul* | Brazil | Yes |
| *Cedrela fissilis Vell.* | Brazil | Yes |
| *Cedrela odorata* | Tanzania | |
| *Cedrela odorata* | Colombia | Yes |
| *Cercis canadensis* | USA | Yes |
| *Citharexylum mirianthum* | Brazil | Yes |
| *Clathrotropis brunnea* | Colombia | Yes |
| *Copaifera langsdorffii Desf* | Brazil | Yes |
| *Dacryodes edulis* | Cameroon | Yes |
| *Dipterocarpus crinitus* | Malaysia | Yes |

| | | |
|---|---|---|
| *Dryobalanops aromatica* | Malaysia | Yes |
| *Duranta mutisii* | Colombia | Yes |
| *Durio zybethinus* | Malaysia | Yes |
| *Elaeocarpus nintentifolius* | Hong Kong, China | Yes |
| *Embothrium coccineum* | Chile | Yes |
| Eru - *Gnetum africanum* | Cameroon | |
| *Eucalyptus benthamii* | USA | |
| *Eucalyptus maidenee* | Tanzania | |
| *Eugenia Braziliensis Lam.* | Brazil | Yes |
| *Eugenia involucrata DC.* | Brazil | Yes |
| *Eusideroxylon zwagerii* | Malaysia | Yes |
| *Euterpe edulis* | Brazil | Yes |
| *Fraxinus angustifolia* | Portugal | Yes |
| *Gliricidia sepium* | Philippines | Yes |
| *Gmelina arborea* | Philippines | Yes |
| *Gmelina arborea* | Philippines | Yes |
| *Grivelia robusta* | Tanzania | |
| *Heliocarpus americanus L.* | Brazil | Yes |
| *Hopea kerangasensis* | Malaysia | Yes |
| *Inga edulis* | Brazil | Yes |
| *Inga uruguensis Hook. & Arn* | Brazil | Yes |
| Iroko - *Milicia excelsa* | Cameroon | |
| *Irvingia gabonensis* | Cameroon | Yes |
| *Kandelia candel* | India | Yes |
| *Khaya anthotheca* | Malawi | Yes |
| *Laurus nobilis* | Portugal | Yes |
| *Macaranga kilimandscharia* | Tanzania | Yes |
| *Machilus pauhoi* | Hong Kong, China | |
| *Magnolia maudiae* | Hong Kong, China | Yes |
| *Mahogany* | Ghana | Yes |
| *Mangifera indica* | Philippines | Yes |
| *Mangifera indica* | Cameroon | Yes |
| *Meriania nobilis* | Colombia | Yes |
| *Michelia chapensis* | Hong Kong, China | Yes |
| *Mimosa bimucronata* | Brazil | Yes |
| *Mimosa tenuiflora* | Brazil | Yes |
| *Nothofagus betuloides* | Chile | Yes |
| *Nothofagus nitida* | Chile | Yes |
| *Nothofagus pumilio* | Chile | Yes |
| *Ostrya virginianum* | USA | Yes |
| *Paraserianthes falcataria* | Philippines | Yes |
| *Parkia biglobosa* | Ghana | Yes |

| | | |
|---|---|---|
| *Parkia speciosa* | Malaysia | Yes |
| *Pentaspodon motleyii* | Malaysia | Yes |
| *Phyllanthus emblica* | India | Yes |
| *Pimienta gorda maya allspice* | Guatemala | Yes |
| *Pinus elliottii* | USA | Yes |
| *Pinus halepensis* | Spain | Yes |
| *Pinus palustris* | USA | Yes |
| *Pinus patula* | Tanzania | |
| *Pinus pinaster* | Spain | Yes |
| *Pinus strobus* | USA | Yes |
| *Pinus sylvestris* | Mongolia | Yes |
| *Pinus taeda* | USA | Yes |
| *Plathymenia reticulata* | Brazil | Yes |
| *Prunus africana* | Cameroon | Yes |
| *Pseudobombax grandiflorum* | Brazil | Yes |
| *Pterocarpus indica* | Philippines | Yes |
| *Pterocarpus indicus* | Philippines | Yes |
| *Quercus alba* | USA | Yes |
| *Quercus bambusifolia* | Hong Kong, China | Yes |
| *Quercus canariensis* | Portugal | Yes |
| *Quercus edithiae* | Hong Kong, China | Yes |
| *Quercus faginea* | Portugal | Yes |
| *Quercus ilex* | Spain | Yes |
| *Quercus leucotricophora* | India | Yes |
| *Quercus rotundifolia* | Portugal | Yes |
| *Quercus rubra* | USA | Yes |
| *Quercus suber* | Portugal | Yes |
| *Ramón maya nut* | Guatemala | Yes |
| *Rauvolfia caffra* | Tanzania | Yes |
| *Rhizophora apiculata* | India | Yes |
| *Salix atrocinera* | Portugal | Yes |
| *Scheflera abysinica* | Cameroon | Yes |
| *Schinus terebinthifolius* | Brazil | Yes |
| *Shorea contorta* | Philippines | Yes |
| *Shorea leprosula* | Malaysia | Yes |
| *Shorea macrophylla* | Malaysia | Yes |
| *Sonneratia apetala* | India | Yes |
| *Swietenia macrophylla* | Philippines | Yes |
| *Syzygium hancei* | Hong Kong, China | Yes |
| *Tapirira guianensis* | Brazil | Yes |
| *Terminalia belerica* | India | Yes |
| *Terminalia chebula* | India | Yes |
| *Trema micrantha* | Brazil | Yes |

| | | |
|---|---|---|
| *Upuna borneensis* | Malaysia | Yes |
| *Verbesina crassiramea* | Colombia | Yes |
| *Viburnurn triphylum betham* | Colombia | Yes |
| *Vitellaria paradoxa* | Cameroon | |
| *Vitex parviflora* | Philippines | Yes |
| *Vitex parviflora* | Philippines | Yes |
| *Xylosma spiculifera* | Colombia | Yes |
| Genus | | |
| *Albizzia spp.* | Cameroon | Yes |
| *Cassia spp.* | Ghana | Yes |
| *Dipterocarpus spp.* | Philippines | Yes |
| *Eucalyptus spp.* | Malawi | Yes |
| *Guibourtia spp.* | Cameroon | Yes |
| *Hibiscus spp.* | Cameroon | |
| *Jacaranda spp.* | Tanzania | |
| *Moringa spp.* | Cameroon | |
| *Myrcianthes spp.* | Colombia | Yes |
| *Vitex spp.* | Cameroon | Yes |