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Closing the Loop: Circular Economy Approaches to Enhance Reforestation Efforts. A Quantitative Analysis of a Lebanese NGO

Tesi di Laurea

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Abstract

This research investigates the potential impact of implementing circular economy practices in reforestation projects, using a non-governmental organization (NGO) based in Lebanon as a case study. A country grappling with deforestation and waste management issues qualified as a good fit to explore the potential of circular economy principles to address these challenges, especially given the increasing global emphasis on sustainable development and the urgent need to address environmental challenges, for which reforestation is a critical tool. Hence, understanding how to make these projects more effective and sustainable is of paramount importance.

The term "Circular Economy" refers to an economic system aimed at eliminating waste and the continual use of resources. It employs reuse, sharing, repair, refurbishment, remanufacturing, and recycling to create a closed-loop system, minimizing the use of resource inputs and the creation of waste, pollution, and carbon emissions. It is a flexible system that is still under study, and its application must be specifically adjusted to each industry. In the context of reforestation, circular economy measures could include recycling, community-led execution, pre-project training, and natural pest management, among others.

The research employs a quantitative approach, using a quasi-experimental design, to compare the outcomes of reforestation projects with varying exposure to circular economy practices. The study challenges the null hypothesis, providing empirical evidence that circular economy measures significantly impact the environmental and social outcomes of reforestation projects. Therefore, this study contributes to the academic discourse by providing a comprehensive, quantifiable perspective on the interplay between the circular economy and reforestation. It offers practical guidance for the design and implementation of future reforestation initiatives for maximizing benefit and sustainability.

Introduction

In the literature review section, we delve into existing scholarly works to trace the evolution of the circular economy, starting from linear to circular paradigms. We examine the historical development of the circular economy concept and explore its practical implementation in non-governmental work. Moreover, we investigate the specific intersection of the circular economy and reforestation, emphasizing the significance of reforestation efforts and their alignment with sustainable development goals. Additionally, we explore stakeholder engagement in the circular economy as well as the social aspects linked to reforestation projects.

The subsequent section presents a detailed analysis of the case study. We provide a comprehensive overview of Lebanon's political, environmental, and economic contexts to establish a solid understanding of the unique circumstances in the country. Within this context, we examine Lebanon's position concerning the circular economy, identifying the challenges and opportunities it presents. Furthermore, we focus on the non-governmental organization (NGO) under research, Lebanon Reforestation Initiative (LRI). Through an exploration of LRI's goals, programs, and integration of circular economy principles, we shed light on the practical implementation of circular economy concepts in reforestation practices.

The research objectives section clarifies the purpose of the study, highlighting the specific research question and hypotheses. By elucidating the main goals of the research, we aim to contribute to the existing knowledge on the circular economy and reforestation, ultimately fostering sustainable practices.

Moving forward, the research methodology section provides an in-depth understanding of the methodological approach employed in this study. We discuss the chosen research design and approach, tailored to address the research question effectively. Additionally, we outline the sampling strategy, including the population, variables, and sample size. Moreover, we elaborate on the data collection and management processes, emphasizing the relevance, reliability, and operationalization of the collected data. The section concludes with an overview of the data analysis methods employed, such as regression model estimation and content validity assessment. Ethical considerations related to the research are also addressed.

The subsequent section presents the results derived from the analysis of the collected data. Descriptive statistics provide an overview of the variables, while reliability assessment ensures the quality and consistency of the measurements. Simple and multiple linear regression analyses are conducted to explore the relationships between the variables of interest.

Following the presentation of results, the discussion section provides a comprehensive analysis and interpretation of the findings. We summarize the main results and offer insights into their implications and applications. Unexpected findings are discussed, and their potential impact on the research question is assessed. Furthermore, we contextualize the findings within the existing literature, highlighting their contributions to the field. The section concludes with a reflection on the limitations and constraints encountered during the research process. Future directions for research are proposed, along with recommendations for the NGO involved in reforestation efforts.

In conclusion, the final section of the thesis summarizes the main findings and contributions of the study. We reflect on the significance of the research and its implications for circular economy practices in the context of reforestation. The conclusion also highlights the broader applications of the study's findings and offers recommendations for future research and practical implementations.

Finally, the bibliography section provides a comprehensive list of the sources referenced throughout the thesis, ensuring proper attribution and credibility.

Literature Review

Introduction: From Linear to Circular

The traditional linear economy is a model of production and consumption that follows a "take-make-dispose" approach. This means that resources are extracted from nature, used to create products, and then discarded as waste once the product has reached the end of its useful life (Sariatli, 2017). This model assumes that resources are abundant and cheap, and that waste can be easily disposed of, when the truth is that resources are finite and finite resources cannot be extracted indefinitely without consequences, such as environmental degradation, especially with the extraction of fossil fuels, minerals, and timber (Dunlap et al., 2012). Mining activities, for example, can result in soil erosion, deforestation, and the loss of biodiversity, while oil and gas extraction can cause air and water pollution, and contribute to climate change because of greenhouse gas emissions, which mining activities are responsible for 4% to 7% of, according to the Intergovernmental Panel on Climate Change (IPCC), therefore leading to more frequent natural disasters, rising sea levels, and ecosystem disruption as the planet's temperatures change drastically (Chakravarty, 2017).

Moreover, due to their finite nature, resources can become depleted and cannot be replaced or replenished in an adequate time frame. This can lead to economic dangers such as competition for resources, and therefore higher product prices, which in turn may lead to economic instability when the prices for essential resources such as oil and minerals increase, impacting many main industries such as agriculture, transportation, manufacturing, among others (Wackernagel et al., 1997). For example, during the 1970s, the global oil crisis occurred when OPEC, the Organization of the Petroleum Exporting Countries, imposed an oil embargo on several countries in response to their support of Israel in the Yom Kippur War. The resulting decrease in oil supply led to skyrocketing prices and widespread economic impacts, including a global recession, high inflation, and increased competition for alternative energy sources. This crisis highlighted the dependence of many economies on finite resources and the need for more sustainable and diversified energy sources (Mitchell, 2010).

In addition, the social impact of the extraction of resources affects the communities in vicinity of the extracted resources, as they may experience displacement, loss of livelihoods, and negative health effects. The benefits of resource extraction usually are not distributed equitably as well, leading to social inequality (Coad et al., 2008). One example can be the Ogoni community in Nigeria, which has experienced all of the above issues due to oil extraction activities in the Niger Delta. The Ogoni people have been protesting against oil extraction by Shell and other companies since the 1990s, citing widespread pollution, gas flaring, and the loss of fishing and farming livelihoods. The community has also experienced violence and human rights abuses, including the execution of activist Ken Saro-Wiwa and eight others by the Nigerian government in 1995 (Martin, 2011).

Further, the linear economy model assumes that waste can be easily disposed of, while in reality, waste disposal is a complex issue that poses significant environmental and social challenges. One of the biggest challenges is finding suitable locations for landfills or waste disposal sites. Landfills take up a significant amount of land, and they often emit greenhouse gases. They can also contaminate groundwater and soil, posing a threat to human health and the environment. Another challenge is the high volume of waste generated by society as the linear economy model encourages the use of single-use products, which generates a large amount of waste (Sariatli, 2017). Additionally, according to the US Environmental Protection Agency (EPA), the disposal of hazardous waste, like chemicals, batteries, and electronic waste, can pose serious risks to human health and the environment because they contain toxic substances that can leach into soil and water supplies, leading to soil contamination, water pollution, air pollution, and many other risks.

The EPA regulates hazardous waste under the Resource Conservation and Recovery Act (RCRA), which states that soil contamination occurs when hazardous waste is improperly disposed of and seeps into the soil, making it difficult or impossible for plants to grow, therefore creating unsafe conditions for humans and animals. Water pollution, on the other hand, can occur when hazardous waste leaches into groundwater and surface water, contaminating drinking water supplies and harming aquatic life, leading to a range of health problems such as cancer, neurological damage, and reproductive problems (World Health Organization (WHO), 2016). Air pollution can also result from hazardous waste, with certain chemicals emitting toxic gases or particulate matter, which can lead to respiratory problems and other health issues in humans and animals.

In addition to its environmental effects, waste disposal also has social effects. Landfills and waste disposal sites are often located in low-income and minority communities, which leads to environmental injustice. These communities are disproportionately affected by the mentioned negative impacts of waste disposal (Cutter, 1995). Waste disposal also creates a significant financial burden for communities, as they must pay for the costs of waste management and disposal. For example, Accra, the capital of Ghana in West Africa, generates an estimated 2,700 tons of solid waste per day, much of which is not properly collected or disposed of. Waste pickers collect recyclable materials from households and businesses and sell them to local traders. However, this is insufficient to handle the volume of waste generated in the city. Thus, much of the waste ends up in unregulated landfills or is burned in open pits. The financial burden of waste management in Accra is significant, with its cost estimated at around $200 million per year. As the city government lacks the resources and capacity to provide adequate waste management services, Accra continues to rely on informal waste management systems (World Bank, 2017).

Another main problem with the linear economy is that it is not sustainable in the long term. As resources become scarcer and more expensive, businesses and organizations will need to find new ways to reduce their dependence on raw materials and energy. In addition, the environmental and social costs of waste and pollution are becoming increasingly apparent, leading to growing pressure from consumers, regulators, and other stakeholders for businesses, organizations, and governments to adopt more sustainable practices (Jorgensen, 2018). One of the most promising alternatives is the ‘Circular Economy’ model, through which resources are used and reused as efficiently as possible. It is a regenerative economic system that aims to keep resources in use for as long as possible through strategies such as recycling, reusing, and repurposing. This model is designed to minimize waste and pollution, while promoting sustainable resource management and economic growth. Its three key principles are ‘designing products for durability and reuse instead of the one-time-use products, optimizing resource use as efficiently as possible, and regenerating natural systems by working to restore ecosystems, protect biodiversity, and reduce pollution and other environmental harms’ (Ghisellini2016).

The circular economy also utilizes the business model of ‘product as a service’, which emphasizes leasing products to customers rather than selling them. This allows manufacturers to retain ownership of the product and encourages them to design for durability and repairability, reducing waste and resource consumption. Another important practice in the circular economy model is the use of renewable energy sources, such as wind and solar power, to reduce dependence on non-renewable resources and promote more sustainable production processes (Ghisellini et al., 2016). In Myanmar, for example, the Worldview International Foundation has developed a drone system that uses wind power to distribute tree seeds over large areas of land. The drones are powered by a small wind turbine, which allows them to operate in remote areas where access to electricity is limited. Moreover, a very important economic system that the circular economy aims to create is the closed-loop system, also known as a closed-loop supply chain, where products are designed and managed to minimize waste and promote reuse and recycling.

The goal of a closed-loop system is to keep materials circulating within a cycle rather than being discarded after their initial use. Hence, the life cycle of a product is divided into different stages, including raw material extraction, production, consumption, and disposal. At each stage, efforts are made to minimize waste and maximize the reuse of materials through several measures. Starting with the design of a product, the materials to be used are selected based on their ability to be reused or recycled at the end of their life cycle. The product is then manufactured and distributed, with the goal of minimizing waste throughout the supply chain (Ghisellini et al., 2016). After the product has been used by the consumer, it is then collected and recycled or reused. The recycling process involves separating the materials and breaking them down into their basic components, which can then be used to make new products. Reusing a product involves cleaning and repairing it to extend its life cycle. Finally, the closed-loop system encourages extended producer responsibility, through which manufacturers are responsible for the end-of-life disposal of their products. This motivates them to design products for easy recycling and reuse, as well as to take responsibility for the environmental impact of their products (MahmoumGhonbadi et al., 2021).

The History and Progress of the Circular Economy

The concept of the circular economy has its roots in several related schools of thought, including the functional service economy (performance economy), cradle-to-cradle, biomimicry, industrial ecology, and the blue economy. These concepts, which have been developed over the past several decades, all propose a new approach to economic growth that is decoupled from the consumption of finite resources (Bocken et al., 2016).

The circular economy is a systemic approach to economic development designed to benefit businesses, society, and the environment. It is underpinned by a transition to renewable energy sources, the circular design of products and materials, and a shift towards using services rather than owning goods (Stahel, 2016). The concept of the circular economy is not new. It has its roots in the 1960s and 1970s, with the emergence of the first ideas about sustainable development and the recognition of the negative impacts of linear production and consumption patterns (Boulding, 1966; Stahel and Reday, 1976).

The concept was further developed in the 1980s and 1990s, with the introduction of the performance economy concept by Walter Stahel (Stahel and Reday, 1981). This concept proposes that a more sustainable economy could be achieved by selling services rather than products, thereby incentivizing businesses to produce goods that are durable, reusable, and recyclable. This idea was further expanded by Michael Braungart and William McDonough in their 2002 book "Cradle to Cradle: Remaking the Way We Make Things", which proposes that products should be designed from the outset so that, at the end of their life, they can be broken down and the materials reused in a continuous cycle.

In the early 2000s, the concept of the circular economy began to gain traction in policy and business circles, particularly in Europe and China. The Ellen MacArthur Foundation, established in 2010, played a significant role in promoting the concept globally. The foundation defined the circular economy as a restorative and regenerative system by design, aiming to keep products, components, and materials at their highest utility and value at all times, and created a ‘Butterfly Diagram’ to better visualize it (Ellen MacArthur Foundation, 2013). It has been further refined and expanded over the years. For instance, Korhonen et al. (2018) proposed four different types of circular economy, namely, the circular economy of materials, energy, value, and finance. They argued that these four types are interconnected and that the transition to a circular economy requires a systemic change involving all four types (Korhonen et al., 2018).

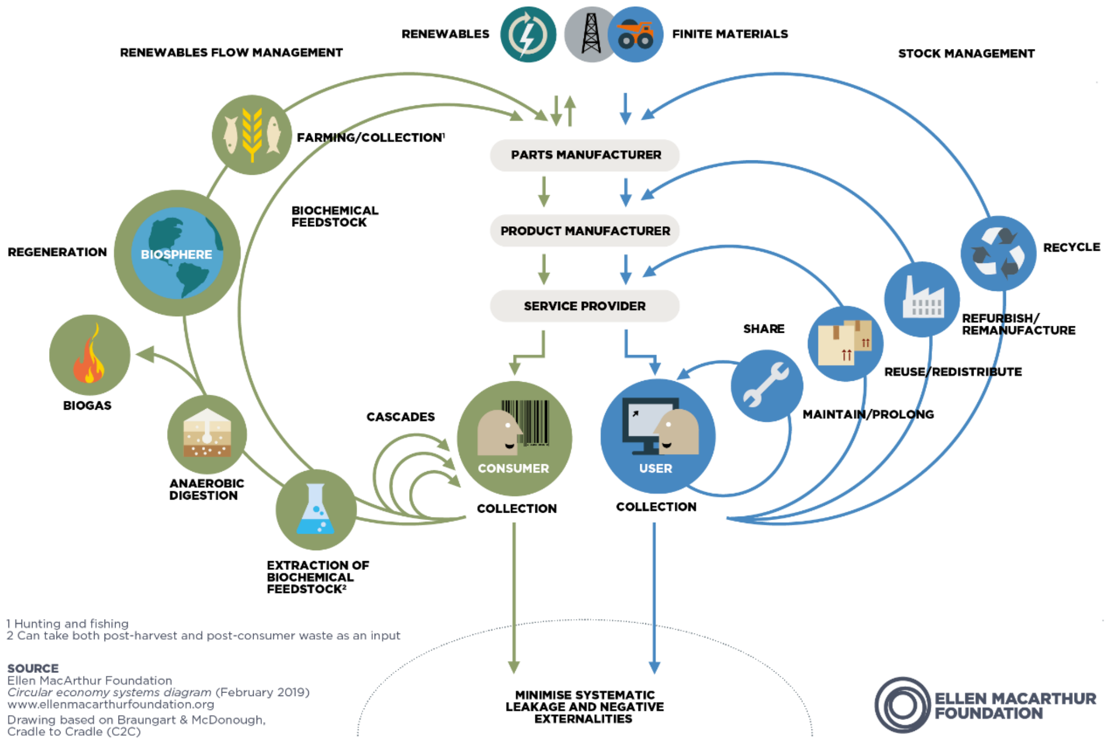


FIGURE 1: The Butterfly Diagram by the Ellen MacArthur Foundation

In recent years, the circular economy has been increasingly linked with sustainability and the need to address environmental challenges. For example, Geissdoerfer et al. (2017) argued that the circular economy could be a vehicle for sustainability, providing a framework for developing sustainable products and services and reducing environmental impacts. They also highlighted the role of innovation in driving the transition to a circular economy (Geissdoerfer et al., 2017).

When it comes to its adoption and implementation, it can be a complex process that involves a multitude of stakeholders and sectors, and it is driven by a combination of environmental, economic, and social factors. From an environmental perspective, the circular economy aims to minimize waste and the depletion of natural resources (Kirchherr et al., 2017). For instance, in the manufacturing sector, companies are increasingly adopting circular strategies such as remanufacturing and refurbishing to extend the life of products and reduce waste (Geissdoerfer et al., 2017).

Economically, the circular economy presents significant opportunities for value creation. It promotes the development of new business models that can generate additional revenue streams, such as product-as-a-service models where companies retain ownership of the product and customers pay for the service it provides (Bocken et al., 2016). Moreover, the circular economy can lead to cost savings through improved resource efficiency and waste reduction (Geissdoerfer et al., 2017).

Socially, the circular economy can contribute to job creation and social inclusion. For example, the repair and refurbishment of products can create local jobs, while the promotion of sharing and leasing models can increase access to goods and services for people who cannot afford to buy them outright (Bocken et al., 2016).

The Circular Economy in Non-Governmental Work

Non-governmental organizations play a critical role in promoting sustainable development by advocating for social and environmental justice, raising awareness, providing education, and developing and implementing projects and programs to improve the livelihoods of communities (Gallagher et al., 2008). With the growing awareness of the need for more sustainable practices, NGOs have an important role to play in supporting the transition to a circular economy. This can be through advocating for the use of renewable resources, promoting the use of recycled materials, and encouraging the adoption of sustainable farming practices. NGOs can also support the development and implementation of circular economy projects and programs. For example, they can work with communities to develop waste reduction and recycling programs, promote the use of circular business models, and support the development of circular supply chains. They can also promote the circular economy by supporting research and innovation in sustainable technologies and practices through funding the research, or providing education and training to support the transition to a circular economy (Murray et al., 2017).

One example of an NGO that promotes the transition to a circular economy is the Ellen MacArthur Foundation. Founded in 2010 in the United States, the NGO is dedicated to promoting a circular economy by working with businesses, governments, and academics to develop and promote sustainable practices by providing research, education, and training on circular economy principles and practices. It also develops and implements circular economy projects and initiatives, such as the Circular Fibres Initiative, which aims to build a sustainable textile industry by promoting the use of circular materials and design principles. Additionally, the Ellen MacArthur Foundation advocates for the adoption of circular economy policies and regulations by working with policymakers and governments around the world. It has influenced over $1 trillion of investment toward the circular economy while working with over 2,500 organizations worldwide.

On another note, NGOs supporting the circular economy will be benefiting their work from this model, especially the ones working in reforestation, as it can help them maximize their use of resources and reduce waste while promoting sustainable practices and circularity. Moreover, it can generate economic benefits for them through the reduction of the costs associated with resource extraction and waste disposal, as well as by generating value from waste materials, therefore creating new revenue streams. On an environmental level, the circular economy model can help NGOs working in reforestation reduce their environmental footprint through its various measures (de Abreu et al., 2018). For example, the Rainforest Alliance is an NGO that works to promote sustainable forestry practices and protect biodiversity. They have incorporated circular economy principles into their work by promoting the use of recycled materials in their reforestation efforts, as well as by supporting circular business models like agroforestry. They also work with companies to promote sustainable supply chains, which can help reduce waste and resource consumption.

The Circular Economy in the Context of Reforestation

When it comes to their application, the principles of circular economy can be adjusted to each industry or activity. In the context of reforestation, the design of products for durability and reuse can be applied in many ways; one way is by choosing tree species and seedlings that are well-suited to the local climate and soil conditions, which will increase their chances of survival and reduce the need for replanting. Another way is by implementing protective measures of the trees and area during the reforestation project, such as stone mulching or the removal or invasive species from the reforestation site. Also, to optimize resource use, natural fertilizers can be used, rather than relying on chemical fertilizers that can be harmful to the environment. Water can also be conserved through the use of rainwater for harvesting and other water management strategies (Macarthur, 2019).

Natural systems are another focus of the circular economy, as they are the complex network of ecosystems, biodiversity, and natural resources that sustain life on earth, as well as an essential part of the global economy, for they provide the raw materials and resources that support the production and consumption of goods and services. However, human activities such as industrialization, deforestation, and pollution have put enormous pressure on natural systems, leading to environmental degradation, biodiversity loss, and climate change (Arruda et al., 2021). Therefore, in a circular economy, natural systems are recognized as valuable assets that must be protected and regenerated to support future sustainability. This means minimizing waste and pollution, using resources as efficiently as possible, and preserving biodiversity and ecosystems. By doing so, we can ensure that natural systems continue to provide the essential resources and services that support human well-being and economic development (Arruda et al., 2021).

One way to support natural systems is by avoiding monoculture, which is the agricultural practice of growing a single crop species in a given area, often over a large scale. This is in contrast to polyculture, where multiple crops are grown together in the same area, often in a way that mimics natural ecosystems (Hames, 1983). Monoculture is widely used in industrial agriculture to maximize yields and simplify management, but it can lead to problems such as soil degradation, as the United Nations Food and Agriculture Organization (FAO) states that soil degradation affects around 33% of the world's arable land, with monoculture being a contributing factor. This is because growing the same crop in the same location year after year can deplete soil nutrients and increase susceptibility to pests and diseases.

This can lead to reduced crop yields and the need for increased use of fertilizers and pesticides, which according to a study published in the journal Environmental Health Perspectives, is associated with increased risk of certain cancers, neurological disorders, and developmental problems in children. Additionally, monoculture can have negative impacts on biodiversity and ecosystem health, as it often involves clearing large areas of natural vegetation to make way for crops. This can result in the loss of habitat for a variety of plant and animal species, leading to declines in biodiversity. According to a study published in the journal Nature, monoculture crops cover around 1.5 billion hectares of land worldwide, and are a major contributor to global declines in biodiversity.

Polyculture, on the other hand, refers to the practice of growing multiple crops or species together in a given area, creating multi-species forests, which are more resilient to environmental stresses such as drought or disease. In the context of a circular economy, a circular measure would be setting a minimum number of species in a reforestation site to promote polyculture, as it can be seen as a more sustainable approach to agriculture because it supports biodiversity, reduces reliance on synthetic inputs, and promotes efficient resource use in several ways. First, polyculture supports the principle of optimizing resource use by making use of natural synergies between different plant species and reducing waste. For example, different plants can be grown together to enhance nutrient cycling, reduce soil erosion, and increase water retention. This leads to more efficient use of resources and reduces the need for synthetic inputs such as fertilizers and pesticides. Second, polyculture supports the principle of regenerating natural systems by promoting biodiversity and ecosystem services. By growing a diverse range of crops, polyculture supports beneficial insects and microorganisms that can help control pests and diseases, improve soil fertility, and increase overall ecosystem resilience. This helps to create a more sustainable and balanced system that can support long-term resource use (Hames, 1983).

The Importance of Reforestation

Reforestation, the process of replanting areas where forests have been cleared or degraded, is a critical tool in the fight against climate change and biodiversity loss. The environmental benefits of reforestation are manifold, ranging from carbon sequestration to habitat restoration and soil erosion prevention. Forests act as carbon sinks, absorbing carbon dioxide (CO2), a major greenhouse gas, from the atmosphere. A study published in the journal Science in 2019 estimated that global reforestation has the potential to sequester approximately two-thirds of all the CO2 emissions that have been released into the atmosphere due to human activities since the Industrial Revolution. This equates to the sequestration of about 205 gigatons of carbon over the next century, achieved by planting approximately 1 trillion trees (Bastin et al., 2019).

Reforestation also plays a crucial role in biodiversity conservation, as forests are home to a vast array of species, and their destruction leads to habitat loss and species extinction. By replanting trees, we can restore these habitats and promote biodiversity. A study on the environmental responses to reforestation showed that manipulating the configuration of plantings (location, size, species mix, and tree density) can increase a range of environmental benefits, including habitat provision for a variety of species (Paul et al., 2015). Moreover, reforestation helps prevent soil erosion. Tree roots stabilize the soil, preventing it from being washed away by rain or wind. This is particularly important in areas prone to landslides or other forms of soil degradation. A study conducted in Victoria, Australia, inferred that reforestation of deforested creek banks had a positive impact on soil conditioning, thus preventing soil erosion (Xu et al., 2015).

Finally, reforestation also contributes to water regulation. Forests can absorb and retain large amounts of water, reducing the risk of natural disasters such as floods and landslides. This is particularly important in regions with shallow aquifers, where reforestation can be used to reduce water pollution or maintain water yields (Paul et al., 2015).

On the other hand, when it comes to the social benefits of reforestation, it can contribute to poverty alleviation and income generation. The establishment and maintenance of tree plantations provide job opportunities for local communities, which can help to reduce poverty levels. For instance, a study by McElwee and Nghi (2021) on tree planting by smallholders in Vietnam found that reforestation programs can provide significant social benefits, including income generation from the sale of timber and non-timber forest products. Secondly, reforestation can lead to improved food security. Many reforestation programs include the planting of fruit trees and other edible species, which can provide a source of food for local communities. Moreover, the restoration of forest ecosystems can support the recovery of wild food sources, such as game and edible plants, contributing to local food security.

However, it is crucial to note that the social benefits of reforestation are not automatic and require careful planning and implementation. For example, a study by Hua et al. (2018) in southwestern China found that while tree cover increased by 32% due to the conversion of croplands to tree plantations, this was accompanied by a net loss of 6.6% in native forests. The study highlights the importance of ensuring that reforestation efforts promote the recovery of native forests, which are often more beneficial for local communities and biodiversity than monoculture plantations.

Moreover, a study by Ros-Tonen, Derkyi, and Insaidoo (2014) on Ghana's modified taungya system, a co-management system for reforestation, found that the system faced challenges in terms of continual learning, transcending jurisdictional boundaries, developing adaptive capacity, and securing long-term funding and benefits. The study suggests that transitioning from co-management to landscape governance, which involves negotiated land use at the landscape level, could help to address these challenges and enhance the social benefits of reforestation.

The Circular Economy and Reforestation Supporting SDGs

FIGURE 2: Sustainable Development Goals by the United Nations

The Sustainable Development Goals (SDGs) are a collection of 17 global goals designed to be a "blueprint to achieve a better and more sustainable future for all". The SDGs were set in 2015 by the United Nations General Assembly and are intended to be achieved by the year 2030. They are part of a UN Resolution called the 2030 Agenda or what is colloquially known as Agenda 2030. The goals are broad and interdependent, yet each has a separate list of targets to achieve. Achieving all 169 targets would signal accomplishing all 17 goals. The SDGs cover a broad range of social and economic development issues including poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, urbanization, environment, and social justice (Sachs, 2012).

The circular economy and reforestation contribute significantly to several of the SDGs. For instance, the circular economy, which emphasizes the reduction, reuse, and recycling of materials, directly contributes to SDG 12: Responsible Consumption and Production. This goal aims to ensure sustainable consumption and production patterns, a core principle of the circular economy (Rodríguez-Antón et al., 2021). Further, a key aspect of the CE is the concept of "closing the loop" of product lifecycles through greater recycling and re-use, which can lead to significant reductions in waste generation (Kirchherr et al., 2017). This directly contributes to target 12.5 of SDG 12, which aims to substantially reduce waste generation through prevention, reduction, recycling, and reuse by 2030 (United Nations, 2015).

Moreover, the CE encourages the sustainable management and efficient use of natural resources, which is the focus of target 12.2 (United Nations, 2015). By promoting the use of renewable resources and enhancing the efficiency of resource use, the CE can contribute to the sustainable management of natural resources (Ghisellini et al., 2016). The CE also promotes sustainable industrial processes, which is a key aspect of target 12.4 (United Nations, 2015). By encouraging industries to adopt sustainable practices and to integrate sustainability information into their reporting cycle, the CE can contribute to achieving environmentally sound management of chemicals and all wastes (Murray et al., 2017).

Also, the CE can contribute to target 12.8, which aims to ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature (United Nations, 2015). The CE model encourages businesses and consumers to consider the entire lifecycle of products, which can enhance understanding and awareness of sustainable consumption and production (Prieto-Sandoval et al., 2018).

On another note, the circular economy also contributes to SDG 9: Industry, Innovation, and Infrastructure, in several ways. Firstly, it encourages sustainable industrialization by promoting resource efficiency and reducing waste. This is achieved through strategies such as recycling, remanufacturing, and refurbishing, which not only minimize resource extraction but also extend the life of products and materials, thereby reducing industrial waste (Lieder & Rashid, 2016). Secondly, the circular economy fosters innovation by creating new business models and opportunities. For instance, product-as-a-service models, where companies retain ownership of their products and customers pay for the service these products provide, encourage companies to design durable, reusable, and recyclable products. This not only reduces resource use and waste but also drives innovation in product design and service delivery (Bocken et al., 2016).

When it comes to reforestation and circular economy together, they significantly contribute to the achievement of Sustainable Development Goal (SDG) 13, which aims to "take urgent action to combat climate change and its impacts" (United Nations, 2015). Both strategies offer innovative and sustainable solutions to reduce greenhouse gas emissions and enhance resilience to climate change impacts. The circular economy specifically contributes to SDG 13 by reducing greenhouse gas emissions associated with the extraction, production, and disposal of goods. For instance, a study by Korhonen et al. (2018) found that the circular economy could reduce the EU's industrial greenhouse gas emissions by 56% by 2050. Moreover, the circular economy can enhance climate resilience by promoting the efficient use of resources and reducing dependency on non-renewable resources (Korhonen et al., 2018).

Reforestation, on the other hand, was found to be able to provide a third of the cost-effective climate mitigation needed by 2030 to keep warming below 2°C. Additionally, reforestation enhances climate resilience by protecting against extreme weather events, maintaining water quality, and preserving biodiversity (Griscom et al., 2017). It also plays a crucial role in achieving SDG 15: Life on Land, which aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. By restoring forested lands, reforestation helps to increase biodiversity, sequester carbon, and reduce the impacts of climate change, all of which are key aspects of this goal (Moshkal et al., 2022).

Engaging the Stakeholders of the Circular Economy

Stakeholder engagement and collaboration are critical components of implementing circular economy models for reforestation. Local communities, governments, and industry must all work together to ensure the success of reforestation efforts and to create a sustainable and resilient future. Local communities play a crucial role in the success of reforestation efforts. They are often the ones most directly impacted by deforestation and the loss of natural resources. Engaging with local communities is essential to understanding their needs, values, and priorities, and to ensuring that their interests are represented in decision-making processes. Additionally, involving local communities in reforestation activities can create economic opportunities and promote social well-being, contributing to long-term sustainable development (Mansilla-Obando et al., 2022). According to a study by the World Bank, community forestry programs in Nepal and Uganda have created about 50,000 and 60,000 jobs, respectively, providing income opportunities for local communities (World Bank, 2016).

Governments also have a crucial role to play in promoting sustainable reforestation. They can provide policy support, such as incentives for companies that engage in sustainable reforestation practices, or regulations that encourage the use of circular economy principles in forestry operations (Moon et al., 2004). Governments can also help facilitate stakeholder engagement and collaboration, bringing together local communities, industry, and other stakeholders to work towards common goals by providing a platform for dialogue, setting up working groups, and organizing community meetings. They can help to identify key stakeholders and bring them together to discuss their concerns, interests, and priorities. In a study of stakeholder engagement in forest management in Tanzania, it was found that involving local communities in decision-making processes led to more successful and sustainable outcomes, with a 96% success rate in forest regeneration projects that involved community participation compared to a 60% success rate for projects that did not (Peskett et al., 2008).

Governments can also provide support for stakeholder engagement activities, such as funding for community outreach and education programs. They can act as intermediaries between different stakeholders, helping to build trust and promote collaboration. Furthermore, governments can help to establish frameworks for decision-making and governance, such as multi-stakeholder platforms or advisory committees, that involve all relevant parties in decision-making processes. This can help to ensure that all stakeholders have a say in the planning and implementation of reforestation projects, and that decisions are made transparently and equitably (Ameha et al., 2014). By facilitating stakeholder engagement and collaboration, governments can help to build consensus, create shared goals, and ensure that reforestation efforts are sustainable, effective, and beneficial for all stakeholders involved.

Industry stakeholders, including forestry companies and other businesses that rely on natural resources, can also play a critical role in implementing circular economy models for reforestation. By adopting circular economy principles, these businesses can reduce waste and resource use, lower costs, and improve their environmental and social performance. This, in turn, can create new business opportunities, such as the development of new products and services that promote sustainable reforestation, and can support the economic development of local communities. Collaboration between these stakeholders is essential for creating a sustainable and resilient future. By working together, they can identify shared priorities, leverage each other's expertise and resources, and develop innovative solutions to complex challenges. For example, the collaboration between local communities and forestry companies can lead to the development of sustainable forest management practices that benefit both the environment and the economy. Similarly, the collaboration between governments, industry, and NGOs can create policy frameworks and funding mechanisms that support sustainable reforestation initiatives (Moya et al., 2019).

An example of one country that has made significant efforts to promote stakeholder collaboration in implementing circular economy models for reforestation is Brazil. In the Brazilian Amazon, various stakeholders, including local communities, NGOs, industry, and government, have come together to develop and implement sustainable forestry practices that promote reforestation and economic development. For example, the Brazilian government has established the Amazon Fund, which provides funding for sustainable forestry initiatives and engages stakeholders in decision-making processes. Additionally, forestry companies operating in the region have adopted circular economy principles, such as using recycled materials in their operations and reducing waste. NGOs like the Amazon Environmental Research Institute (IPAM) work with local communities to support sustainable reforestation practices and provide education and training on circular economy principles. Through stakeholder collaboration, these initiatives have helped to reduce deforestation rates and promote sustainable economic development in the region (Lambin et al., 2014).

Social Aspects of the Circular Economy in Reforestation

Adopting circular economy practices in reforestation efforts can bring several anthropological benefits, which are closely related to the social aspects of sustainability. First, local communities can be empowered as circular economy practices involve promoting community participation, and engaging with local communities in reforestation efforts can have a significant impact on the success of the project. By involving local communities in decision-making and implementation, they can be empowered, sensing ownership in the project, which can help in the long-term sustainability of the reforestation efforts (Ameha et al., 2014).

Moreover, NGOs can build social capital through implementing circular economy practices, as they emphasize collaboration and building relationships between stakeholders. This can help create new partnerships, business opportunities, and job opportunities, and address social and economic challenges in the community. The created opportunities can improve livelihoods by making them more sustainable, which in turn can help alleviate poverty and reduce social inequality (Mnasilla-Obando et al., 2022).

Furthermore, local communities often have traditional knowledge and practices related to forest management and conservation. By engaging with these communities and involving them in reforestation efforts, NGOs can help preserve and promote traditional knowledge, which can be valuable in ensuring the long-term sustainability of the project. This can be considered a way of protecting cultural heritage, as forests are often associated with cultural heritage and identity, especially for indigenous communities. By adopting circular economy practices in reforestation efforts, NGOs can help protect cultural heritage and promote the preservation of cultural identity (Salvioni et al., 2020).

On a socio-economic level, implementing the circular economy in reforestation can significantly contribute to job creation. This is achieved through various mechanisms, such as the creation of new roles in waste management, the development of sustainable products, and the promotion of local economies. For instance, in reforestation efforts, jobs can be created in the collection and processing of organic waste to produce compost, which can then be used to improve soil fertility and boost tree growth. Such activities not only provide employment but also help to build skills and capacities within marginalized communities (Jones & Comfort, 2018).

Moreover, the circular economy can contribute to social inclusion by providing opportunities for women and marginalized communities to participate in decision-making processes. This can empower these communities and enable them to benefit from reforestation efforts (Lata, Wiering, & Witjes, 2023). This is particularly true in developing countries, where both often play a crucial role in managing natural resources and supporting their families' livelihoods. This way, the CE would be contributing to gender equality by ensuring that women have equal access to the benefits of reforestation projects, such as employment opportunities and training programs, and that they have a voice in decision-making processes related to forest management (Le, Park & Tran, 2020).

Also, the circular economy can facilitate community engagement by promoting transparency and collaboration. For instance, decision-making processes related to reforestation can be made inclusive, allowing community members to voice their opinions and concerns (Mansourian et al., 2017). This inclusive approach can foster a sense of community ownership and stewardship, ultimately contributing to the success and sustainability of reforestation efforts. Moreover, local communities can learn about sustainable forest management practices, such as selective logging and agroforestry, which can increase forest resilience and productivity (Bocken et al., 2016).

Finally, since the circular economy promotes the idea of "fair share," equitable distribution of resources and benefits would be implemented. In reforestation, this can be achieved through community forestry initiatives that give local communities control over forest resources and the benefits derived from them (Bhattacharya et al., 2019). This not only ensures that the benefits of reforestation are shared equitably but also encourages community participation and ownership, which are key to the success of reforestation efforts as they promote social equity (Bhattacharya et al., 2019). It can also be promoted by education and capacity building. For example, reforestation projects can provide training programs for local communities on sustainable forest management practices, thereby enhancing their skills and knowledge and improving their livelihoods (Bhattacharya et al., 2019).

The Gap in the Literature

The concept of the circular economy has gained significant traction in recent years, with numerous studies exploring its potential benefits and applications across various sectors. However, the integration of circular economy principles in reforestation efforts remains largely unexplored. This is surprising given the potential synergies between the two. Reforestation efforts can benefit from the circular economy's emphasis on resource optimization, waste reduction, and system-level sustainability. Conversely, the circular economy can benefit from reforestation's capacity for carbon sequestration, biodiversity conservation, and ecosystem restoration.

Despite these potential synergies, the literature on the intersection of the circular economy and reforestation is sparse. Most studies on the circular economy focus on industrial applications, such as waste management and product design, with little attention given to its potential applications in reforestation or other environmental restoration efforts. Similarly, studies on reforestation tend to focus on traditional approaches to forest management, with little consideration of how circular economy principles could enhance reforestation outcomes.

Moreover, the few studies that do explore the intersection of the circular economy and reforestation tend to be theoretical or conceptual in nature, offering predictions and proposals but little empirical evidence. There is a lack of quantitative studies that measure the actual impact of implementing circular economy measures in reforestation projects. This lack of empirical evidence makes it difficult to assess the effectiveness of such measures and to develop evidence-based policies and practices.

This gap in the literature is significant for several reasons. First, it limits our understanding of the potential benefits of integrating circular economy principles in reforestation efforts. Without empirical evidence, it is difficult to make informed decisions about whether and how to implement such integration. Second, it hinders the development of innovative strategies for sustainable development. The integration of circular economy principles in reforestation efforts could offer a novel approach to addressing environmental challenges and promoting sustainability. However, without adequate research, the potential of this approach remains largely untapped.

Our research aims to fill this gap in the literature by providing empirical evidence on the impact of implementing circular economy measures in reforestation projects. By doing so, we hope to contribute to a deeper understanding of the potential synergies between the circular economy and reforestation, and to inform the development of effective and sustainable reforestation strategies.

Presentation of Case Study

Overview of Lebanon

Lebanon is a small country located in the eastern Mediterranean region of Western Asia. It has a diverse population of around 6 million people, made up of various ethnic and religious groups. After gaining independence from France in 1943, Lebanon established a democratic system of government and quickly became known as a regional financial and trade centre. During the 1950s and 1960s, Lebanon's economy grew rapidly, driven by a thriving banking sector and a vibrant tourism industry. However, this growth was not evenly distributed and disparities between different social and economic groups began to emerge (Eikelman, 1998).

In the 1970s, Lebanon was plunged into a civil war that lasted for over 15 years, severely damaging the country's infrastructure, economy, and social fabric. The war also had a significant impact on Lebanon's political landscape, as different factions vied for power and influence. After the war ended in 1990, Lebanon entered a period of reconstruction and economic recovery, with a focus on rebuilding infrastructure, revitalizing the economy, and restoring political stability. However, the country faced several challenges, including a large national debt, high levels of corruption, and regional political instability (Eikelman, 1998).

Despite these challenges, Lebanon's economy continued to grow throughout the 1990s and early 2000s, driven by many sectors including banking, real estate, and tourism. Yet, the country's economic growth was not sustainable, as it was heavily dependent on foreign investment and borrowing. In the late 2000s, Lebanon was hit hard by the global financial crisis, which had a major impact on the country's banking and real estate sectors (Jamali, 2006). In addition, political instability in the region, including the ongoing conflict in neighbouring Syria, has had a negative impact on the country's economy and social stability.

The Political Context in Lebanon

Lebanon's political system is based on a power-sharing arrangement called confessionalism. This means that political power is divided among the different religious and ethnic groups in the country, with each group having a certain quota of positions in government and public institutions. The major religious groups in Lebanon include Christians (Maronite, Greek Orthodox, and Armenian) and Muslims (Sunni, Shia, and Druze). This system was established in 1943 when Lebanon gained independence from France and has been enshrined in the country's constitution (Eikelman, 1998).

The confessional political system has had significant impacts on the country's economic system. Political patronage and corruption are examples of these impacts, where political leaders distribute resources and government positions based on religious and ethnic identity. This has contributed to high levels of corruption and nepotism, which have hindered economic growth and development. According to the World Bank, Lebanon's GDP growth rate has been negative since 2018, with a contraction of 6.7% in 2019 and 20.3% in 2020 (World Bank, 2022). Also, the Lebanese Transparency Association (LTA) estimated in a 2019 report that corruption costs the Lebanese economy around 9% of its GDP annually (Abdallah, 2020).

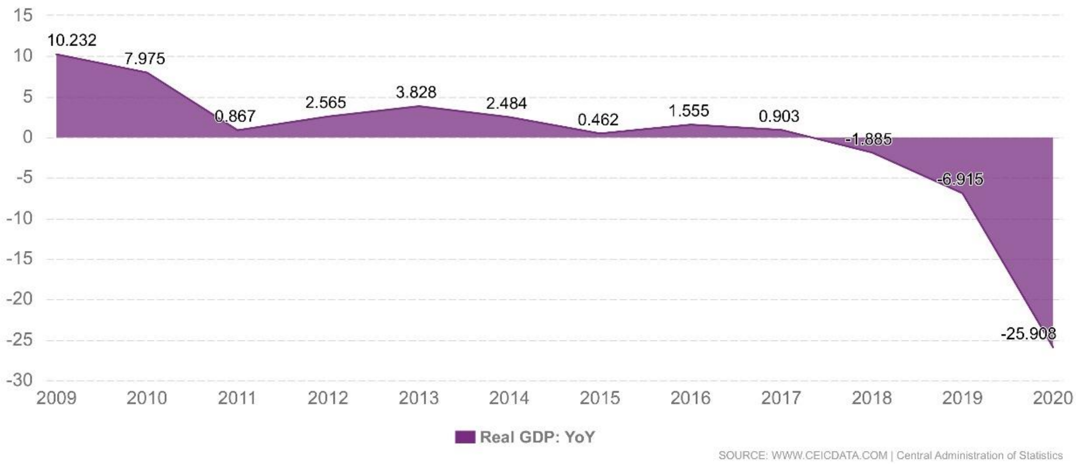


FIGURE 3: Lebanon’s Real GDP by Statista

Moreover, confessionalism and corruption have led to fragmented and inefficient governance in the country, with different political parties and religious groups competing for power and resources. This has made it difficult for the government to implement effective policies and strategies to promote economic growth and development. This has been reported by The World Bank's 2018 "Public Expenditure Review", stating that Lebanon's public sector is characterized by "high fragmentation and duplication" and a "lack of clear policies and priorities," which has led to inefficient use of public resources (World Bank, 2018).

Consequently, all the above resulted in a lack of investment in infrastructure and other areas that could promote economic growth. The country's power-sharing system has made it difficult to reach a consensus on major policy decisions, such as infrastructure investment, and has led to a lack of accountability and transparency in government spending (Salloukh, 2019. For example, the lack of investment has led to a crumbling road network and unreliable electricity supply, which in turn has hindered business growth and development. According to the World Bank, electricity outages cost Lebanon an estimated $2 billion annually in lost productivity and output (World Bank, 2018).

The Environmental Context in Lebanon

Lebanon faces numerous environmental challenges that pose significant threats to the country's natural resources. One of the major challenges is deforestation, which has been ongoing for decades due to population growth, urbanization, and unsustainable land use practices (Charara, 2020). According to the Food and Agriculture Organization of the United Nations (FAO), Lebanon's forest cover decreased from 35% in the early 1900s to less than 13% in 2015, representing a significant loss of natural resources (FAO, 2016). The country's forests and woodlands have been severely degraded, resulting in soil erosion, loss of biodiversity, and reduced water quality, which can have negative economic impacts such as reduced agricultural productivity and increased risk of landslides.

Lebanon also faces water scarcity due to its arid climate and the high demand for water resources from various sectors, including agriculture, industry, and households. The country relies heavily on water from rivers and groundwater, which are often overexploited and polluted. According to the World Resources Institute, Lebanon is among the 20 most water-stressed countries in the world, with renewable freshwater resources per capita estimated at around 1,000 cubic meters per year, which is well below the threshold of 1,700 cubic meters per person per year that defines water scarcity (Wassermann, 2019). As a consequence, a study by the United Nations Development Programme (UNDP) found that water scarcity has resulted in a significant reduction in agricultural productivity in Lebanon. The study estimated that around 30% of the country's agricultural land is affected by water scarcity, resulting in a loss of around 190,000 tons of crops per year and a decrease in agricultural GDP of around USD 180 million per year (UNDP, 2019).

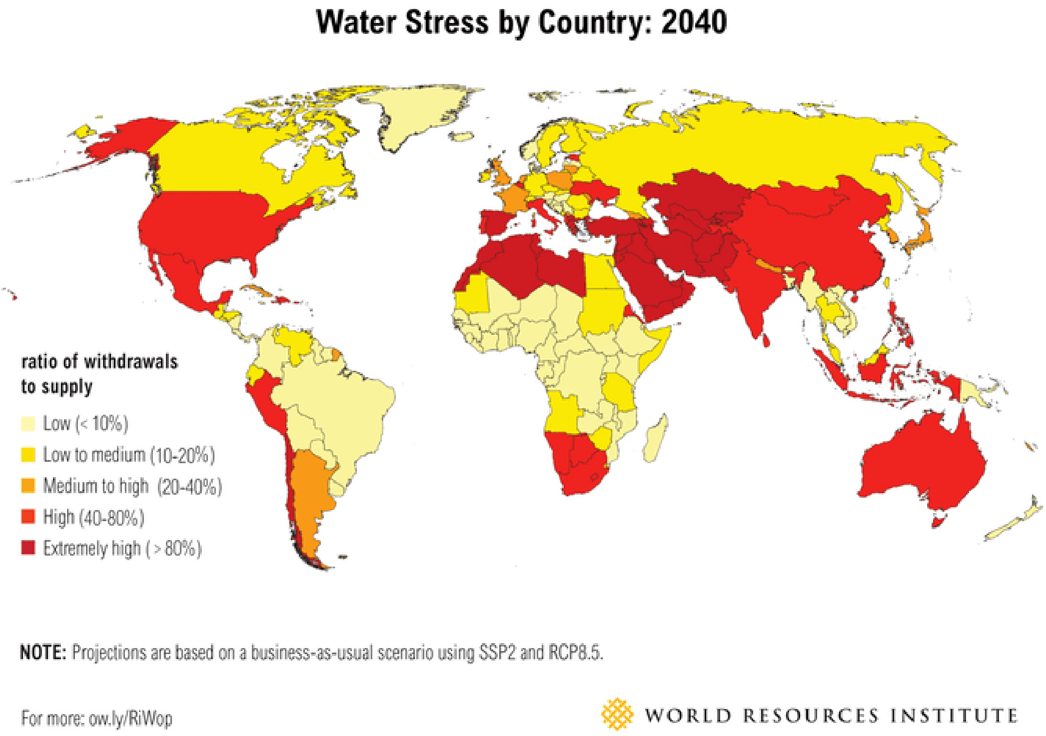


FIGURE 4: Water Stress Map by World Resources Institute

In addition to the above, waste management is a critical environmental issue in Lebanon, as the country has been struggling for years to deal with the increasing amounts of waste produced by its growing population. According to the World Bank, Lebanon generated approximately 2.1 million tons of municipal solid waste (MSW) in 2018. This represents a 143% increase in MSW generation since 2000, with an average annual increase of 5.5% per year (World Bank, 2020). On top of that, there exists an issue in collecting the produced waste, and this lack of collection has led to serious environmental problems, including soil and water pollution, and has also contributed to the spread of diseases. According to the Lebanese Ministry of Environment, only about 50% of the country's waste is collected, leaving the remaining waste to accumulate in the streets, rivers, and countryside (MOE, 2017).

Further, the waste that is actually collected is often disposed of in open-air landfills, which are not properly designed or managed. The largest landfill in the country, the Naameh landfill, was opened in 1997 and was supposed to be temporary. However, it continued to operate for over 20 years, and by the time it was closed in 2015, it had exceeded its capacity by over four times. The landfill was a source of significant environmental pollution, including toxic gases and leachate, which contaminated nearby water sources, as it is estimated that Lebanon produces 20,000 tons of hazardous waste per year, including medical, industrial, and electronic waste (Citton, 2020). Yet, the closure of the Naameh landfill led to a waste management crisis in Lebanon, as there was no alternative plan in place for the disposal of the country's waste. Waste began to accumulate on the streets, and citizens took to protesting against the government's handling of the issue (Geha, 2019).

Eventually, a temporary solution was found, which involved opening new landfills in other parts of the country. However, the new landfills have not been without their own problems. In 2019, a landfill in the southern town of Bisri was proposed, but the project has been met with opposition from local residents and environmental activists. The landfill would be located near the Bisri River, which is a vital source of water for the region. Activists raised concerns about the potential for the landfill to contaminate the river and the surrounding area, as well as the impact on the local community, which led to cancelling the proposal (Nemer, 2019).

Another issue facing Lebanon's waste management system is the lack of recycling infrastructure. According to the Lebanese Ministry of Environment, only about 8% of the country's waste is recycled, compared to the global average of 14%. This is partly due to a lack of government support for recycling initiatives and a lack of incentives for businesses and individuals to recycle. In addition, there is a lack of separation at the source, which means that recyclable materials often end up in landfills (MOE, 2017).

The economic costs of poor waste management in Lebanon are also significant. A study conducted by the American University of Beirut (AUB) estimated that the direct and indirect costs of poor waste management in Lebanon amounted to $370 million per year in 2015. These costs include the impact of waste on public health, tourism, and the environment, as well as the economic costs of cleaning up waste and managing waste-related crises (Mourtada, 2015).

The Economic Context in Lebanon

Lebanon has a small and open economy that heavily relies on international trade and foreign investment due to its favourable tax policies and regulatory environment. The country has a long history of commercial activity and is strategically located at the crossroads of Europe, Asia, and Africa, making it an important hub for trade and investment in the Middle East region. The free trade agreements with several countries, including the European Union, Turkey, and the Arab League, and its membership in the World Trade Organization (WTO) have contributed to its well-developed financial sector, strong banking system, and vibrant capital market (Müller-Jentsch, 2005). Among these agreements is The European Union-Lebanon Association Agreement, signed in 2002, which aims to promote trade and investment between the EU and Lebanon. As a result of this agreement, the EU has become Lebanon's largest trading partner, accounting for around 27% of the country's total trade. In addition, the Turkey-Lebanon Free Trade Agreement, signed in 2010, aimed to increase bilateral trade between Turkey and Lebanon by removing trade barriers and promoting investment. Since the agreement came into effect, bilateral trade between the two countries has increased significantly, reaching USD 1.4 billion in 2019, up from USD 528 million in 2010 (European Commission, 2021).

Lebanon’s economy is market-oriented and mainly dependent on services, particularly banking and tourism, accounting for the majority of the country's gross domestic product (GDP) and employing a significant portion of the workforce, thanks to Lebanon's rich cultural heritage and Mediterranean climate attracting visitors from around the world. According to the World Bank, services accounted for 70.3% of Lebanon's GDP in 2019. The country also has a significant industrial sector, which includes food processing, textiles, and chemicals, among others. However, this sector has faced challenges in recent years, including high energy costs and competition from cheaper imports. The agricultural sector is small but still plays an important role in the economy, particularly in rural areas. The country is known for producing a variety of high-quality crops, such as grapes, olives, and citrus fruits (World Bank, 2022). For instance, according to Invest in Lebanon (IDAL), in 2019, Lebanon was among the world's top 10 producers of olives (IDAL, 2022).

However, the country's economy has been facing significant challenges in recent years, which have impacted its position within the global economy. One of the major challenges facing Lebanon's economy is its high public debt, which stood at 177% of GDP in 2019, according to the International Monetary Fund (IMF). This has put significant pressure on the government's finances, leading to austerity measures and a decline in public services (IMF, 2019). Its position within the global economy is further challenged by its vulnerability to regional conflicts and geopolitical tensions. The country has been impacted by the Syrian refugee crisis, with an estimated 1.5 million refugees in the country as of 2020, according to the UN Refugee Agency (UNHCR). This has put significant strain on the country's resources and infrastructure, particularly in the areas of education and healthcare, as they are diverted from investment in productive sectors towards humanitarian aid and support for refugees. According to the International Monetary Fund (IMF), the refugee crisis has reduced Lebanon's potential growth rate by 2-2.5% per year since 2011 (IMF, 2019).

Finally, what has impacted the Lebanese economy the most has been the economic crisis that hit it in 2019, which is considered to be one of the worst economic crises in modern history. The country's banking sector regressed, with several banks facing liquidity challenges and restrictions on foreign currency transfers, with the total banking sector losses estimated at $83 billion as of August 2021 (World Bank, 2021).

The Lebanese Economic Crisis

Lebanon's economic crisis began in 2019 and was exacerbated by the COVID-19 pandemic. The crisis has led to high inflation, currency devaluation, and a sharp decline in economic activity. These challenges have undermined investor confidence and hindered economic development. The crisis was triggered by a combination of factors, including political instability, corruption, and mismanagement of the economy, and has had a profound impact on the country and its people, leading to widespread poverty, inflation, and unemployment (Elia, 2020).

One of the main causes of the economic crisis was the high level of public debt. The government's inability to pay its debt obligations led to a loss of confidence in the country's financial system and a subsequent decline in the value of the Lebanese pound. The Lebanese banking system, which had been a source of stability and growth for many years, also became a major source of instability during the crisis. Bank deposits were frozen, and many people were unable to access their savings, leading to widespread anger and protests (Elia, 2020).

The crisis also led to a sharp increase in inflation, with prices of basic goods and services skyrocketing, as the annual inflation rate reached 84.9% in August 2021, up from 66.7% in July 2021. The devaluation of the Lebanese pound to less than 10% of its value in September 2019 also made imports more expensive, leading to shortages of essential goods such as fuel and medicine (Hoteit, 2021). A study conducted by the Lebanese Center for Policy Studies in 2019 explains how the devaluation of the Lebanese pound has made it more expensive for businesses to import sustainable materials and technologies (such as energy-efficient lighting and insulation) with the cost of imports increasing, which has discouraged their adoption. Moreover, The majority of businesses surveyed (72%) reported that they had not received any funding or support for sustainable development initiatives. The lack of funding and access to credit has made it difficult for businesses to invest in sustainable practices, as they struggle to cover their basic operating costs (Harb, 2019).

Ultimately, the economic crisis in Lebanon has had a profound impact on the country's workforce, with rising unemployment rates being a significant consequence. According to the World Bank, the unemployment rate in Lebanon increased from 6.1% in 2018 to 28.3% in 2020 (World Bank, 2021), with the COVID-19 pandemic worsening the situation, as more than 470,000 jobs were lost in Lebanon due to the pandemic in 2020 alone, according to the International Labor Organization (ILO) (ILO, 2020).

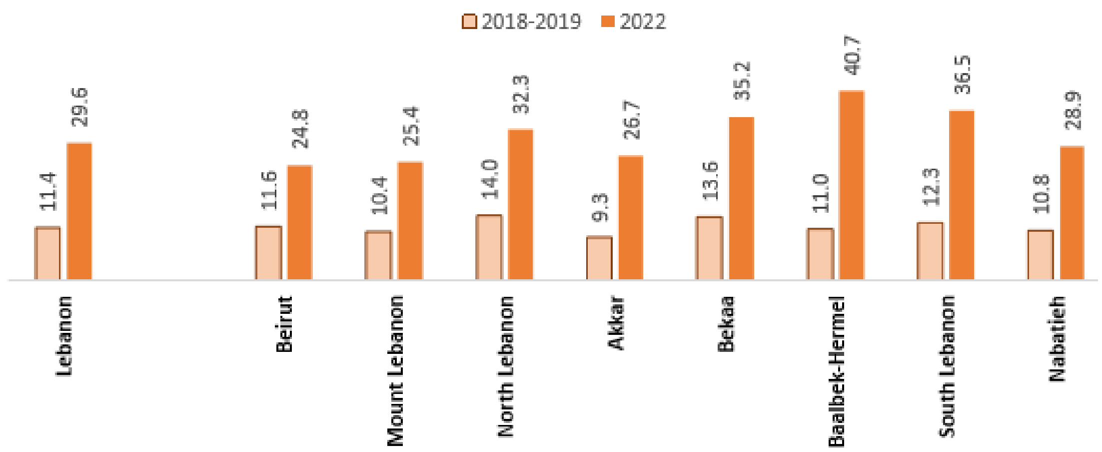


FIGURE 5: Lebanon’s unemployment rates per governorate between 2018 and 2022

This issue has been felt across all sectors of the economy, with no industry or profession being immune to the effects of the economic crisis. However, some sectors have been hit harder than others. For example, the hospitality and tourism industry, which is one of the largest employers in Lebanon, has been decimated by the crisis. According to the Lebanese Ministry of Tourism, the number of tourist arrivals in Lebanon decreased from 1.8 million in 2019 to just 537,000 in 2020, representing a decrease of 70% (MOT, 2020). This decline in tourism has had a significant impact on the industry, leading to the closure of many hotels, restaurants, and other businesses that depend on tourism.

The decline in employment opportunities has had a significant impact on the living standards of Lebanese citizens. The high levels of unemployment have made it difficult for individuals and families to make ends meet, leading to a rise in poverty rates. According to the World Bank, the poverty rate in Lebanon increased from 28% in 2019 to 55% in 2020. This increase in poverty has had a profound impact on the health and well-being of Lebanese citizens, with many struggling to access basic necessities such as food and healthcare (World Bank, 2021).

Lebanon's Position regarding the Circular Economy

From the Crisis to the Circular Economy

The economic crisis in Lebanon has forced many Lebanese businesses and individuals to look for new and innovative ways to survive and has made it imperative for the country to embrace new economic trends and opportunities to sustain its economic growth and development. The circular economy offers a range of opportunities to do so as it has the potential to create new business opportunities, improve resource efficiency, and enhance sustainability. In Lebanon, it has been gaining traction in recent years, driven by a growing awareness of the need for sustainable development and the potential economic benefits that it can bring. With the country's currency devalued and foreign imports becoming increasingly expensive, many Lebanese businesses and consumers have turned to local production and consumption as a way to stay afloat. This shift has created new opportunities for circular economy initiatives, such as local food systems and community-based production networks.

As many Lebanese businesses and consumers turned to local production and consumption as a way to stay afloat with foreign imports becoming increasingly expensive, community-supported agriculture (CSA), where consumers subscribe to receive a weekly box of locally grown produce, became popular in Lebanon. The number of CSAs in Lebanon has grown from just a few in 2015 to over 20 in 2020, according to a report by the Food and Agriculture Organization (FAO) (FAO, 2021). By supporting local farmers, CSA initiatives not only improve resource efficiency and enhance sustainability but also create new business opportunities and strengthen local communities.

In addition to local food systems, circular economy initiatives such as community-based production networks can also play a significant role in sustainable development in Lebanon. These networks bring together local producers and consumers to create closed-loop systems that reduce waste and enhance resource efficiency. For example, the Lebanese startup FabricAID has developed a circular economy model for textile waste by collecting, sorting, and redistributing used clothing to people in need. The company has diverted over 400 tons of textile waste from landfills and donated over 140,000 clothing items since its launch in 2018 (FabricAID). Another example is the Lebanese NGO Recycle Lebanon, which collects and recycles waste materials from businesses and households and transforms them into new products. The organization has recycled over 500 tons of waste and created employment opportunities for disadvantaged communities in Lebanon (Recycle Lebanon, 2023).

Another recent circular economy trend in Lebanon is sustainable tourism, which can provide a new avenue for growth and development in the sector. For example, the Lebanese startup Live Love Recycle has developed a platform that connects tourists with local communities and encourages sustainable tourism practices. The platform offers tours and experiences that showcase Lebanon's cultural and natural heritage while also promoting sustainable practices such as waste reduction and recycling (United Nations, 2019). By supporting sustainable tourism, circular economy initiatives can not only create new business opportunities but also help to protect and enhance Lebanon's natural and cultural resources for future generations.

Another way in which the economic crisis has driven interest in the circular economy is through the promotion of alternative energy sources. With electricity and fuel shortages becoming increasingly common in Lebanon, there has been a growing interest in alternative energy sources, such as solar and wind power. And finally, the economic crisis has driven interest in the circular economy through the promotion of innovative financing models. With traditional financing sources becoming increasingly scarce, many Lebanese businesses and entrepreneurs have turned to alternative financing models, such as crowdfunding and impact investing.

In 2019, the first impact investing fund in Lebanon, the Middle East Venture Fund (MEVF), was launched with a target size of $50 million. The fund focuses on investing in early-stage companies in the MENA region that have a positive social or environmental impact. In addition, Microfinance institutions (MFIs) have been providing access to credit for low-income individuals and small businesses in Lebanon. According to a report by the Sanabel Microfinance Network (SMF), the total loan portfolio of MFIs in Lebanon reached $118 million in 2019, with an average loan size of $4,500 (SMF, 2020). These models are particularly well-suited to circular economy initiatives, which often rely on community support and investment to get off the ground.

The Challenges of the Circular Economy in Lebanon

As the concept of the circular economy is still in its infancy in Lebanon, the country is facing several challenges in its efforts to transition towards a more circular economy. One of the major challenges is the lack of infrastructure and resources needed to support circular economy practices. This includes inadequate waste management systems, limited access to recycling facilities, and a shortage of skilled personnel with expertise in circular economy practices (Nehme, 2020). In addition, there is a need for the development of policies and regulations that incentivize circular practices and penalize wasteful practices. Many policies have been successful in promoting circular economy practices in other countries and could be adapted and implemented in Lebanon.

For example, ‘Extended Producer Responsibility (EPR)’ is implemented in several countries, including Sweden, Germany, and Japan. This policy holds producers responsible for the entire lifecycle of their products, including disposal and recycling. Producers are required to pay for the collection, treatment, and disposal of their products at the end of their useful life (Hilton, 2019). Another policy is Pay-As-You-Throw (PAYT), which charges consumers based on the amount of waste they generate. The more waste they generate, the more they pay. This policy is implemented in several European countries, including Belgium, France, and the Netherlands (Reichenbach, 2008).

Another challenge facing the circular economy in Lebanon is the lack of awareness and understanding among the general public about the importance of circular practices. Most people in Lebanon are not familiar with the concept of the circular economy, and as a result, they do not see its importance. This lack is also prevalent among policymakers and government officials, making it challenging to introduce policies and regulations that support the circular economy (Nehme, 2020). Therefore, there is a need to raise awareness and build capacity among policymakers, industry leaders, and the general public about the benefits and opportunities of the circular economy.

Moreover, the lack of infrastructure in Lebanon to support the circular economy worsens the situation. Lebanon has limited waste management facilities, and those that exist are not equipped to handle the complex needs of the circular economy. This lack of infrastructure means that implementing a circular economy in Lebanon would require significant investment in new infrastructure, technologies, and business models that can support circular economy practices. For example, according to a report by the UNDP, the investment required to develop a comprehensive waste management system in Lebanon is estimated at $1.4 billion over ten years (UNDP, 2022).

Furthermore, Lebanon has a weak regulatory framework, making it challenging to introduce policies that support the circular economy. For example, Lebanon ranked 143rd out of 190 countries in terms of regulatory quality in the World Bank's 2019

Ease of Doing Business report (World Bank, 2019). There is also a lack of coordination between different government agencies, according to the World Bank's 2018 Lebanon Economic Monitor, which makes it challenging to implement policies and regulations (World Bank, 2018). Also, the cultural attitudes towards waste and resource management pose a significant challenge to implementing the circular economy in Lebanon. The Lebanese society has a culture of waste and disposal, which means that many people do not see the value in reducing waste or recycling. This attitude is also prevalent among businesses, which may prioritize profits over sustainable practices (Chammas, 2020). For instance, a study by the Lebanese Center for Policy Studies (LCPS) found that 63% of households in Lebanon dispose of their waste by burning it, burying it, or throwing it in the sea, and that 56% of Lebanese citizens believe that waste management is the government's responsibility, rather than their own (LCPS, 2019).

Despite the many challenges facing the Lebanese economy, there are also some opportunities for growth and development. For example, the country has a highly educated workforce and a strong entrepreneurial culture. Lebanon also has the potential to become a hub for renewable energy and sustainable development, given its strategic location in the Mediterranean and its abundant natural resources.

The Lebanon Reforestation Initiative

Overview of the NGO

The Lebanon Reforestation Initiative (LRI) is a Lebanese NGO registered at the Ministry of Interior and Municipalities under no. 1186 on 18 June 2014 that had started as a project launched in 2010 by the United States Forest Service (USFS) Office of International Programs (IP) through the support and funding of the United States Agency for International Development (USAID). LRI’s long-term vision is: “Communities in Lebanon sustainably managing their forests and landscapes for the benefit of the environment and for their wellbeing". LRI's mission is to expand, manage and protect Lebanon's forests and landscapes through a community-based approach. LRI works on building resilient communities to environmental threats, increasing environmental awareness and education, advocating for forest conservation, and advancing research in the forestry field.

FIGURE 6: Lebanon Reforestation Initiative and USAID Logos

The Goals of LRI

- Improve forest and landscape management across Lebanon, in a participatory approach with the local communities and the private sector.
- Integrate Climate Change considerations in LRI programs and activities.
- Establish a functioning Research Unit in LRI and partner with national, regional and international research institutions.
- Institutionalize and upscale environmental education and awareness programs.
- Advocate for forest protection.
- Develop urban forestry programs and activities.

The Programs of LRI

LRI focuses on seven program areas:

1) Integrated Landscape Management: Aims at supporting local communities to manage Lebanon's landscapes, while building their capacities to preserve their surrounding ecosystems, address the ecological challenges faced in their villages, and lead to prosperous and sustainable livelihoods. Through this program, LRI seeks to achieve community-based landscape restoration through the introduction of innovative environmental techniques and new economic opportunities through forestry that will further boost rural development and encourage youth to stay in their towns.

2) Climate Change Resilience Program: Focuses on the significant relation between sustainable development and climate change. The program aims at supporting the Lebanese Government's mitigation & adaptation policies targeting the forestry and the energy sector.

3) Research & Development Program: Works with academic institutions, research centres and experts to advance the knowledge in landscape restoration and management across the country.

4) Environmental Advocacy & Lobbying Program: Aims at supporting local communities in creating solutions for their environmental challenges through an efficient approach that energizes people to work on a specific cause and influences decision-makers to create a change.

5) Environmental Education, Awareness & Capacity Development Program: Aims at raising awareness and improving new generation knowledge of forestry and forest issues, to contribute to improving attitudes and behaviours to restrict damages on the forests specifically and on the environment generally.

6) Urban Forestry Program: Aims at introducing various urban forestry concepts to Lebanon's cities, improving urban citizens' understanding of the value of green spaces and working with them to improve their wellbeing and food security.

7) Rural Tourism Program: Aims at developing sustainable and responsible rural tourism models based on sound nature and culture conservation practices and well-developed environmental education programs, while supporting livelihoods of rural citizens and bringing about sustainable rural development.

The Circular Economy to LRI

As mentioned before, many businesses and NGOs in Lebanon started to consider the circular economy model in their work after the economic crisis hit Lebanon in 2019. LRI was one of the NGOs that realised the model's potential in improving the NGO's work efficiency. Hence, the NGO started researching with experts on this domain the feasibility of implementing circular practices into its projects. Since then, it has executed some projects with circular measures implemented during the planning and execution stages of the projects.

By including circular measures in its work, LRI aims to create a more sustainable and efficient approach to its reforestation projects. In addition to environmental benefits, LRI also hopes to achieve social and economic benefits through increased community involvement and empowerment, as well as the creation of new economic opportunities. Through its research and implementation of circular practices, LRI is positioning itself as one of the leaders in sustainable reforestation in Lebanon. By sharing its experiences and insights with other NGOs and businesses, it can help to promote the adoption of circular practices more broadly in the country, leading to a more sustainable and resilient economy.

Research Objectives

Research Purpose

The purpose of this research is to investigate the potential benefits and implications of applying circular economy principles to reforestation efforts, specifically through the lens of a Lebanese non-governmental organization (NGO). The study will explore and provide evidence-based insights into the potential benefits of implementing circular practices in the context of reforestation projects. The research will examine the outcomes of the projects by measuring various indicators on the environmental and social levels, and assessing the impact of circular practices on these outcomes.

Our choice of research topic was driven by the recognition of the critical role of reforestation and the circular economy in sustainable development, the significant gap in the literature regarding the integration of circular economy principles in reforestation efforts, and the potential of our research to contribute to policy, practice, and the global sustainable development agenda.

By demonstrating the potential benefits of circular economy practices in the context of reforestation, this study could help to promote the adoption of these practices more broadly, contributing to the development of more effective and sustainable environmental policies and practices in Lebanon and other countries that have similar environmental challenges. Additionally, the study could help to inspire further research and exploration of the potential applications of circular economy practices in other areas of environmental and sustainable development.

Research Question and Hypotheses

What is the impact of implementing circular economy measures in the planning and execution phases of a reforestation project on the environmental and social outcomes of the reforestation project?

- H0: The implementation of circular economy measures in the planning and execution phases of a reforestation project has no significant impact on the environmental and social outcomes of the reforestation project.
- H1: The implementation of circular economy measures in the planning and execution phases of a reforestation project positively impacts the environmental and social outcomes of the reforestation project.

To answer these questions, the study uses a quantitative research approach to collect and analyze data related to the outcomes of the reforestation projects implemented by the Lebanon Reforestation Initiative. The study uses a sample of reforestation projects that have been implemented by the NGO, and data on the specific circular economy practices implemented and their impacts are collected from project reports and other relevant sources. The study analyzes the data using statistical methods to identify any significant differences in the outcomes of reforestation projects that have implemented specific circular economy measures and those that have not. This provides evidence-based insights into the potential benefits of applying circular economy practices in reforestation projects.

Expected Outcomes

The expected outcomes of the research are several. First, providing empirical evidence on the impact of circular economy practices on reforestation efforts. By challenging the null hypothesis through a quasi-experimental design, we expect to demonstrate that the integration of circular economy principles can significantly enhance the environmental and social outcomes of reforestation projects.

In addition, this study seeks to contribute to the academic discourse on the circular economy and reforestation. By exploring the interplay between these two areas, we expect to offer a new perspective that can enrich the existing body of knowledge and stimulate further research.

Moreover, the findings of this research are expected to provide practical guidance for NGOs, policymakers, and other stakeholders involved in reforestation initiatives. By identifying effective strategies and practices, we aim to help these entities design and implement more sustainable and effective reforestation projects.

Also, this research could have significant policy implications. By demonstrating the potential benefits of integrating circular economy principles into reforestation efforts, we hope to influence policy decisions and encourage the adoption of such practices at a broader level.

Ultimately, this research seeks to promote sustainability. By highlighting the potential of the circular economy as a tool for enhancing reforestation efforts, we aim to encourage its adoption, thereby contributing to the broader goal of sustainable development.

Research Methodology

Research Design

The research design for this study is quasi-experimental with a non-equivalent group design, through which researchers compare pre-existing projects that have different levels of exposure to the independent variables. In this study, the dependent variables are the environmental and social outcomes of the reforestation projects, while the independent variables are the circular economy measures implemented in the planning and execution of the reforestation projects. The groups are reforestation projects that were carried out by Lebanon Reforestation Initiative and that had different exposure to the different independent variables.

The chosen projects have implemented between one and twelve circular economy measures during their execution, which is the total number of independent variables in this study. This design allows us to compare the outcomes between the different projects and assess the effects of the independent variables on the dependent variables while considering the natural variations in exposure.

Several reasons led to the selection of a quasi-experimental design for this study. Firstly, it is not feasible to randomly assign reforestation projects to a control group and an experimental group. Reforestation projects are complex, long-term, and resource-intensive projects that require significant planning and coordination. Secondly, the NGO carries out reforestation projects based on community needs, availability of funding, and other factors that are beyond our control. Thirdly, the NGO has already carried out reforestation projects with different levels of inclusion of circular economy measures. This provides a natural experimental setting in which the quasi-experimental design can be used to compare the outcomes of the different projects.

Fourthly, the quasi-experimental design is suitable for studying the impact of a treatment or intervention on a naturally occurring group. In this case, the treatment is the circular economy measures, and the study aims to determine whether this treatment has significant impacts on the outcomes of reforestation projects. Lastly, the quasi-experimental design is also advantageous because it allows for the use of quantitative data, which are collected for this research through project reports and other relevant sources.

Research Approach

The research approach utilized is quantitative, since it allows for the collection and analysis of numerical data. It is particularly suited to this study because the research question aims to investigate the impact of implementing circular economy measures on the outcomes of reforestation projects. By measuring the outcomes of the reforestation projects numerically, allowing for statistical analysis of the data. To collect the necessary data, quantitative data is collected through project reports and other relevant sources.

Sampling

Population and Variables

Population: The population in this research is all of the reforestation projects done by the NGO Lebanon Reforestation Initiative.

Independent Variables: Circular economy measures implemented in the planning and execution stages of the reforestation projects.

Dependent Variables: The environmental and social outcomes of the reforestation projects.

Sampling Method

The sampling method used in this study is the criterion purposive sampling method, a non-probability sampling technique that allows us to target specific parts of the population that possess certain traits or characteristics that are essential for the study. This method is particularly useful in this research since we have a specific research question and we want to ensure that the sample selected is representative of the population of interest. Additionally, this method is cost-effective and more efficient than other sampling methods because it allows us to target the specific needed group without having to sample the entire population.

This method involves the selection of the projects based on a predetermined criterion that is relevant to the research question and should be based on prior knowledge or research, which is whether or not the reforestation project included at least one circular economy measure. The population is all of the reforestation projects done by the Lebanon Reforestation Initiative, and the sample includes projects that implemented between one and twelve circular economy measures, to ultimately study the impacts of the measures on the projects' outcomes. Consequently, the selected sample is representative of the population of interest.

Sample Size

The sample is made of thirty-eight projects of reforestation done by the Lebanon Reforestation Initiative. This number is influenced by many factors, which first, is the total number of projects implemented by the NGO, which is about four hundred projects in general, and fifty projects that have included circular economy measures. From fifty total reforestation projects, choosing a sample size of thirty-eight projects provides a representative sample of the population while still being manageable within the timeframe and resources available for our research.

This size of the sample also allows for a more in-depth analysis of each project, as more detailed information and data can be gathered for a smaller number of projects. This approach can lead to a richer and more nuanced understanding of the impact of circular economy measures on reforestation outcomes, as selecting a sample size that is too small may lead to biased results that are not representative of the population, while selecting a sample size that is too large can be costly, time-consuming, and inefficient. Therefore, selecting a sample size that is representative of the population and is feasible within the constraints of the research is crucial.

Finally, our research is exploratory in nature, and a sample size of thirty-eight projects is sufficient to generate insights and hypotheses for future research, especially since not enough research has been done on the impacts of circular economy measures on the outcomes of reforestation projects. This means that there is no clear precedent for the ideal sample size to use in our research. Therefore, our chosen sample size depends on our knowledge of the population of interest and the practical constraints of the research.

The Sample

The thirty-eight projects that comprise the sample are all part of one megaproject 'LiF: Livelihood in Forests'. Lif is a $5M USAID-funded project implemented by the Lebanon Reforestation Initiative in different cities around Lebanon between 2018 and 2021. It consisted of fifty individual projects spanning over five hundred hectares of land. Its primary objective is to restore and revive degraded ecosystems through the planting of over a million trees. This initiative held great significance both socially and environmentally, and brought about positive change on multiple fronts in Lebanon.

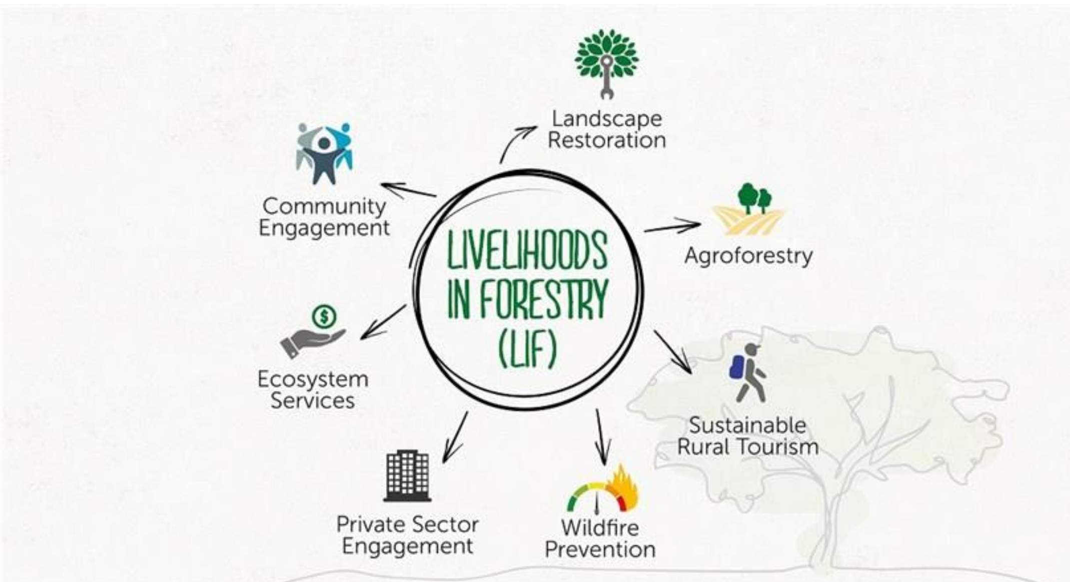


FIGURE 7: Overview of the goals of the LiF: Livelihood in Forests project by LRI

From a social perspective, the Lif project focused on creating tangible benefits for local communities. One of its key objectives was to generate employment opportunities by involving community members in various reforestation activities. By providing jobs related to tree planting, forest management, and maintenance, the project contributed to economic development and improved the livelihoods of individuals living in the project areas. On the environmental front, LiF sought to address the urgent need for ecosystem restoration. By planting over a million trees across the vast project area, the initiative rehabilitated degraded landscapes, enhanced biodiversity, and mitigated the impacts of climate change.

From a circular point of view, Lebanon Reforestation Initiative had started its research on ways to implement the circular economy in their practices for some time. The logistic conditions of LiF made it a suitable candidate to start the application of LRI's research in reforestation projects. Thus, they chose to implement a different set of circular measures in each reforestation project (between one and twelve circular measures in total) to benefit from the results for researching future developments in the domain of circularity in the NGO.

The thirty-eight projects chosen for this research all had durations between one and two years for their planning and implementation together. Each project covered between five and fifty hectares of land. Thus, the inclusion criteria of the projects in this research were based on their location, size, and the inclusion of circular economy measures.

The projects are referred to by the location where they took place. Their identifier is according to their numbering as presented below:

	Name/ Location	Circular Measures Implemented
1	Aaqoura	Pre-Project Training, Recycling, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use
2	Ain Arab	Pre-Project Training, Post-Project Maintenance, Tree Productivity Quota, Stone Mulching
3	Ainata	Pre-Project Training, Tree Species Requirement: Carbon Sequestering, Tree Quota, Natural Pest Management, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use, Stone Mulching
4	Aitanit	Pre-Project Training
5	Bakka	Pre-Project Training, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use
6	Bakka 2	Pre-project Training, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Native Seedlings Use, Stone Mulching
7	Baaloul	Species Quota, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution
8	Baskinta	Pre-Project Training, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use

9	Bazoun	Pre-Project Training, Tree Species Requirement: Carbon Sequestering, Tree Quota, Recycling, Stone Mulching
10	Bcharreh	Species Quota, Post-Project Maintenance, Tree Productivity Quota
11	Bireh	Species Quota, Tree Species Requirement: Carbon Sequestering, Tree Quota, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use, Stone Mulching
12	Dahr El Ahmar	Pre-Project Training, Post-Project Maintenance, Tree Productivity Quota, Community-Led Execution, Stone Mulching
13	Ehden	Pre-Project Training, Invasive Species Removal, Post-Project Maintenance, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use
14	Hasroun	Pre-Project Training, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Tree Quota, Tree Productivity Quota, Native Seedlings Use, Stone Mulching
15	Hasroun 2	Pre-Project Training, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Community-Led Execution, Stone Mulching
16	Jaj	Pre-Project Training, Invasive Species Removal, Community-Led Execution, Native Seedlings Use
17	Joub Jannine	Pre-Project Training, Invasive Species Removal, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota
18	Kawkaba Abou Arab	Pre-Project Training, Invasive Species Removal, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling,

		Tree Productivity Quota, Community-Led Execution, Native Seedlings Use, Stone Mulching
19	Kfar Denis	Pre-Project Training, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Tree Productivity Quota
20	Kfar Denis 2	Pre-Project Training, Invasive Species Removal, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use, Stone Mulching
21	Kherbit Rouha	Pre-Project Training, Invasive Species Removal, Tree Quota, Natural Pest Management, Tree Productivity Quota, Community-Led Execution
22	Kfarmechki	Pre-Project Training, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Native Seedlings Use, Stone Mulching
23	Lala	Pre-Project Training, Species Quota, Invasive Species Removal, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution, Stone Mulching
24	Machghara	Pre-Project Training, Species Quota, Invasive Species Removal, Native Seedlings Use
25	Majdal Balhis	Pre-Project Training, Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Native Seedlings Use, Stone Mulching

26	Majdal Balhis 2	Species Quota Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Tree Productivity Quota, Community-Led Execution
27	Majdal Balhis 3	Species Quota, Invasive Species Removal, Post-Project Maintenance, Tree Quota, Natural Pest Management, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use
28	Manara Hamara	Pre-Project Training, Species Quota, Invasive Species Removal, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution, Stone Mulching
29	Maaser Chouf	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Native Seedlings Use, Stone Mulching
30	Maaser Chouf 2	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Productivity Quota, Native Seedlings Use
31	Mdoukha	Pre-Project Training, Species Quota, Invasive Species Removal, Tree Productivity Quota, Community-Led Execution, Stone Mulching
32	Mdoukha 2	Pre-Project Training, Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Native Seedlings Use
33	Niha	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use

34	Qaraoun	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Stone Mulching
35	Rafid	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Tree Quota, Natural Pest Management, Recycling
36	Sohmor	Species Quota, Invasive Species Removal, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Community-Led Execution, Native Seedlings Use, Stone Mulching
37	Tannourine	Species Quota, Invasive Species Removal, Tree Species Requirement: Carbon Sequestering, Post-Project Maintenance, Tree Quota, Natural Pest Management, Recycling, Tree Productivity Quota, Stone Mulching
38	Yamouneh	Species Quota, Invasive Species Removal, Native Seedlings Use

Confounding Variables

This section is to identify and describe the several potential confounding variables that needed to be considered in this study, and the appropriate measures that were taken to address or control for them:

- Project Date: The variable of time poses a potential confounding factor in this research, considering the longevity of the work of the NGO under study, which has implemented reforestation projects over a span of more than 10 years. This extended period encompasses diverse project execution phases, including variations in reforestation strategies, technological advancements, and changes in land and soil conditions. To mitigate the influence of time as a confounding variable, we have restricted the focus of the research to reforestation projects undertaken within a specific timeframe, specifically between 2018 and 2021. By narrowing the temporal scope, we aim to control for the potential effects of different time periods and enable a more accurate evaluation of the impact of circular economy measures on the environmental and social outcomes of the reforestation projects.

- Project Location: One of the most critical factors that could affect the outcomes of a reforestation project is the site where the project is carried out. Site characteristics, such as soil type, climate, topography, and existing vegetation, may vary widely from one site to another and influence the growth, survival, and biodiversity of the planted trees. To control for this potentially confounding variable, we have selected projects implemented only in five out of eight Governorates in Lebanon (North, Beqaa, Keserouan, Baalback, and Mount Lebanon) that have similar characteristics in comparison to the three remaining sites due to their vicinity to each other, as well as other factors that the Lebanon Reforestation Initiative have discovered through their research via satellite images, soil surveys, and climate records, and verified through on-site visits and measurements, all done before choosing sites for reforestation projects.

- Project Size: Another potential confounding factor in this research is the size of the reforestation projects. The NGO under study, Lebanon Reforestation Initiative (LRI), has implemented projects that vary in size, ranging from less than 1 hectare to more than 100 hectares. The project size can influence various aspects of the reforestation outcomes. To address the potential confounding effect of project size, we have limited our research to projects within a specific size range, specifically between 30 and 50 hectares. Reforestation projects within the 30-to-50-hectare range are generally considered ecologically effective. This range allows for the establishment of viable forest ecosystems that can provide habitat for various flora and fauna, contribute to biodiversity conservation, and potentially enhance ecosystem services such as carbon sequestration and water regulation. Within the 5 to 50-hectare range, it is reasonable to expect meaningful ecological benefits without excessively diminishing returns.

- Funding Source: In this research, potential confounding effects related to funding sources have been addressed by selecting reforestation projects that fall under the same megaproject and are funded by a single source. By ensuring consistency in the funding source, we aim to minimize variations in project scale, implementation strategies, and resource allocation that could potentially influence the outcomes. This control allows us to focus specifically on the impact of circular economy measures implemented within the projects, rather than confounding effects associated with different funding sources.

- Project Management: The potential confounding effects related to project management have been controlled for in this research as all selected projects are part of the same megaproject and are managed by the same team. By maintaining consistency in project management, including planning, coordination, and implementation strategies, we aim to reduce variations in project outcomes that could be attributed to different management practices. This control enables us to isolate the influence of circular economy measures on the social and environmental outcomes of the reforestation projects.

6- Ecological Context: To address potential confounding effects related to the ecological context, the selected reforestation projects were chosen in locations that were carefully considered to be similar in terms of environmental characteristics. Additionally, all the projects occurred within the same considerably short timeframe, ensuring that the general climate and environmental conditions in the country remained consistent throughout the research period.

Data Collection and Management

Data Collection Methods

The techniques we employed in this research to gather the necessary information to investigate the impacts of circular economy measures on the outcomes of reforestation projects conducted by the Lebanon Reforestation Initiative were document analysis and secondary data collection. These approaches allowed us to extract valuable insights from existing project documents, reports, and external sources, providing a comprehensive understanding of the subject matter.

In this section, we discuss in detail the techniques used, along with the instruments and tools employed for each technique. First, document analysis involved the careful examination and interpretation of relevant project documents and reports of the specific projects we had chosen during the sampling stage. Among the documents were the following:

- Reforestation Project Proposal: This document presents the formal proposal for the reforestation project. It includes a comprehensive description of the project, its methodologies, expected outcomes, and the resources required for its implementation. It also provides a clear statement of what the project aims to achieve in terms of ecological, social, or economic outcomes.

- Lebanon Reforestation Initiative Reforestation/Afforestation Guidelines: This document provides guidelines and recommendations specific to the reforestation and afforestation initiatives undertaken by the Lebanon Reforestation Initiative. It includes instructions for site preparation, species selection, planting techniques, and maintenance practices.

- Forest Management Plan: This document outlines the plan for managing the forest areas within the reforestation project. It includes details on sustainable forest management practices, conservation strategies, and monitoring and evaluation frameworks.

- Financial Report of the Reforestation Project: This document provides information about the budget and finances of the reforestation project. It includes a breakdown of the allocated funds, expenditures, income sources, and financial management aspects of the project.

- Outplanting Monitoring Report: This document presents the results of monitoring activities carried out after the out-planting phase of the reforestation project. It includes information on survival rates, growth rates, and overall performance of the planted seedlings.

- Field Officer Report: This document is a report submitted by field officers or project staff who are responsible for overseeing and monitoring the reforestation project activities. It provides updates, observations, and progress reports from the field.

- Seedling Inventory Report: This document contains information about the number and species of seedlings used in a reforestation project. It provides a comprehensive inventory of the seedlings planted, their quantities, and the specific species involved.

- Training Participant Report: This document provides details about the individuals who received training through a reforestation project. It includes information such as the number of participants, their names or unique identifiers, and possibly additional details like their demographic information or the specific training modules they completed.

- Workforce Participation Log: This document tracks the number and details of the individuals involved in working on a reforestation project. It includes information such as the number of workers, their names or unique identifiers, and other details like their roles or responsibilities within the project.

- Tools Inventory List: This document outlines the tools used in a reforestation project. It provides a comprehensive list of the tools utilized, their quantities, and possibly additional information such as their specific types or descriptions.

These documents, among others, served as valuable sources of information about the work of the Lebanon Reforestation Initiative as a whole, as well as the specifics we needed to answer our research question. The instruments and tools used for document analysis included a laptop equipped with appropriate software for reading and organizing digital documents. We made use of file management software ‘Google Drive’ to keep the documents organized and accessible throughout the analysis process.

During the analysis, we carefully read and examined each document, taking detailed notes, extracting relevant data, and categorising it based on the research objectives and variables of interest. By systematically analyzing the documents, we aimed to identify patterns, trends, and insights regarding the implementation of circular economy measures and their potential impact on reforestation outcomes. Some visits to the office of the NGO were essential to clarify the information with the project managers and field officers.

Further, the secondary data collection involved gathering information from external sources to supplement the primary data collected through document analysis. This technique allowed us to access existing research studies, academic publications, Lebanese government reports by the ministries of tourism, agriculture, and finance, and relevant statistical data related to the outcomes of reforestation projects in the country. By incorporating secondary data, we aimed to provide a broader context for understanding the research objectives. To gather the data, we employed only digital instruments and tools, such as the following:

- File Management Software: To keep the project-specific documents organized and easily accessible, Google Drive was utilized. This software facilitated the creation of a structured digital file system, enabling efficient data management throughout the analysis process.

- Citation Management Software: To organize and manage the secondary data sources, a citation management software called ‘Zotero’ was utilized. This tool helped in keeping track of the references and sources, ensuring proper citation and referencing in the study.

- Online Databases: Various online databases were utilized to access academic publications, research studies, and statistical data related to reforestation projects and circular economy measures. These databases provided a wide range of secondary data sources and facilitated efficient searching and retrieval of relevant information.

- Digital Repositories: Digital repositories containing relevant reports and publications were accessed to gather additional secondary data. These repositories offered a centralized location for accessing scholarly materials and reports from various sources.

- Scholarly Search Engines: Scholarly search engines were utilized to conduct targeted searches for academic publications and research studies related to the research topic. These search engines provided access to a vast array of scholarly articles and research papers.

We chose to employ document analysis and secondary data collection techniques for several reasons that align with the objectives and scope of our research. First and foremost, document analysis is a suitable technique because it allows us to directly access and examine project-specific documents and reports provided by the Lebanon Reforestation Initiative that contained valuable information regarding the objectives, methodologies, and outcomes of the reforestation projects. Document analysis helped us understand the underlying framework and decision-making processes guiding the integration of circular economy measures within the reforestation projects.

In addition to document analysis, the inclusion of secondary data collection was crucial to provide a broader context and support the findings derived from the primary data. As we aimed to leverage the knowledge and insights gained from previous research and reports, thereby enriching the findings of our study. Academic databases, Lebanese government websites, and digital repositories served as valuable sources of information for accessing a wide range of secondary data. These sources enabled us to gather statistical data, case studies, and expert opinions related to working with reforestation projects.

The utilization of secondary data also allowed us to benchmark the performance of the Lebanon Reforestation Initiative against other similar NGOs that implement reforestation projects. This broader perspective helped us identify best practices, emerging trends, and potential challenges related to the integration of circular economy measures in reforestation projects. By drawing on a diverse range of secondary data sources, we ensured that our research was informed by a comprehensive and robust knowledge base.

Relevance and Reliability

The reliability of the primary data sources was ensured through several measures. Firstly, the documents were sourced directly from the Lebanon Reforestation Initiative, an authoritative organization responsible for implementing reforestation projects. This ensured that the information contained in the documents were accurate and trustworthy. Additionally, to enhance the reliability of the data, we made visits to the office of the Lebanon Reforestation Initiative, engaging in discussions with project managers and field officers. These visits allowed us to clarify any ambiguities, validate the data extracted from the documents, and establish a rapport with the organization, enhancing the trustworthiness and reliability of the primary data sources. By engaging in discussions and seeking additional information, we ensured a comprehensive and well-rounded analysis of the available documents.

In addition to primary data, the relevance of the selected secondary data sources is rooted in their ability to enrich our understanding of the integration of circular economy measures in reforestation projects. While their reliability was ensured through careful selection and verification of the credibility of the information obtained. Academic databases and digital repositories are known for their rigorous peer-review processes, ensuring the quality and reliability of published research studies and publications. The inclusion of reputable academic sources in our study, such as the 'United Nations, the Food and Agriculture Organization, and the World Bank', enhances the credibility and reliability of the secondary data used.

Additionally, the Lebanese government reports obtained from official government websites are reliable sources of information, as they are based on extensive research, data collection, and analysis conducted by the relevant government ministries. To further enhance the reliability of the secondary data sources, we cross-referenced information obtained from multiple sources. This helped in validating the consistency and accuracy of the data, minimizing the risk of relying on potentially biased or unreliable information. By incorporating multiple reliable sources, we ensured that our research findings were supported by a robust and diverse knowledge base.

Data Management

Once the data collection phase was completed, we focused on organizing, storing, and managing the collected data to ensure its accessibility, security, and ease of analysis. We stored the documents on online password-protected cloud storage, after dividing them into folders according to the project, and according to the circular measures implemented in each. We chose this standard as it is the core of the research methodology, so it facilitated the data analysis at a later stage of the work, and we chose Google Drive storage to ensure the integrity and security of the collected data against potential data breaches or computer failures. No access to the data was given to any external account. Finally, since our research focuses on circular measures and outcomes of reforestation projects, the data collected was mostly numerical. Thus, no data coding was needed. Instead, data analysis is implemented involving statistical analysis and interpretation.

When it comes to accuracy, we implemented rigorous quality control measures throughout the data collection process. These measures aimed to minimize errors and inconsistencies in the collected data. First, we implemented double-entry verification when transferring the data from the official documents of the Lebanon Reforestation Initiative as well as from the literature found online to the documents we created for the processed data, in which we included only the specific information required for the research. This involved processing the data twice in two different documents and then cross-checking the entries for discrepancies. Any inconsistencies or errors identified during the verification process were rectified, ensuring accurate data entry. Moreover, after the data collection phase, a thorough data cleaning process was conducted. This involved carefully reviewing each data entry, and checking for missing values, outliers, or any inconsistencies to ensure that the dataset was free from inaccuracies or data entry errors.

Similarly, protecting the confidentiality and integrity of the collected data is of utmost importance. To ensure it, the first step taken was obtaining the consent of the management of the Lebanon Reforestation Initiative in using their data for the research, after clearly explaining the purpose of the study, the data collection process, and how the data would be used and stored. Consent to use the data was given while protecting its confidentiality. Further, with data that contained personal and financial details about the employees and trainees of the projects of Lebanon Reforestation Initiative, anonymization and de-identification were ensured to protect their privacy by removing any identifying information, such as names, addresses, or other personally identifiable details, from the dataset.

Finally, after the dataset was completely organized, we performed data standardization using Jamovi software to ensure fair comparisons and eliminate the influence of scale, as the dataset contained variables that had different measurement units and scales, which could potentially introduce biases and distort the analysis results. Data standardization transformed the variables onto a common scale with a mean of zero and a standard deviation of one. This rescaling procedure allowed us to compare variables directly and evaluate their relative importance without being biased by their original measurement units or scales. It also ensured that no single variable dominated the analysis solely due to its larger magnitude.

Data Identification and Operationalization

Independent Variables

The choice to create a set of circular measures specifically tailored for reforestation projects was driven by the lack of a comprehensive and dedicated framework in the existing literature. Despite the growing interest in circular economy principles and their application in various sectors, there was a notable gap when it came to specific measures applicable to reforestation projects. As such, the need arose to develop a set of measures that align with circular economy concepts and could effectively guide reforestation efforts.

To overcome this gap, the research endeavour involved an extensive review of the available literature on both circular economy principles and reforestation practices. This included examining scholarly articles, reports, guidelines, and case studies related to circular economy approaches in different industries. Additionally, leading associations and companies in the field of circular economy were consulted, including but not limited to the Ellen MacArthur Foundation, World Economic Forum, Sustainable Apparel Coalition, Closed Loop Partners, and Circular Economy Club. These sources provided valuable insights into circular economy practices, strategies, and metrics that could be adapted and applied to reforestation projects.

By combining the knowledge obtained from the literature review and the expertise of these prominent organizations, a comprehensive set of circular measures for reforestation projects was developed. The set was also based on the specific context of the research conducted in collaboration with LRI, which served as a valuable partner, providing on-the-ground expertise and experience in implementing reforestation projects. The NGO's firsthand knowledge of the local environmental conditions, socio-economic dynamics, and community engagement practices played a crucial role in shaping the set of circular measures.

The NGO’s practical experience and lessons learned from already adopting and implementing certain circular economy principles and practices within their reforestation projects provided a solid foundation for the development of the set of circular measures. By incorporating and building upon the NGO's established practices, the research ensured alignment with their ongoing efforts and enhanced the relevance and feasibility of the measures within the local context.

Yet, it is important to emphasize that while the set of circular measures developed for reforestation projects was context-specific, they were also designed to be adaptable and scalable. The intention was to create a framework that could serve as a reference for other reforestation initiatives facing similar challenges and seeking to integrate circular economy principles. The set of circular measures is presented below:

Circularity Principle	Circular Measure
Stakeholder Engagement and Empowerment	Collaborative Community-Led Execution
	Pre-Project Training
Biodiversity Restoration	Tree Quota
	Species Quota

	Tree Species Requirement: Carbon Sequestering
	Tree Productivity Quota
Ecosystem Protection	Removal of Invasive Species
	Natural Pest Management
	Stone Mulching
Efficient Resource Management	Native Seedlings Use
	Recycling
	Post-Project Maintenance

The four principles of Stakeholder Engagement and Empowerment, Biodiversity Restoration, Ecosystem Protection, and Efficient Resource Management provide a holistic and sustainable approach that goes beyond tree planting, by incorporating social, ecological, and economic considerations. By embracing these principles, reforestation projects can enhance community involvement, restore biodiversity, optimize resource utilization, and ensure long-term environmental benefits. The implementation of circular measures based on these principles is essential for fostering sustainable development, mitigating climate change, and promoting the conservation of our ecosystems.

- Stakeholder Engagement and Empowerment

Stakeholder Engagement and Empowerment is a fundamental principle of the circular economy that emphasizes the active involvement of various stakeholders, including local communities, governments, and NGOs. In the context of reforestation projects, stakeholder engagement plays a crucial role in ensuring the success and sustainability of these initiatives. By involving local communities, their knowledge and expertise can be leveraged, leading to better project outcomes and increased ownership.

Engaging stakeholders also promotes transparency, accountability, and equitable distribution of benefits, fostering social cohesion and support for reforestation efforts.

- Community-Led Execution: All the planning and execution of projects that include this measure happened through participatory and collaborative processes with the local community. In detail, community meetings, workshops, and consultations between delegates from the NGO and chosen community members, through which project organizers actively listened to the community's concerns, aspirations, and traditional knowledge related to the environment. After conducting a needs assessment, co-design and planning of the project took place between the community and the NGO. This included selecting tree species, determining planting techniques, and establishing monitoring and evaluation mechanisms.

This measure is circular because it promotes stakeholder engagement, ensuring that the perspectives and voices of community members are taken into account. It actively involves them in decision-making, empowering them by providing a platform to express, fostering a sense of ownership and responsibility among community members.

- Pre-Project Training: Every project that included this measure, included a training program on reforestation before the start of the reforestation project.
The training program lasted for a few months and taught the participants reforestation techniques. The level of the program varied from one project to another based on the initial education of the participants. The main rules of the program also following a circular path were the following:

- The minimum number of participants is thirty people, ensuring that a significant number of community members received the necessary knowledge and skills to actively participate in the reforestation efforts. By training a substantial group, the NGO aimed to create a ripple effect, where trained individuals could further disseminate their knowledge within the community.

- A quota of participants was reserved for marginalized groups within the community (Syrian refugees and workers (Hall, 2020)). This quota aimed to address social inequalities and provide equal opportunities for individuals who may face barriers to participation. By specifically allocating a portion of the training program for marginalized community members, the project aimed to promote inclusivity and empower those who may have been historically marginalized or disadvantaged.
- Another quota was dedicated to women within the community. This specific allocation recognized the importance of gender equality and the role of women in environmental conservation and community development. By reserving a quota for women, the project aimed to encourage their active involvement and ensure their representation and participation in decision-making processes, especially since their role in these practices specifically can be very minor usually when compared to men's.

This measure contributes to the circular economy by enhancing local capacity and empowering individuals with the necessary expertise. The measure fosters self-reliance, reduces dependency on external resources, and promotes the circular economy's goal of utilizing local knowledge and resources efficiently. Furthermore, the training project strengthens social ties, encourages collaboration, and establishes a shared sense of responsibility for the long-term success and sustainability of the reforestation project.

- Biodiversity Restoration

Biodiversity and Ecosystem Restoration is another vital principle of the circular economy that emphasizes the preservation and restoration of natural ecosystems. Reforestation projects contribute to ecosystem restoration by planting trees, which help enhance habitat connectivity and promote biodiversity conservation. Trees provide vital ecosystem services, including carbon sequestration, water regulation, soil erosion prevention, and support for wildlife. Incorporating this principle ensures that reforestation projects go beyond mere tree planting, focusing on the restoration of complex and resilient ecosystems that can sustain diverse plant and animal species.

- Tree Quota: Projects that included this circular measure planted a minimum number of six hundred trees per hectare.

This measure aligns with the circular economy by promoting the restoration and enhancement of biodiversity, as well as ecological balance and resilience, and ensuring the long-term sustainability of the reforestation project. Planting a significant number of trees enhances habitat diversity and supports the regeneration of native flora and fauna.

- Species Quota: projects that included this measure planted a minimum number of seven species per reforestation site.

This measure is considered a circular measure due to its numerous benefits. Firstly, it promotes preserving and enhancing the variety of plant species within the reforested areas. This, in turn, leads to a healthier and more resilient ecosystem. Secondly, the inclusion of multiple tree species contributes to ecological stability by reducing the risk of widespread tree loss caused by specific threats such as pests or diseases. Additionally, diverse tree species provide a wider range of ecosystem services, maximizing the overall benefits of reforestation efforts. Moreover, incorporating a variety of species creates a greater diversity of habitats and niches, fostering a complex and interconnected ecosystem that supports a higher level of ecological interactions. The measure also enhances the resilience of reforestation projects to climate change by ensuring the adaptability of the ecosystem to changing environmental conditions.

- Tree Species Requirement: Carbon Sequestering: At least twenty per cent of the tree species planted in the projects that included this measure are ‘high carbon sequestering’ species.

Some of the high carbon sequestering tree species that LRI uses are: ‘Cedrus libani, Cupressus sempervirens, Juniperus excelsa, and Pinus pinea, among others.’

This measure is considered circular due to its alignment with the principles of circular economy. Firstly, it emphasizes the efficient use of resources by strategically selecting tree species that have a higher capacity for carbon sequestration. This approach ensures that the reforestation project maximizes its potential to mitigate climate change by capturing and storing atmospheric carbon dioxide. Secondly, by incorporating high carbon sequestering species, the measure promotes the sustainable use of natural resources. These species play a vital role in maintaining the carbon balance in the environment, contributing to the circular flow of carbon within the ecosystem. Moreover, the inclusion of such species enhances the resilience of the reforested area, ensuring the long-term effectiveness of the project. Additionally, the planting of high carbon sequestering species supports the development of diverse and healthy forests, which are essential for maintaining overall ecosystem health and functioning. Furthermore, this measure encourages the conservation of valuable tree species that have ecological, economic, or cultural significance.

- Tree Productivity Quota: At least fifty per cent of the tree species planted in projects that included this measure were productive or fruit-bearing.
Some of the productive or fruit-bearing tree species planted by LRI:'Amygdalus sp., Acer monspessulanum, Arbutus andrachne, Cedrus libani, Celtis australis, Crataegus sp., Cupressus sempervirens, Fraxinus angustifolia, Juniperus excelsa, Pinus pinea, Quercus calliprinos, Rosa sp., and others'.

Having between 50 and 60 per cent of the tree species planted in a reforestation project (considering that the percentage differs among the project) as productive or fruit-bearing species aligns with the principles of the circular economy by promoting the restoration of diverse and functional ecosystems. By incorporating productive and fruit-bearing species, the reforestation project not only contributes to the overall biodiversity of the area but also enhances the ecological functionality and resilience of the ecosystem. These species provide a range of benefits that support the local ecosystem and surrounding communities. Many communities have deep-rooted cultural connections to specific fruit-bearing or productive species, and their inclusion in the reforestation project helps preserve cultural heritage and promote community engagement.

- Ecosystem Protection

Ecosystem protection is a critical principle of the circular economy that highlights the need to safeguard and conserve natural ecosystems. In the context of reforestation projects, ecosystem protection focuses on preserving and restoring the integrity of existing ecosystems and their associated services. This principle recognizes the interconnectedness of ecosystems and the importance of maintaining their health and functionality.

- Invasive Species Removal: All the projects that included this measure had a step at the beginning of the project of removing all the invasive species from the reforestation site.

This is a significant circular measure that focuses on restoring and preserving native ecosystems. Invasive species can outcompete native flora, disrupt ecological processes, and negatively impact biodiversity and ecosystem functioning. By actively removing invasive species, the reforestation project aims to restore ecological balance, prevent the spread of invasives, and create suitable conditions for the establishment and growth of native species. This measure aligns with the circular economy's principles by recognizing the importance of maintaining healthy and resilient ecosystems as a foundation for sustainable development and the circular use of ecosystem services.

- Natural Pest Management: projects that included this measure did not include the use of any hazardous chemicals such as pesticides. Instead, natural pest management was implemented.

This is a circular measure because it prioritizes the health and balance of the ecosystem and promotes its natural resilience by allowing beneficial insects, birds, and other organisms to play their roles in controlling pests. By preserving the natural predator-prey relationships, the reforestation project fosters a sustainable and self-regulating ecosystem that can withstand pest outbreaks without the need for harmful chemical interventions. This circular approach to pest management not only safeguards the health of the environment but also reduces the negative impacts on human health and biodiversity, ensuring long-term ecological protection and sustainability.

- Stone Mulching: In projects that included this measure, stones are used as a protective layer over the soil surface around the planted trees.
This measure acts as a physical barrier against soil erosion, preventing the loss of valuable topsoil and protecting the integrity of the ecosystem. Secondly, it helps to conserve soil moisture by reducing evaporation and maintaining a more stable moisture level, which is crucial for the survival and growth of planted trees. Additionally, stone mulching inhibits weed growth, reducing competition for resources and allowing the planted trees to thrive without the need for chemical herbicides. Furthermore, the use of stones in mulching can enhance the microclimate around the trees by regulating soil temperature and moisture, providing a more favourable environment for ecosystem development.

- Efficient Resource Management:

Efficient Resource Management is a very important principle of the circular economy. In the context of reforestation, this principle ensures that resources are allocated efficiently and effectively to achieve the desired outcomes. By adopting efficient resource management practices, the NGO can contribute to the overall resilience and adaptability of the reforestation initiatives.

- Native Seedlings Use: Projects that applied this measure used only native seedlings for the whole reforestation project.
Using only native seedlings in a reforestation project is considered a circular measure as this approach ensures that the resources invested in the project, such as time, effort, and financial resources, are utilized efficiently and effectively. By selecting and planting native seedlings, the reforestation project aligns with the natural ecological conditions of the area, maximizing the chances of successful establishment and

growth. Native species are adapted to the local environment, requiring fewer external inputs, such as water, fertilizer, and pesticides, to thrive. This reduces the dependency on external resources and minimizes the environmental impact associated with the project. Additionally, using native seedlings supports the preservation and propagation of local plant genetic diversity, contributing to the conservation of native species and their associated ecological functions.

- Recycling: All the waste generated from projects that included this measure was recycled.

Recycling is a key circular measure that plays a crucial role in efficient resource management by closing the loop of resource utilization. By recycling, valuable resources are conserved, reducing the need for extracting and processing virgin materials. This significantly minimizes the environmental impact associated with resource extraction. It also helps optimize resource use by extending the lifespan of materials. Instead of being discarded as waste, recyclable materials are diverted from landfills and reintroduced into the production cycle, reducing the demand for new raw materials. This contributes to the conservation of natural resources and reduces the strain on ecosystems.

- Post-Project Maintenance: projects that implemented this measure included a phase after the end of the reforestation phase for project maintenance and follow-up.

During this phase which lasted for one year per project, specific activities were carried out to ensure the survival and healthy growth of the planted trees, such as regular monitoring of the trees' condition, watering and irrigation as needed, weed control to minimize competition for resources, and further pest and disease management. Additionally, any necessary adjustments or corrective measures were implemented to address challenges or issues that arise.

The post-project maintenance phase is considered a circular measure due to its focus on long-term resource management and ecosystem preservation. By ensuring the survival and healthy growth of the planted trees, this phase contributes to the efficient use of resources invested in the initial planting phase. It promotes the circularity of the project by extending the lifespan of the trees, maximizing their carbon sequestration potential and other ecosystem services. Additionally, the ongoing monitoring and management activities during the maintenance phase help protect the biodiversity and overall health of the ecosystem, creating a self-sustaining cycle where the forest can thrive and provide continuous benefits to the environment and local communities.

Dependent Variables

By selecting the following set of reforestation outcomes as dependent variables, the study aims to provide a comprehensive assessment of the social and environmental impacts of reforestation projects. It is based mainly on the data the NGO was capable of providing from its projects, as well as research on the theoretical framework of reforestation.

Outcome Category	Outcome
Social Outcomes	Local Hiring
	Marginalized Hiring
	Women Hiring
	Income Generation
Environmental Outcomes	Forest Density
	Survival Rate
	Biodiversity
	Waste Disposal
	Carbon Sequestration

- Local Hiring: This variable measures the percentage of workers hired from the local community. By prioritizing local hiring, reforestation projects aim to generate employment opportunities and economic benefits for the communities living near the project site. Local hiring supports social development, reduces unemployment, and enhances community engagement and ownership of the project. It ensures that the benefits of reforestation directly reach the local population, fostering positive social outcomes and a sense of shared responsibility.

- Marginalized Hiring: This variable focuses on the percentage of workers hired from marginalized groups, specifically Syrian refugees in the context of Lebanon. Including marginalized populations in reforestation projects promotes social inclusion, addresses inequalities, and provides equal opportunities for individuals who may face barriers to employment. By actively involving marginalized groups, reforestation projects contribute to social cohesion, diversity, and empowerment, while also supporting the integration of vulnerable populations into the local community.

- Women Hiring: This variable measures the percentage of female workers hired in reforestation projects. Women's participation in reforestation efforts is crucial for promoting gender equality, empowering women, and recognizing their significant role in environmental conservation and community development. By ensuring women's representation and active involvement in decision-making processes, reforestation projects contribute to gender mainstreaming and the advancement of women's rights and opportunities.

- Income Generation: This variable measures the number of individuals who secure income through various means related to the reforestation project, apart from job salaries. Income generation opportunities may arise from activities such as eco-tourism, sustainable harvesting of forest products, or value-added processing of forest resources. By creating income-generating avenues, reforestation projects contribute to local economic development, poverty reduction, and the diversification of livelihoods.

Income generation promotes the sustainable utilization of forest resources, incentivizes community participation, and strengthens the economic resilience of local communities.

- Forest Density: This variable assesses the number of trees per hectare that successfully survive and continue to grow after one year of the completion of the reforestation project. Forest density is an essential indicator of the project's success in achieving the desired reforestation objectives. A high forest density signifies successful tree establishment, growth, and canopy cover, which are crucial for enhancing ecosystem functions, supporting biodiversity, and mitigating climate change. Forest density reflects the overall health and resilience of the reforested area and indicates the effectiveness of reforestation efforts.

- Survival Rate: The survival rate variable measures the percentage of planted trees that successfully survive and continue to grow one year after the completion of the reforestation project. This variable is important as it reflects the project's success in establishing a healthy and resilient forest ecosystem. A higher survival rate indicates that the reforestation efforts were effective in providing suitable conditions for tree growth, including proper site preparation, appropriate species selection, and adequate post-planting care.

- Biodiversity: The biodiversity variable assesses the number of species that successfully survive and continue to grow one year after the reforestation project. It indicates the project's impact on enhancing species diversity and promoting ecological resilience. By measuring the number of different species that have established themselves in the reforested area, this variable provides insights into the project's success in creating a habitat conducive to various plant species, supporting ecosystem functions, and increasing overall biodiversity.

- Waste Disposal: The waste disposal variable quantifies the amount of waste generated by the reforestation project and disposed of through conventional waste disposal methods in grams. Reforestation projects may involve activities such as site preparation, tree planting, and maintenance, which can generate waste materials such as packaging, equipment, or leftover plant materials. Monitoring waste disposal helps assess the project's environmental impact and its adherence to proper waste management practices, including recycling, reuse, or responsible disposal. Minimizing waste generation and implementing sustainable waste management practices contribute to the project's overall environmental sustainability.

- Carbon Sequestration: the carbon sequestration variable measures the total amount of carbon dioxide (CO_2) sequestered by the reforestation site within the year following the completion of the reforestation project. Forests play a vital role in mitigating climate change by absorbing CO_2 through photosynthesis and storing it in their biomass. Evaluating carbon sequestration helps assess the project's effectiveness in sequestering CO_2, contributing to climate change mitigation efforts. Higher carbon sequestration values indicate the project's positive impact on reducing greenhouse gas emissions and enhancing the overall carbon balance in the atmosphere.

Data Analysis

Chosen Methods

In this study, the data collected from the reforestation projects are analyzed through several steps. The main test to be conducted is multiple linear regression, along with other statistical means to better explore and verify the data, such as:

- Descriptive Statistics

First, descriptive statistics are calculated to provide a summary of the data collected. This includes several measures such as measures of central tendency, variability, and frequency distributions. These descriptive statistics can help us understand the distribution and basic characteristics of the data.

- Plot Analysis

A box plot analysis is performed to obtain a visual summary of the distribution of the dataset. This allows the detection of outliers visually, which is important as they may indicate data entry errors, measurement inconsistencies, or unusual observations that require further investigation. Consequently, the relevant strategy is taken into consideration to deal with the outliers in case they exist before the next steps of the data analysis.

- Reliability Assessment

To ensure the robustness and consistency of measurement instruments used in our research studies, determine the reliability of our data collection tools, and ensure that the measurements yield consistent results over time and across different contexts, internal consistency testing is implemented using Cronbach's alpha through Jamovi software.

- Simple Linear Regression

Initially, simple linear regression models are conducted to examine the relationships between each independent variable and each dependent variable separately. This can help us determine the individual impacts of circular economy measures on each social and environmental outcome. The regression models assess the significance of the relationships and provide information on the direction and strength of these relationships.

- Multiple Linear Regression

Subsequently, multiple linear regression models are developed to assess the combined effect of the set of predictors explored by the cross-tabulation analysis on the outcomes of reforestation, while controlling for other potential variables and including the relevant confidence interval. The multiple regression analysis provides insights into the unique contribution of circular economy measures when other factors are taken into account.

Further testing is done through the multiple linear regression for:

- Assumptions and Diagnostics

  During the analysis, assumptions of linear regression are verified (normality, heteroskedasticity, autocorrelation, and collinearity). Diagnostic tests are performed to assess the model's validity and identify any potential issues or violations of assumptions.

- Hypothesis Testing

  Based on the results of the linear regression analysis, hypothesis testing is conducted to evaluate the significance of the relationships between circular economy measures and the social and environmental outcomes of reforestation. The significance level is used to determine the statistical significance of the relationships.

- Significance Testing

  The significance of each coefficient representing the relationship between an independent variable (circular economy measure) and a dependent variable (social or environmental outcome) is assessed. This is done by calculating t-statistics and obtaining the associated p-values for each coefficient. The p-values indicate the probability of observing the estimated coefficient if there is no true relationship between the predictor and the outcome variable.

- Significance Testing for Overall Model Significance

  In addition to assessing the significance of individual coefficients, the overall significance of the multiple linear regression model is also evaluated. This is done by calculating the F-statistic and obtaining the associated p-value.

Multiple linear regression analysis was chosen as the statistical method for the research study as it allows the examination of the relationship between multiple independent variables and a single dependent variable. It aligns well with the objectives of our research, which aims to investigate the effects of several circular measures on the outcomes of reforestation. It provides a comprehensive and flexible framework that allows us to control for confounding factors, explore interaction effects, and assess the overall model fit.

In this particular research context, this analytical approach is highly suitable for exploring the complex interplay of various circular economy measures and their impact on specific outcomes of reforestation. By using multiple linear regression, it is possible to examine the unique contributions of each predictor while controlling for other factors simultaneously. This enables a comprehensive analysis of the relationships between the variables involved in the research.

Furthermore, multiple linear regression provides a quantitative and systematic way to assess the strength and significance of each predictor variable. Through the estimation of regression coefficients, standard errors, and p-values, it is possible to evaluate the individual contributions of the independent variables and determine their statistical significance. This helps to identify which predictors have a significant impact on the outcome variable and which may have limited or negligible influence.

Additionally, multiple linear regression allows for the examination of interaction effects among the independent variables. In this research, we recognize that the relationships between the predictors and the outcome variable may not be independent of each other. By including interaction terms in the regression model, we can explore how the effects of one predictor may be modified by another predictor. This analysis helps to uncover complex relationships and provides deeper insights into the underlying mechanisms influencing the outcome variable.

Moreover, multiple linear regression provides a framework to assess the goodness-of-fit of the model. R-squared and adjusted R-squared values enable the evaluation of the proportion of variance explained by the predictors and determine how well the model fits the observed data.

Regression Model Estimation

The technique used to estimate the regression model in this research is ordinary least squares (OLS) regression, and the software employed for the analysis is Jamovi. OLS regression aims to find the best-fitting line or hyperplane that minimizes the sum of the squared differences between the observed values of the dependent variable and the predicted values based on the independent variables. This estimation technique allows for the quantification of the relationships between the predictors and the outcome variable.

In the case of this research, OLS regression is chosen as it provides a comprehensive framework for examining the relationship between multiple independent variables (circular economy measures) and a single dependent variable (every outcome of reforestation projects). By estimating the regression coefficients, it becomes possible to assess the individual contributions of each predictor and determine their impact on the outcome variable.

The estimation process in OLS regression involves calculating the coefficients, standard errors, and p-values associated with each predictor. The coefficients represent the change in the dependent variable for a one-unit change in the corresponding independent variable, assuming all other variables are held constant. The standard errors provide information about the precision of the coefficient estimates, while the p-values indicate the statistical significance of the relationships.

To facilitate the estimation of the regression model and perform the necessary statistical analyses, Jamovi software is utilized. This ensures accuracy and efficiency in the analysis. The software handles the calculations involved in estimating the coefficients, standard errors, and p-values, saving time and reducing the risk of manual errors. It also provides various diagnostic tests and assumption checks, allowing researchers to evaluate the validity and reliability of the regression model.

Content Validity Assessment

As mentioned before in the variables section, the in-depth literature review and previous knowledge were the main tools through which content validity was checked. They played a crucial role in guiding the selection of the independent variables. By extensively reviewing existing research on circularity by prominent associations in the field such as 'Ellen MacArthur Foundation' and the 'European Commission', we identified and incorporated essential components of circularity in reforestation projects in our final set of measures.

Ethical Considerations

While conducting this research study, a range of ethical considerations were carefully addressed to ensure the protection, privacy, and well-being of all individuals and organizations involved. The following specific ethical principles were given significant attention:

- Informed Consent: Prior to the commencement of the research, the management of Lebanon Reforestation Initiative, including project managers and field officers, were provided with comprehensive information regarding the research objectives, procedures, and potential benefits. Informed consent was obtained from the NGO, ensuring their voluntary collaboration in the study.

- Privacy and Confidentiality: All personal data included in the documents and information provided by the Lebanon Reforestation Initiative were guaranteed privacy and confidentiality through anonymization and secure storage. Personally identifiable information was coded and kept separate from the research data to maintain participant confidentiality.

- Beneficence and Justice: Throughout the research process, the principle of beneficence and justice was upheld. The research aimed to contribute to the knowledge base on circular economy practices in reforestation projects, with the ultimate goal of promoting sustainable development and environmental conservation in reforestation projects in general, and in the Lebanese context specifically.

- Institutional Review and Approval: This research has obtained the necessary institutional review and approval from the supervisors ‘Prof. Alessandro Gusman’ and ‘Prof. Elena Vallino’ at the University of Turin to ensure compliance with ethical standards. The research design, data collection methods, and ethical considerations have been reviewed and approved by the relevant institutional bodies as well.

- Professionalism and Integrity: We maintained professionalism and integrity throughout the research process. Objectivity, transparency, and accuracy were upheld, ensuring that the findings were not influenced by personal biases or external pressures.

- Research Replicability: To promote research replicability and transparency, the research methodology, data collection instruments, and analytical procedures are documented and will be made available to the scientific community by publishing them on ‘Academia.edu’ (a platform for publishing research), in an academic journal, and in the database of the theses and dissertations of the University of Turin.

- Use of Third-Party Services: The only third-party services utilized for data collection and analysis were Google Drive and Jamovi. Their use was carefully evaluated to ensure compliance with data protection and privacy regulations, and all confidential data will be deleted after one year from the publishing of the research, as per the agreement with the Lebanon Reforestation Initiative.

- Collaboration and Partnership: The research study was conducted in collaboration and partnership with the Lebanon Reforestation Initiative. Open and transparent communication was maintained throughout the research process, fostering trust and mutual understanding. The perspectives and inputs of the NGO were valued and well integrated into the research.

Results of the Analysis

Descriptive Statistics

The following table presents the descriptive statistics of the research variables. These statistics offer valuable insights into the distribution and central tendency of the data, helping us gain a better understanding of the variables under investigation.

Descriptives

	N	Missing	Mean	Median	Mode	Sum	SD	Variance	IQR	Range
Local Hiring	38	0	77.58	80.00	100.00	2948	16.74	280.30	23.75	53
Women Hiring	38	0	30.71	31.50	31.00 ᵃ	1167	7.09	50.21	11.75	23
Marginalized Hiring	38	0	51.08	52.00	55.00	1941	6.54	42.78	8.50	24
Income Generation	38	0	47.63	65.00	0.00	1810	40.37	1629.37	80.00	100
Carbon Sequestration	38	0	447.37	460.00	500.00 ᵃ	17000	78.25	6122.62	117.50	330
Waste Disposal	38	0	24.00	26.00	28.00	912	9.71	94.32	14.50	34
Forest Density	38	0	525.00	495.00	400.00	19950	175.23	30706.76	227.50	670
Biodiversity	38	0	7.29	7.00	9.00	277	2.94	8.64	4.00	11
Survival Rate	38	0	60.26	62.50	73.00	2290	20.85	434.85	35.00	73

ᵃ More than one mode exists, only the first is reported

It is important to note that for some variables, such as women hiring, carbon sequestration, and biodiversity, more than one mode exists, but only the first mode is reported. The mode represents the most frequently occurring value in a dataset, providing information on the peak of the distribution.

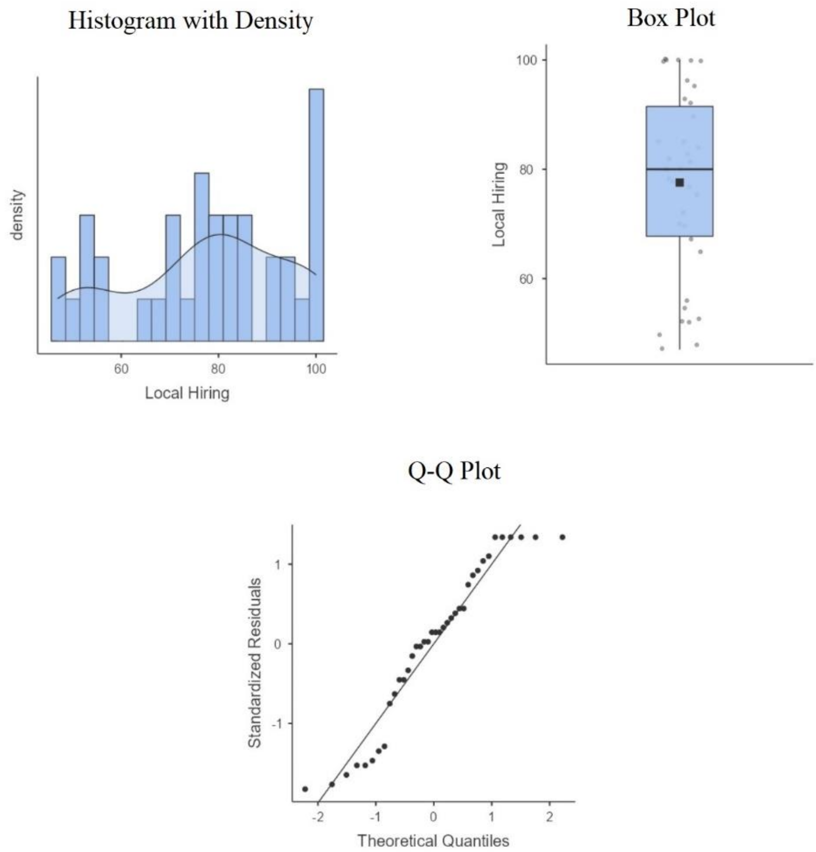
By examining the descriptive statistics, we can begin to explore the characteristics and patterns within each variable. This information serves as a foundation for further analysis and interpretation, helping us to make informed decisions and draw meaningful conclusions about the variables of interest. In the subsequent sections, we delve into the interpretation of each variable's descriptive statistics, exploring their implications and providing a more detailed understanding of the data.

Social Outcomes:

Local Hiring

The average percentage of workers hired from the local community in the reforestation projects is 77.58%. The median value of 80.00% suggests a relatively symmetrical distribution of local hiring proportions. The mode of 100.00% represents the most common proportion of local workers hired in the projects. The standard deviation of 16.74 reflects the dispersion of local hiring proportions around the mean. The interquartile range of 23.75 indicates that 50% of the projects have a local hiring percentage between 56.25% and 80.00%.

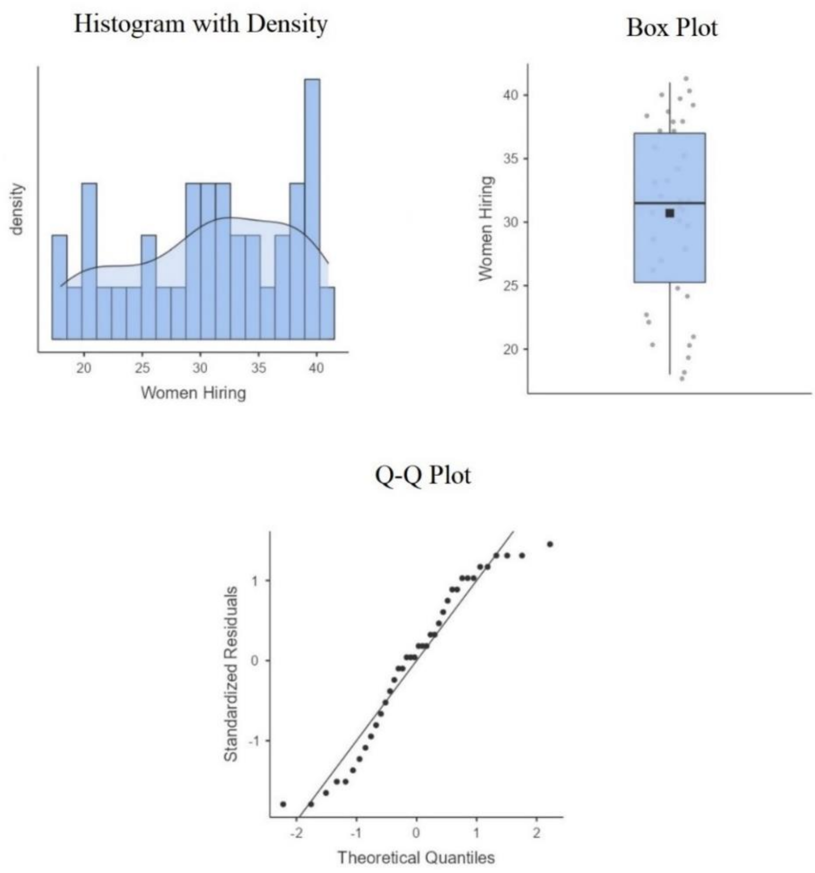
The plots below (FIGURE 8) visualize the descriptive statistics of the Local Hiring variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Women Hiring

The average percentage of female workers hired in reforestation projects is 30.71%. The median value of 31.50% suggests a relatively symmetrical distribution of women hiring percentages. It indicates that around half of the projects have a proportion of female workers close to the median value. The mode of 31.00% represents the most common proportion of female workers hired in the projects. The standard deviation of 7.09 indicates that the variability in gender diversity among the projects is relatively low. The interquartile range of 11.75 indicates that 50% of the projects have the women hiring proportion between 19.75% and 31.50%.

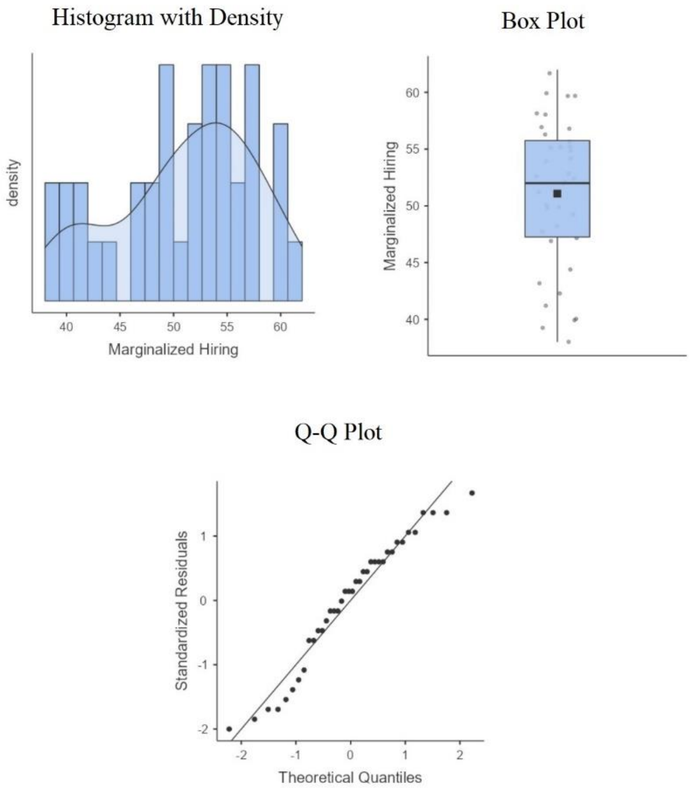
The plots below (FIGURE 9) visualize the descriptive statistics of the Women Hiring variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Marginalized Hiring

The average percentage of workers hired from marginalized groups in the reforestation projects is 51.08%. The median value of 52.00% suggests a relatively symmetrical distribution of marginalized hiring proportions. It indicates that around half of the projects have a proportion of marginalized workers close to the median value. The mode of 55.00% represents the most common proportion of marginalized workers hired in the projects. The standard deviation of 6.54 reflects a relatively low degree of variability in the extent of marginalized employment among the projects. The interquartile range of 8.50 indicates that 50% of the projects have a marginalized hiring percentage between 47.25% and 55.00%.

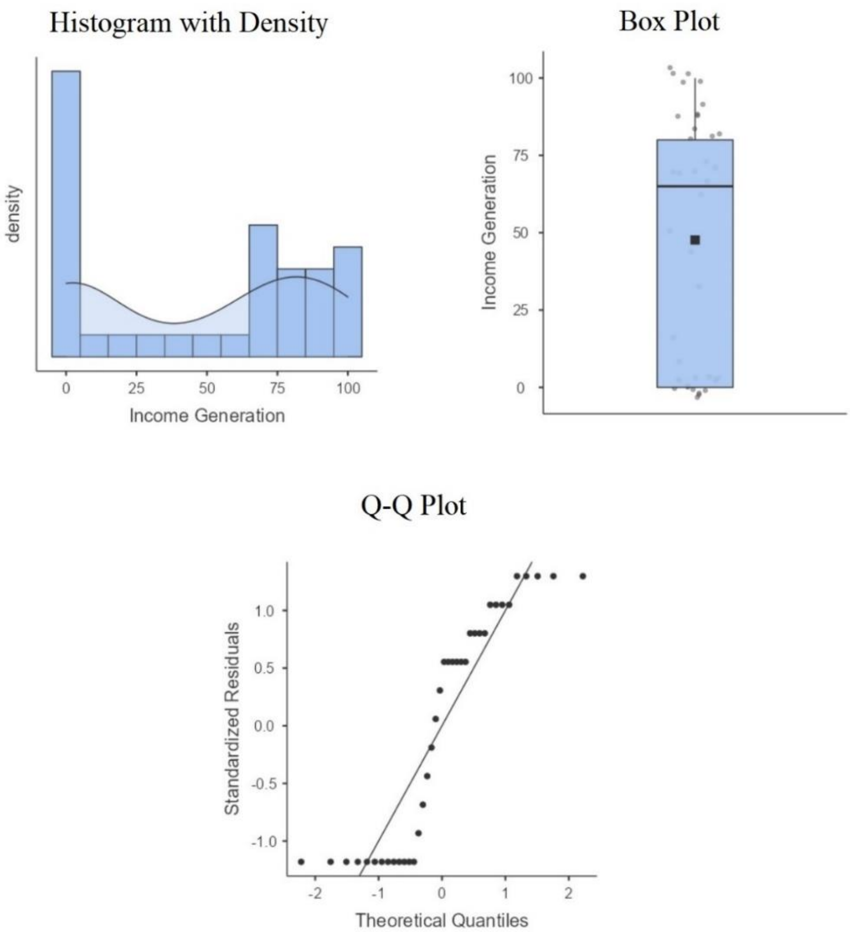
The plots below (FIGURE 10) visualize the descriptive statistics of the Marginalized Hiring variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the values.



Income Generation

On average, 47.63% of the workers generate income from the reforestation projects they take part in. The median value of 65 workers suggests a relatively skewed distribution of income between projects. The mode of 0.00 indicates that some projects did not generate any income for their workers (other than their payments). The interquartile range of 80.00 indicates that 50% of the projects vary in the percentage of workers generating income between 0.00% and 80.00%.

The plots below (FIGURE 11) visualize the descriptive statistics of the 'Income Generation' variable, as well as the distribution of the values. No outliers were detected in the values.

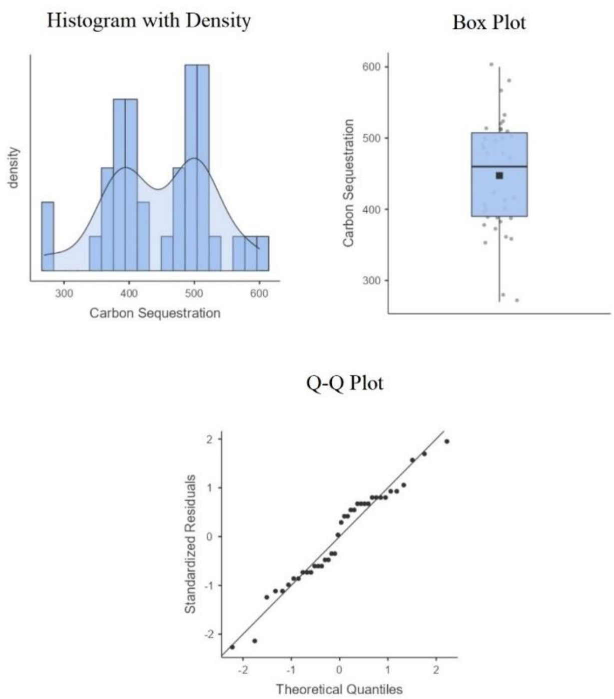


Environmental Outcomes:

Carbon Sequestration

The average amount of carbon dioxide (CO_2) sequestered by the reforestation sites in the year following project completion is 447.37 units. The median value of 460.00 suggests a somewhat symmetrical distribution of carbon sequestration values. It indicates that around half of the projects sequestered carbon close to the median value. The mode of 500.00 units represents the most common amount of carbon sequestration observed among the projects. The total amount of carbon sequestered across all reforestation projects is 17,000 units. The standard deviation of 78.25 indicates a moderate degree of variability in the amount of carbon sequestered among the projects. The interquartile range of 117.50 indicates that 50% of the projects have a carbon sequestration amount between 342.50 units and 460.00 units.

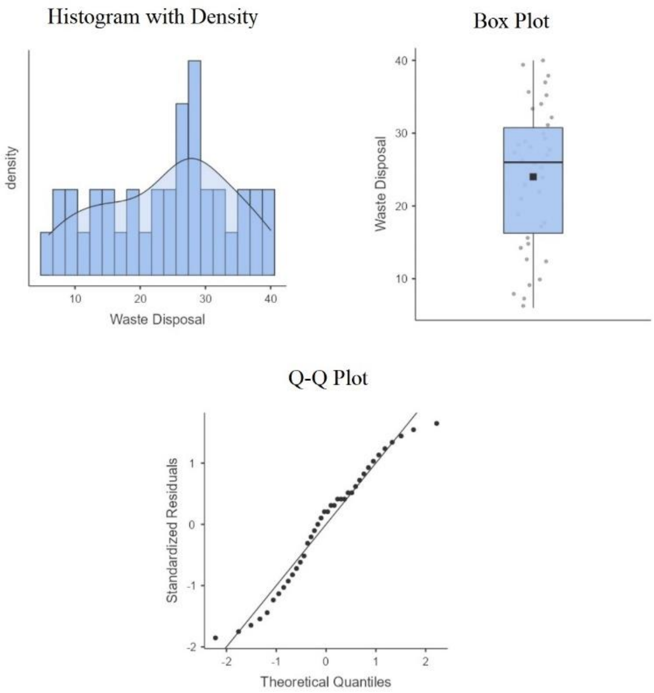
The plots below (FIGURE 12) visualize the descriptive statistics of the Carbon Sequestration variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Waste Disposal

The average amount of waste generated by the reforestation projects and disposed of through conventional waste disposal methods is 24.00 tons. The median value of 26.00 tons suggests a somewhat symmetrical distribution of waste disposal amounts. It indicates that approximately half of the projects generate waste close to the median value. The mode of 28.00 tons represents the most common amount of waste disposal observed among the projects. The total amount of waste generated and disposed of across all reforestation projects is 912 tons. The standard deviation of 9.71 reflects the dispersion of waste disposal amounts around the mean. It indicates a moderate degree of variability in waste generation among the projects. The interquartile range of 14.50 indicates that 50% of the projects generate waste amounts between 11.50 tons and 26.00 tons.

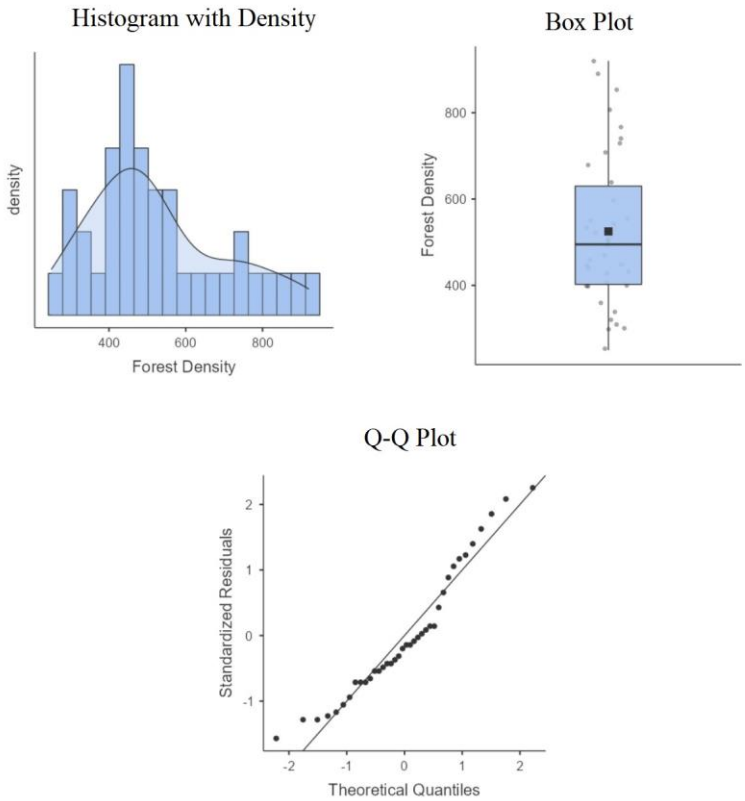
The plots below (FIGURE 13) visualize the descriptive statistics of the Waste Disposal variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Forest Density

The average forest density in the reforestation projects is 525 trees per hectare. The median value of 495 trees per hectare suggests that the distribution of forest density values is somewhat skewed towards lower densities. It indicates that most projects fall below the mean value. The mode of 400 trees per hectare indicates that this density occurs most frequently among the projects. The standard deviation of 175.23 indicates the degree of variation or dispersion around the mean value. It suggests that there is a moderate amount of variability in forest density among the projects. The interquartile range suggests that half of the projects have a forest density value of between 227.50 and 454.00 trees per hectare.

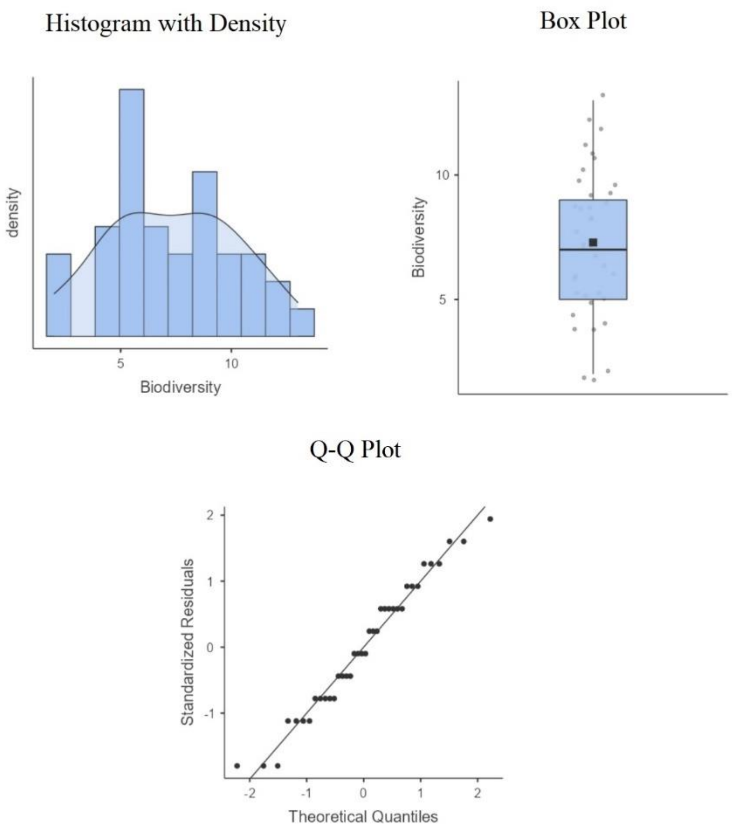
The plots below (FIGURE 14) visualize the descriptive statistics of the Forest Density variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Biodiversity

The average number of planted species that successfully survive and continue to grow one year after the reforestation projects is about 7 species. The median value of 7 suggests a symmetrical distribution of biodiversity values. It indicates that approximately half of the projects have a biodiversity value close to the median. The mode of 9 represents the most common biodiversity value observed among the projects. The standard deviation of 3.41 reflects the dispersion of biodiversity values around the mean. The interquartile range of 4.00 suggests that 50% of the projects have between 4 and 8 species that survived and continued to grow after one year.

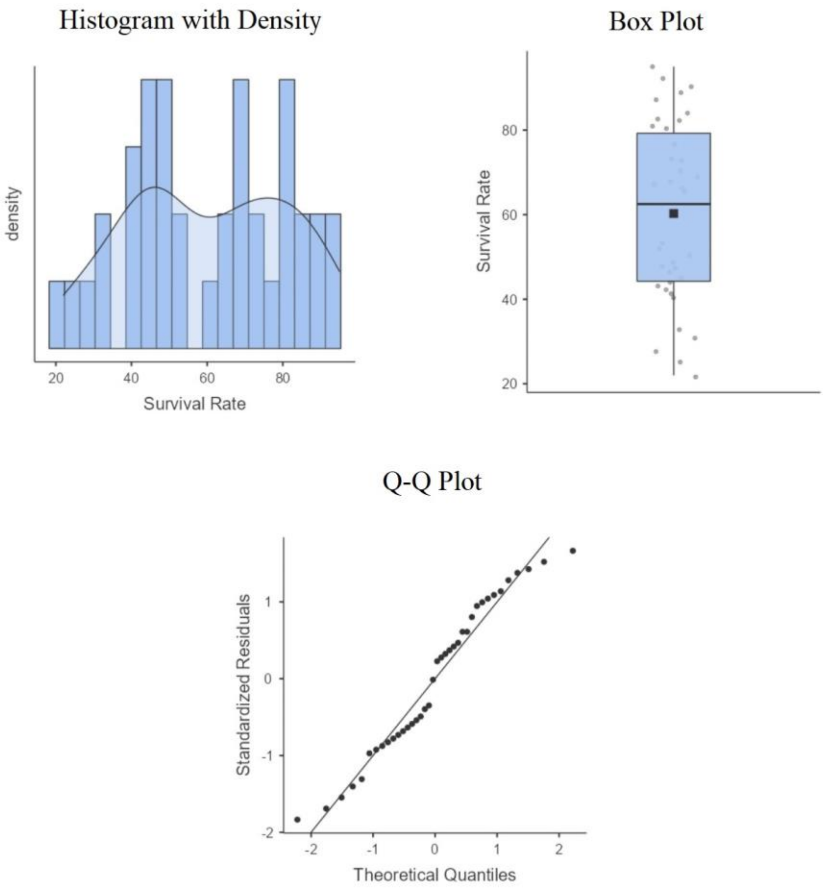
The plots below (FIGURE 15) visualize the descriptive statistics of the 'Biodiversity' variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Survival Rate

The average survival rate of planted trees one year after the completion of reforestation projects is 60.26%. The median survival rate of 62.50% suggests a somewhat symmetrical distribution of survival rates. The mode of 73.00% represents the most common survival rate among the projects. The standard deviation of 20.85 reflects a moderate degree of variation in the success of tree survival among the projects. The interquartile range of 35.00 suggests that 50% of the projects have a survival rate between 27.50% and 62.50%.

The plots below (FIGURE 16) visualize the descriptive statistics of the Survival Rate variable, as well as the distribution of the values. The box plot shows that no outliers were detected in the data.



Reliability Assessment

We conducted a reliability assessment using Cronbach's alpha coefficient to examine the overall reliability of the scale employed in our study, as well as the reliability of individual scale items. This analysis provides insights into the contribution of each item to the overall reliability of the scale. We then visualized the results in a correlation heatmap to better present relations between the different dependent variables.

Reliability Analysis

Scale Reliability Statistics

	Cronbach's α
scale	0.810

Item Reliability Statistics

	If item dropped
	Cronbach's α
Local Hiring	0.765
Women Hiring	0.768
Marginalized Hiring	0.766
Income Generation	0.797
Carbon Sequestration	0.800
Waste Disposal *	0.806
Forest Density	0.803
Biodiversity *	0.819
Survival Rate	0.791

* reverse scaled item

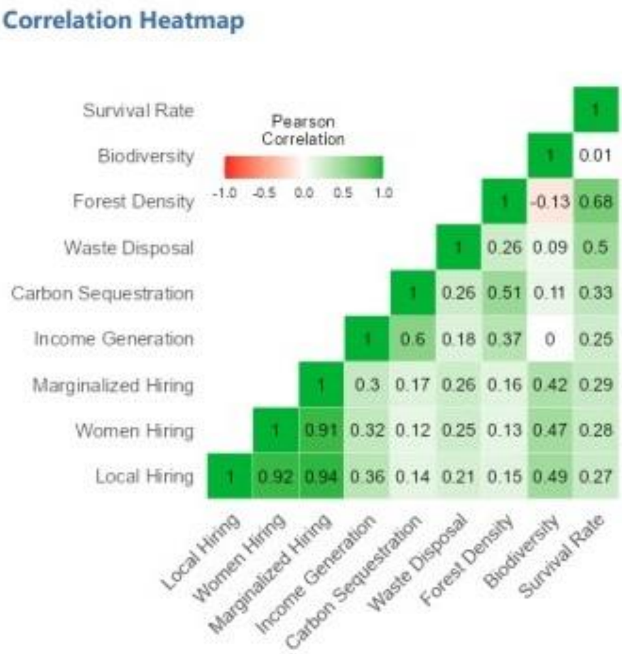


FIGURE 17: Correlation heatmap of the dependent variables

- Scale Reliability Statistics:

Cronbach's α: The overall reliability of the scale used in your study is 0.810. This indicates a relatively good level of internal consistency among the items included in the scale.

- Item Reliability Statistics:

Local Hiring: The item-rest correlation for local hiring is 0.707, indicating a strong association with the overall scale.

Women Hiring: The item-rest correlation for women hiring is 0.687, indicating a strong association with the overall scale.

Marginalized Hiring: The item-rest correlation for marginalized hiring is 0.702, indicating a strong association between this item and the overall scale.

Income Generation: The item-rest correlation for income generation is 0.463, indicating a moderate association with the overall scale.

Carbon Sequestration: The item-rest correlation for carbon sequestration is 0.437, which suggests a moderate association between this specific item and the overall scale.

Waste Disposal: The item-rest correlation for waste disposal is 0.384, indicating a relatively weak association between this item and the overall scale.

Forest Density: The item-rest correlation for forest density is 0.411, suggesting a moderate association with the overall scale.

Biodiversity: The item-rest correlation for biodiversity is 0.275, indicating a weak association with the overall scale.

Survival Rate: The item-rest correlation for survival rate is 0.512, suggesting a moderate association with the overall scale.

The removal of any of the above variables decreases Cronbach's alpha value. Thus, including all of them in the scale improves its internal consistency, except for the Biodiversity variable, whose removal potentially benefits the internal consistency of the scale, since the Cronbach's alpha value increases in this case.

- Correlation Heatmap:

The correlation heatmap provides a visual representation of the general results and the interrelationships between the variables included in our study. Overall, most of the individual items included in the scale show moderate to strong associations with the overall scale, except biodiversity and waste disposal, which exhibit weaker associations.

Simple Linear Regression

After the descriptive analyses, we performed several simple linear regression tests, examining the relationship between each dependent variable and all the independent variables. This rigorous approach allowed us to systematically assess the associations and make informed decisions about which variables should be included in the subsequent multiple regression models. We paired each dependent variable with one independent variable at a time, and then ran a simple regression analysis. The results of these tests provided valuable insights into the strength and direction of the relationships, allowing us to determine the most appropriate set of predictors for each dependent variable. However, given the large number of tests, totalling more than one hundred, it was wise to organize and present the results in an annex for clarity and ease of reference, instead of presenting the results in this section. The sets of predictors are expressed in the multiple linear regressions presented below.

Multiple Linear Regression

Below are the main statistical tests done in this research. The multiple regression analyses explore the relationship between each dependent variable and the set of predictors formulated based on the previously mentioned analyses. They include model fit measures, model-specific results, and several assumption checks for normality, heteroskedasticity, autocorrelation, and collinearity.

Multiple Linear Regression of Local Hiring

Model Fit Measures

Model	R	R^2
1	0.982	0.963

Model Coefficients - Local Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	51.8	1.00	51.6	< .001
Community-Led Execution:				
Yes – No	16.8	1.08	15.5	< .001
Pre-Project Training:				
Yes – No	28.5	1.13	25.3	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.948	0.076
Kolmogorov-Smirnov	0.145	0.397
Anderson-Darling	0.679	0.070

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.158	1.66	0.232

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	1.33	0.514
Goldfeld-Quandt	1.28	0.316
Harrison-McCabe	0.442	0.322

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Community-Led Execution	1.00	0.997
Pre-Project Training	1.00	0.997

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.982, indicating a strong positive correlation between the predictors and Local Hiring. The coefficient of determination

(R^2) is 0.963, which means that approximately 96.3% of the variance in Local Hiring can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the percentage of workers hired from the local community when all predictors are zero. In this case, the estimated intercept is 51.8%.

Community-Led Execution: The predictor "Yes - No" is associated with a coefficient estimate of 16.8. This indicates that, all other factors being equal, if a project includes the community-led execution variable (Yes), the percentage of workers hired from the local community is expected to increase by 16.8% compared to not including the community-led execution variable (No).

Pre-Project Training: The predictor "Yes - No" is associated with a coefficient estimate of 28.5. This suggests that, all other factors being equal, if a project includes pre-project training (Yes), the percentage of workers hired from the local community is expected to increase by 28.5% compared to when it does not include pre-project training (No).

- Hypothesis Testing and Significance Testing:

Both predictors (Community-Led Execution, Pre-Project Training) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Local Hiring. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on the Local Hiring variable.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.948 with a p-value of 0.076, suggesting that the residuals of the model approximately follow a normal distribution. The Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 1.33 with a p-value of 0.514, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Test:

The Durbin-Watson statistic is 1.66, suggesting no significant evidence of autocorrelation in the residuals. The p-value of 0.232 supports this finding.

- Collinearity Tests:

The VIF values for each predictor (Community-Led Execution, Pre-Project Training) are both 1.00, indicating no significant multicollinearity issue. Similarly, the tolerance values are both close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that community-led execution and pre-project training are significant predictors of Local Hiring. Implementing these practices is associated with an increase in Local Hiring, according to the estimated coefficients. The assumptions of normality, homoscedasticity, and no autocorrelation appear to hold for the model.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Local Hiring variable.

FIGURE 18: Residual Plots of Local Hiring

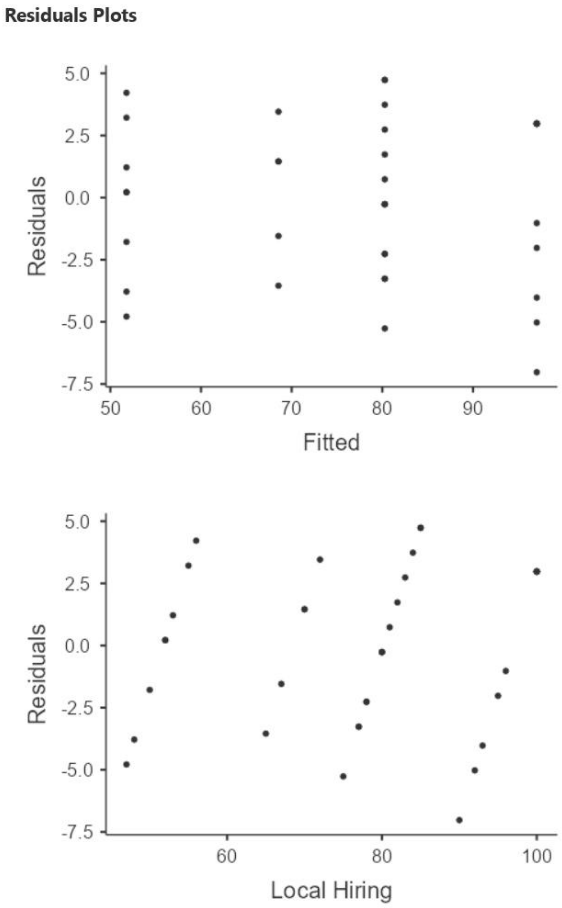
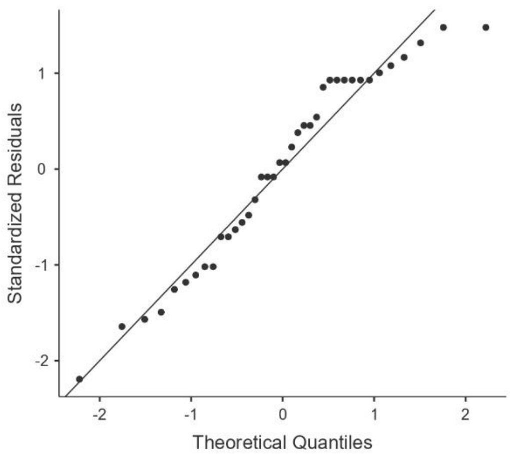


FIGURE 19: Q-Q Plot of Local Hiring



Multiple Linear Regression of Women Hiring

Model Fit Measures

Model	R	R^2
1	0.956	0.914

Model Coefficients - Women Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	20.07	0.651	30.83	< .001
Community-Led Execution:				
Yes – No	6.81	0.703	9.68	< .001
Pre-Project Training:				
Yes – No	11.81	0.731	16.15	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.949	0.085
Kolmogorov-Smirnov	0.106	0.784
Anderson-Darling	0.480	0.221

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.258	1.46	0.064

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	1.26	0.533
Goldfeld-Quandt	1.09	0.434
Harrison-McCabe	0.484	0.442

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Community-Led Execution	1.00	0.997
Pre-Project Training	1.00	0.997

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.956, indicating a strong positive correlation between the predictors and Women Hiring. The coefficient of determination (R^2) is 0.914, which means that approximately 91.4% of the variance in Women Hiring can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Women Hiring when all predictors are zero. In this case, the estimated intercept is 20.07.

Community-Led Execution: The predictor "Yes - No" is associated with a coefficient estimate of 6.81. This indicates that, all other factors being equal, if a project is executed with community-led execution (Yes), the percentage of women hired is expected to increase by 6.81% compared to when it is not executed with community-led execution (No).

Pre-Project Training: The predictor "Yes - No" is associated with a coefficient estimate of 11.81. This suggests that, all other factors being equal, if a project includes pre-project training (Yes), the percentage of women hired is expected to increase by 11.81% compared to not including pre-project training (No).

- Hypothesis Testing and Significance Testing:

Both predictors (Community-Led Execution, Pre-Project Training) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Women Hiring. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Women Hiring.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.949 with a p-value of 0.085, suggesting that the residuals of the model approximately follow a normal distribution. The

Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 1.26 with a p-value of 0.533, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Tests:

The Durbin-Watson statistic is 1.46, suggesting no significant evidence of autocorrelation in the residuals. The p-value of 0.064 suggests a borderline significance, indicating a minor possibility of autocorrelation, but it can not be proven.

- Collinearity Tests:

The VIF values for each predictor (Community-Led Execution, Pre-Project Training) are both close to 1, indicating no significant multicollinearity issue. Similarly, the tolerance values are also close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that implementing community-led execution and pre-project training are significant predictors of Women Hiring. Implementing these practices is associated with an increase in the percentage of women hired, according to the estimated coefficients. The assumptions of normality, homoscedasticity, and no autocorrelation appear to hold for the model.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Women Hiring variable.

FIGURE 20: Residual Plots of Women Hiring

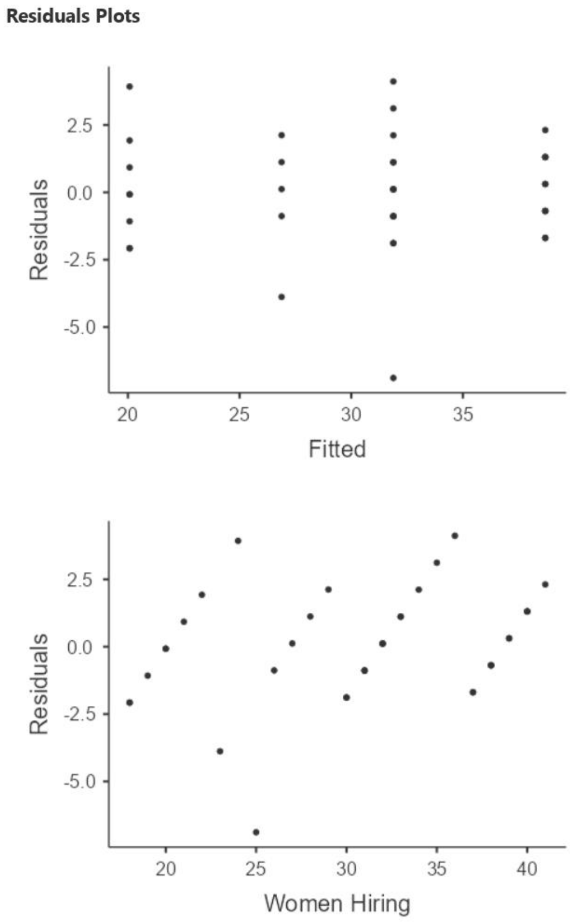
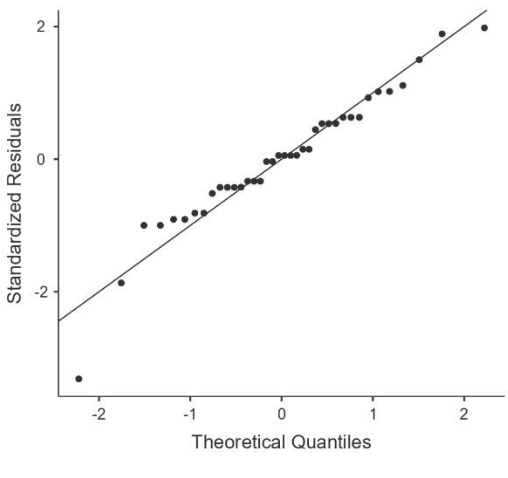


FIGURE 21: Q-Q Plot of Women Hiring



Multiple Linear Regression of Marginalized Hiring

Model Fit Measures

Model	R	R^2
1	0.948	0.899

Model Coefficients - Marginalized Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	41.34	0.652	63.43	< .001
Pre-Project Training:				
Yes – No	10.89	0.732	14.87	< .001
Community-Led Execution:				
Yes – No	6.11	0.704	8.68	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.971	0.410
Kolmogorov-Smirnov	0.114	0.707
Anderson-Darling	0.383	0.381

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.122	1.74	0.328

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	1.32	0.516
Goldfeld-Quandt	1.33	0.286
Harrison-McCabe	0.437	0.274

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Pre-Project Training	1.00	0.997
Community-Led Execution	1.00	0.997

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.948, indicating a strong positive correlation between the predictors and Marginalized Hiring. The coefficient of determination (R^2) is 0.899, which means that approximately 89.9% of the variance in Marginalized Hiring can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Marginalized Hiring when all predictors are zero. In this case, the estimated intercept is 41.34.

Pre-Project Training: The predictor "Yes - No" is associated with a coefficient estimate of 10.89. This indicates that, all other factors being equal, if a project includes pre-project training (Yes), the percentage of workers that are from marginalized groups is expected to increase by 10.89% compared to those not including pre-project training (No).

Community-Led Execution: The predictor "Yes - No" is associated with a coefficient estimate of 6.11. This suggests that, all other factors being equal, if a project is executed with community-led execution (Yes), the percentage of workers that are from marginalized groups is expected to increase by 6.11% compared to when it is not executed with community-led execution (No).

- Hypothesis Testing and Significance Testing:

Both predictors (Pre-Project Training, Community-Led Execution) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Marginalized Hiring. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Marginalized Hiring.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.971 with a p-value of 0.410, suggesting that the residuals of the model approximately follow a normal distribution. The Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 1.32 with a p-value of 0.516, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Tests:

The Durbin-Watson statistic is 1.74, suggesting no significant evidence of autocorrelation in the residuals. The p-value of 0.328 supports this finding.

- Collinearity Tests:

The VIF values for each predictor (Pre-Project Training, Community-Led Execution) are both 1.00, indicating no significant multicollinearity issue. Similarly, the tolerance values are both close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that pre-project training and community-led execution are significant predictors of Marginalized Hiring. Implementing these practices is associated with an increase in the percentage of marginalized workers hired in the reforestation projects, according to the estimated coefficients. The assumptions of normality, homoscedasticity, and no autocorrelation appear to hold for the model.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Marginalized Hiring variable.

FIGURE 22: Residual Plots of Marginalized Hiring

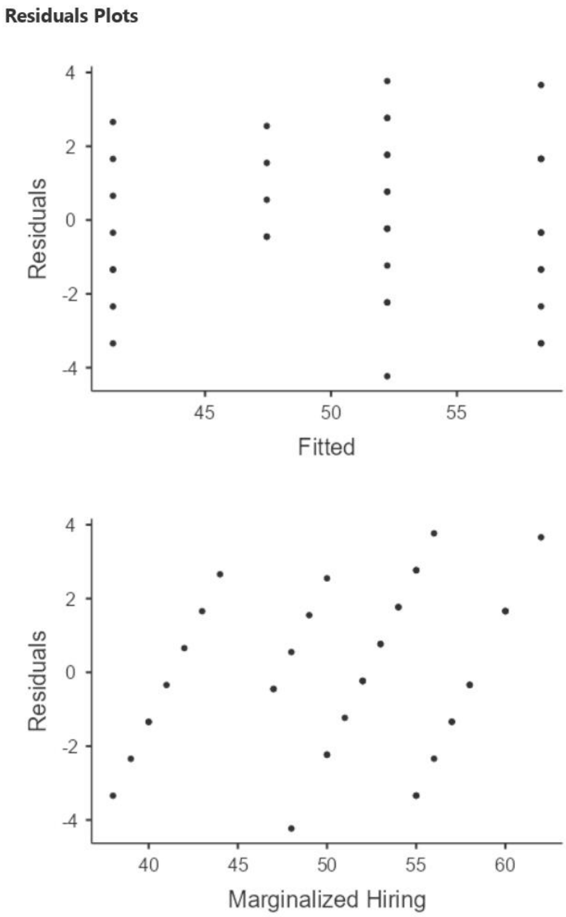
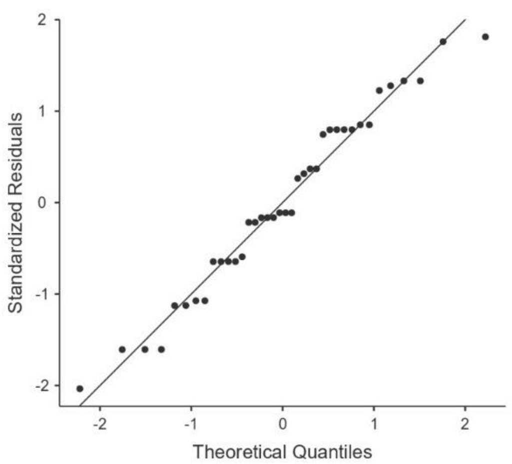


Figure 23: Q-Q Plot of Marginalized Hiring



Multiple Linear Regression of Income Generation

Model Fit Measures

Model	R	R^2
1	0.824	0.680

Model Coefficients - Income Generation

Predictor	Estimate	SE	t	p
Intercept [a]	16.3	5.39	3.03	0.005
Community-Led Execution:				
Yes – No	38.3	14.78	2.59	0.014
Tree Productivity Quota:				
Yes – No	30.4	14.59	2.08	0.045

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.747	< .001
Kolmogorov-Smirnov	0.244	0.021
Anderson-Darling	3.33	< .001

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.340	1.26	0.026

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	3.85	0.146
Goldfeld-Quandt	1.98	0.092
Harrison-McCabe	0.337	0.093

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Community-Led Execution	3.67	0.273
Tree Productivity Quota	3.67	0.273

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.824, indicating a moderate positive correlation between the predictors and Income Generation. The coefficient of determination (R^2) is 0.680, which means that approximately 68% of the variance in Income Generation can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Income Generation when all predictors are zero. In this case, the estimated intercept is 16.3.

Community-Led Execution: The predictor "Yes - No" is associated with a coefficient estimate of 38.3. This indicates that, all other factors being equal, if a project is executed with community-led execution (Yes), 38 more people are expected to generate income from the project compared to when it is not executed with community-led execution (No).

Tree Productivity Quota: The predictor "Yes - No" is associated with a coefficient estimate of 30.4. This suggests that, all other factors being equal, if a project includes a tree productivity quota (Yes), 30 more people are expected to generate income from the project compared to not having a tree productivity quota (No).

- Hypothesis Testing and Significance Testing:

Both predictors (Community-Led Execution, Tree Productivity Quota) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Income Generation. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Income Generation.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.747 with a p-value less than 0.001, suggesting that the residuals of the model do not follow a normal distribution. The

Kolmogorov-Smirnov test yields a p-value of 0.021, indicating a significant deviation from normality. The Anderson-Darling test also supports the non-normality assumption, as it yields a significant p-value.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 3.85 with a p-value of 0.146, suggesting no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Tests:

The Durbin-Watson statistic is 1.26, suggesting some evidence of positive autocorrelation in the residuals. The p-value of 0.016 supports this finding.

- Collinearity Statistics:

The VIF values for each predictor (Community-Led Execution, Tree Productivity Quota) are both 3.67, indicating moderate multicollinearity. Similarly, the tolerance values are around 0.273, suggesting that the predictors are moderately correlated with each other.

Overall, the regression analysis suggests that community-led execution and tree productivity quota are significant predictors of Income Generation. Implementing these circular measures is associated with an increase in the number of people who generate income from the reforestation project, according to the estimated coefficients. The assumptions of normality, autocorrelation, and collinearity appear to be violated in the model. However, given the unique nature of the data, a large number of projects have the value of the dependent variable as 0 since in projects that did not implement the specific circular measures (Tree Productivity Quota and Community-Led Execution) no one was generating any income, while in projects that did implement them, a high number of people generated income. Also, it is necessary to consider the specific context of the study, where the independent variables are inherently linked and influence income generation in a complementary manner. Thus, it is reasonable to assume that the violation of assumptions is acceptable in this context.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Income Generation variable.

FIGURE 24: Residual Plots of Income Generation

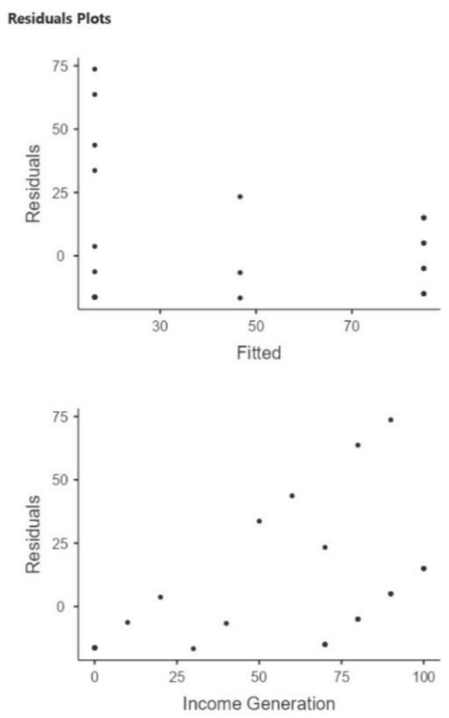
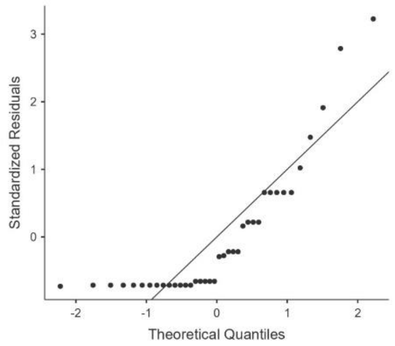


FIGURE 25: Q-Q Plots of Income Generation



Multiple Linear Regression of Carbon Sequestration

Model Fit Measures

Model	R	R^2
1	0.922	0.849

Model Coefficients - Carbon Sequestration

Predictor	Estimate	SE	t	p
Intercept [a]	305.5	11.9	25.66	< .001
Stone mulching:				
Yes – No	82.8	10.7	7.74	< .001
Tree Species Requirement: Carbon Sequestering:				
Yes – No	81.8	10.7	7.64	< .001
Tree Quota:				
Yes – No	107.0	11.3	9.44	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.952	0.103
Kolmogorov-Smirnov	0.0929	0.898
Anderson-Darling	0.494	0.203

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
-0.0991	2.16	0.526

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	6.57	0.087
Goldfeld-Quandt	0.364	0.970
Harrison-McCabe	0.704	0.975

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Stone mulching	1.01	0.991
Tree Species Requirement: Carbon Sequestering	1.08	0.922
Tree Quota	1.09	0.915

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.922, indicating a strong positive correlation between the predictors and Carbon Sequestration. The coefficient of determination (R^2) is 0.849, which means that approximately 84.9% of the variance in Carbon Sequestration can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Carbon Sequestration when all predictors are zero. In this case, the estimated intercept is 305.5.

Tree Quota: The predictor "Yes - No" is associated with a coefficient estimate of 107.0. This indicates that, all other factors being equal, if a project includes the tree quota variable (Yes), the amount of carbon sequestered by the project is expected to increase by 107.0 units compared to not having a tree quota (No).

Tree Species Requirement: Carbon Sequestering: The predictor "Yes - No" is associated with a coefficient estimate of 81.8. This suggests that, all other factors being equal, if a project includes the variable for tree species requirement (carbon sequestering) (Yes), the amount of carbon sequestered by the project is expected to increase by 81.8 units compared to when it does not have such a requirement (No).

Stone Mulching: The predictor "Yes - No" is associated with a coefficient estimate of 82.8. This suggests that, all other factors being equal, if a project includes stone mulching (Yes), the amount of carbon sequestered by the project is expected to increase by 82.8 units compared to when it does not include stone mulching (No).

- Hypothesis Testing and Significance Testing:

All predictors (Tree Quota, Tree Species Requirement: Carbon Sequestering, Stone Mulching) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Carbon Sequestration. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Carbon Sequestration.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.952 with a p-value of 0.103, suggesting that the residuals of the model approximately follow a normal distribution. The Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 6.57 with a p-value of 0.087, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also provide non-significant p-values, supporting the absence of heteroskedasticity.

- Autocorrelation Test:

The Durbin-Watson statistic is -0.0991, suggesting no significant evidence of autocorrelation in the model. The associated p-value of 0.580 further supports this conclusion.

- Collinearity Tests:

The collinearity statistics assess the multicollinearity between predictors in the model. In this case, all predictors (Tree Quota, Tree Species Requirement: Carbon Sequestering, Stone Mulching) have VIF values close to 1 and tolerance values close to 1, indicating that there is no severe multicollinearity issue among the predictors.

In summary, the multiple linear regression analysis for the Carbon Sequestration variable indicates that planting a minimum of 600 trees per hectare, planting a minimum of 20% of the trees as high carbon-sequestering trees, and mulching stones in reforestation projects have significant positive effects on the amount of carbon sequestered by the reforestation project. The model appears to meet the assumptions of normality, homoscedasticity, no autocorrelation, and the absence of severe multicollinearity.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Carbon Sequestration variable.

FIGURE 26: Residual Plots of Carbon Sequestration

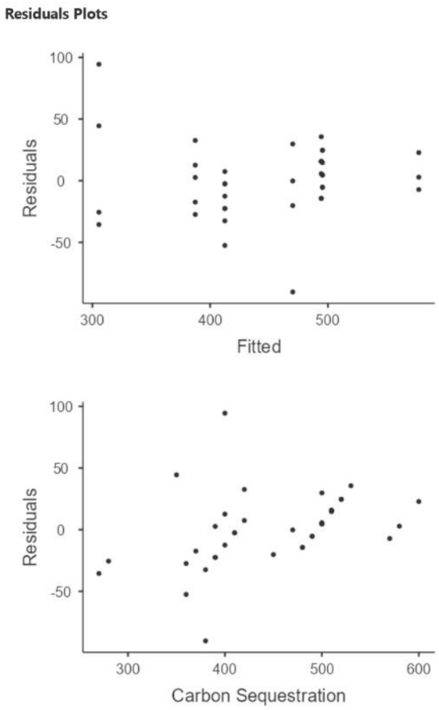
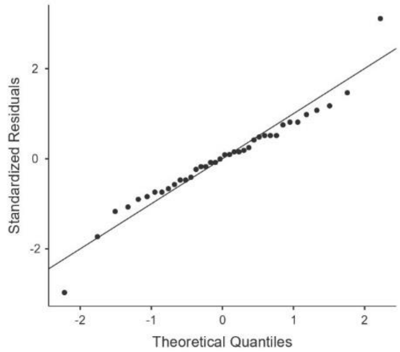


FIGURE 27: Q-Q Plots of Carbon Sequestration



Multiple Linear Regression of Waste Disposal

Model Fit Measures

Model	R	R^2
1	0.982	0.964

Model Coefficients - Waste Disposal

Predictor	Estimate	SE	t	p
Intercept [a]	39.45	0.610	64.69	< .001
Recycling:				
Yes – No	-13.26	0.647	-20.50	< .001
Natural Pest Management:				
Yes – No	-10.99	0.643	-17.09	< .001
Stone mulching:				
Yes – No	-6.35	0.674	-9.41	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.987	0.930
Kolmogorov-Smirnov	0.0738	0.986
Anderson-Darling	0.205	0.863

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.0690	1.80	0.634

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	1.44	0.697
Goldfeld-Quandt	0.420	0.948
Harrison-McCabe	0.678	0.941

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Recycling	1.06	0.945
Natural Pest Management	1.05	0.949
Stone mulching	1.08	0.924

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.982, indicating a strong positive correlation between the predictors and Waste Disposal. The coefficient of determination (R^2) is 0.964, which means that approximately 96.4% of the variance in Waste Disposal can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Waste Disposal when all predictors are zero. In this case, the estimated intercept is 39.45.

Recycling: The predictor "Yes - No" is associated with a coefficient estimate of -13.26. This indicates that, all other factors being equal, if recycling is implemented (Yes), the amount of waste disposed of after the reforestation project is expected to decrease by 13.26 tons compared to when it is not implemented (No).

Natural Pest Management: The predictor "Yes - No" is associated with a coefficient estimate of -10.99. This suggests that, all other factors being equal, if natural pest management is implemented (Yes), the amount of waste disposed of after the reforestation project is expected to result in a decrease of 10.99 tons compared to not implementing natural pest management (No).

Stone Mulching: The predictor "Yes - No" is associated with a coefficient estimate of -6.35. This indicates that, all other factors being equal, if stone mulching is implemented (Yes), the amount of waste disposed of after the reforestation project is expected to lead to a decrease of 6.35 tons compared to not implementing stone mulching (No).

- Hypothesis Testing and Significance Testing:

All predictors (Recycling, Natural Pest Management, Stone Mulching) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Waste Disposal. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Waste Disposal.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.987 with a p-value of 0.930, suggesting that the residuals of the model approximately follow a normal distribution. The Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 1.44 with a p-value of 0.697, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Tests:

The VIF values for each predictor (Recycling, Natural Pest Management, Stone Mulching) are all close to 1, indicating no significant multicollinearity issue. Similarly, the tolerance values are all close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that recycling, natural pest management, and stone mulching as circular measures are significant predictors of Waste Disposal. Implementing these measures is associated with a decrease in the amount of waste the NGO disposes of after a reforestation project, according to the estimated coefficients. The assumptions of normality, homoscedasticity, and no autocorrelation appear to hold for the model.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Waste Disposal variable.

FIGURE 28: Residual Plots of Waste Disposal

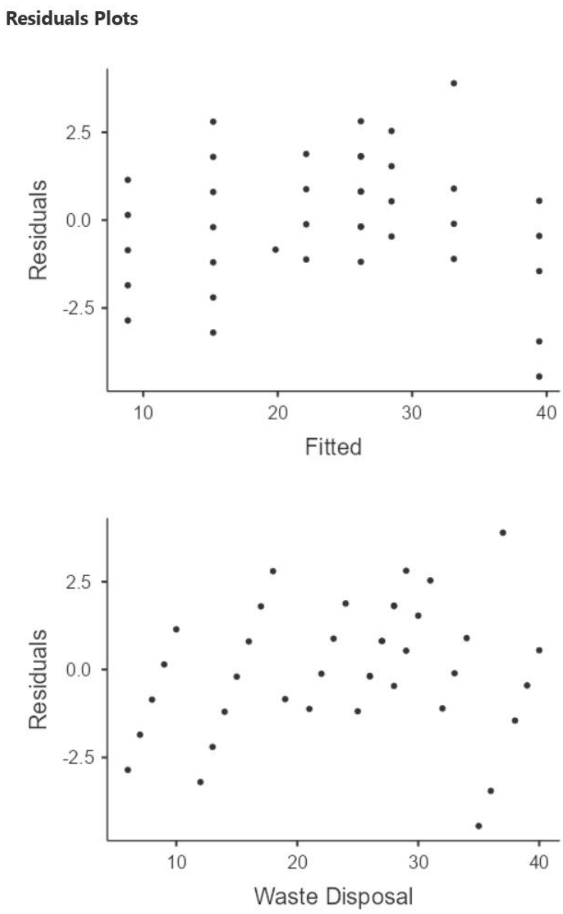
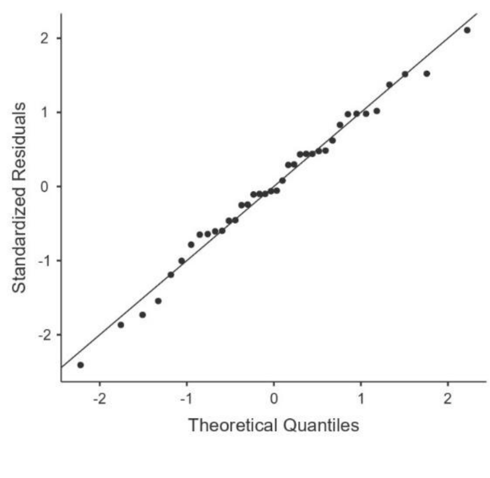


FIGURE 29: Q-Q Plots of Waste Disposal



Multiple Linear Regression of Forest Density

Model Fit Measures

Model	R	R^2
1	0.942	0.888

Model Coefficients - Forest Density

Predictor	Estimate	SE	t	p
Intercept [a]	162	26.1	6.22	< .001
Invasive Species Removal:				
Yes – No	123	21.5	5.70	< .001
Tree Quota:				
Yes – No	270	21.1	12.79	< .001
Native Seedlings Use:				
Yes – No	202	19.9	10.17	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.950	0.089
Kolmogorov-Smirnov	0.102	0.821
Anderson-Darling	0.503	0.193

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
0.0123	1.97	0.832

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	4.39	0.223
Goldfeld-Quandt	2.51	0.043
Harrison-McCabe	0.309	0.039

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Invasive Species Removal	1.02	0.983
Tree Quota	1.02	0.980
Native Seedlings Use	1.00	0.997

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.942, indicating a strong positive correlation between the predictors and the Forest Density. The coefficient of determination (R^2) is 0.888, which means that approximately 88.8% of the variance in the Forest Density can be explained by the independent variables in the model.

- Model-Specific Results:

The intercept represents the Forest Density when all predictors are zero. In this case, the estimated intercept is 162.

Invasive Species Removal: The predictor "Yes - No" is associated with a coefficient estimate of 123. This indicates that, all other factors being equal, if invasive species are removed from the reforestation site (Yes), the number of trees per hectare that survive after one year of the implementation of the project is expected to increase by 123 trees compared to when it is not implemented (No).

Tree Quota: The predictor "Yes - No" is associated with a coefficient estimate of 270. This suggests that, all other factors being equal, if the tree quota is implemented (Yes), the number of trees per hectare that survive after one year of the implementation of the project is expected to increase by 270 trees compared to not implementing a tree quota (No).

Native Seedlings Use: The predictor "Yes - No" is associated with a coefficient estimate of 202. This indicates that, all other factors being equal, using native seedlings (Yes) is expected to lead to a higher number of trees per hectare that survive after one year of the implementation of the project by 202 trees compared to using non-native seedlings (No).

- Hypothesis Testing and Significance Testing:

In the provided regression results, all predictors (Invasive Species Removal, Tree Quota, Native Seedlings Use) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Forest Density. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Forest Density.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.950 with a p-value of 0.089, suggesting that the residuals of the model approximately follow a normal distribution. The Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 4.39 with a p-value of 0.223, indicating no significant evidence of heteroskedasticity in the model. However, the Goldfeld-Quandt and Harrison-McCabe tests suggest the presence of heteroskedasticity based on their significant p-values.

- Autocorrelation Test:

The Durbin-Watson statistic is 1.97, suggesting no significant evidence of autocorrelation in the residuals. The p-value of 0.832 further supports this conclusion.

- Collinearity Tests:

The VIF values for each predictor (Invasive Species Removal, Tree Quota, Native Seedlings Use) are all close to 1, indicating no significant multicollinearity issue. Similarly, the tolerance values are all close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that ‘Invasive Species Removal’, ‘Tree Quota’, and ‘Native Seedlings Use’ are significant predictors of Forest Density. Implementing these practices is associated with a higher number of trees per hectare that survive after one year of the implementation of the project, according to the estimated coefficients.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Forest Density variable.

FIGURE 30: Residual Plots of Forest Density

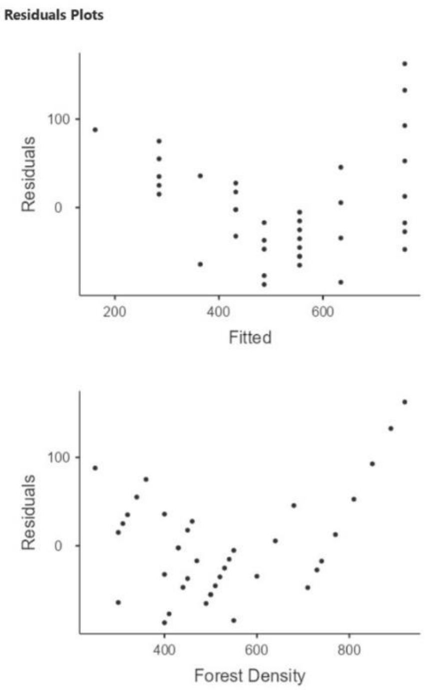
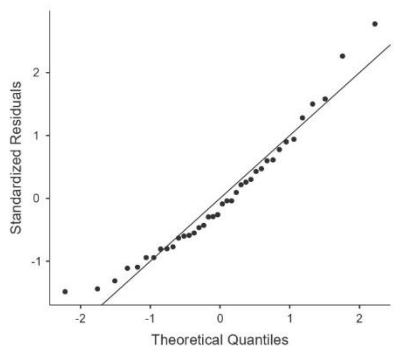


FIGURE 31: Q-Q Plot of Forest Density



Multiple Linear Regression of Biodiversity

Model Fit Measures

Model	R	R^2
1	0.937	0.878

Model Coefficients - Biodiversity

Predictor	Estimate	SE	t	p
Intercept [a]	3.10	0.334	9.29	< .001
Invasive Species Removal:				
Yes – No	2.81	0.411	6.84	< .001
Species Quota:				
Yes – No	4.27	0.382	11.18	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.951	0.094
Kolmogorov-Smirnov	0.143	0.416
Anderson-Darling	0.762	0.043

Note. Additional results provided by *moretests*

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	4.84	0.089
Goldfeld-Quandt	3.01	0.017
Harrison-McCabe	0.250	0.009

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
-0.131	2.08	1.000

Collinearity Statistics

	VIF	Tolerance
Invasive Species Removal	1.13	0.885
Species Quota	1.13	0.885

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.921, indicating a strong positive correlation between the predictors and Biodiversity. The coefficient of determination (R^2) is 0.848, which means that approximately 84.8% of the variance in Biodiversity can be explained by the independent variables in the model.

- Model-Specific Results:

Intercept: The intercept represents the Biodiversity when all predictors are zero. In this case, the estimated intercept is 3.55.

Invasive Species Removal: The predictor "Yes - No" is associated with a coefficient estimate of 2.45. This suggests that, all other factors being equal, if invasive species removal is implemented (Yes), between two and three more species are expected to survive after a year of the implementation of the reforestation project compared to when it is not implemented (No).

Species Quota: The predictor "Yes - No" is associated with a coefficient estimate of 4.12. This indicates that, all other factors being equal, if a species quota is implemented (Yes), between 4 and 5 more species are expected to survive after a year of the implementation of the reforestation project compared to not implementing a species quota (No).

- Hypothesis Testing and Significance Testing:

Both predictors (Invasive Species Removal, Species Quota) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Biodiversity. Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Biodiversity.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.964 with a p-value of 0.257, suggesting that the residuals of the model approximately follow a normal distribution. The

Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 1.58 with a p-value of 0.454, indicating no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also support this conclusion based on their non-significant p-values.

- Autocorrelation Tests:

The Durbin-Watson statistic is -0.120, suggesting the presence of positive autocorrelation in the residuals. However, it is important to note that the Durbin-Watson statistic is close to 2, indicating only weak evidence of autocorrelation.

- Collinearity Statistics:

The VIF values for each predictor (Invasive Species Removal, Species Quota) are both close to 1, indicating no significant multicollinearity issue. Similarly, the tolerance values are both close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that invasive species removal and implementing a species quota are significant predictors of Biodiversity. Implementing these measures is associated with an increase in the number of species that survive after one year of the reforestation project, according to the estimated coefficients. The assumptions of normality, homoscedasticity, and no autocorrelation appear to hold for the model, although there is weak evidence of positive autocorrelation.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Biodiversity variable.

FIGURE 32: Residuals Plots of Biodiversity

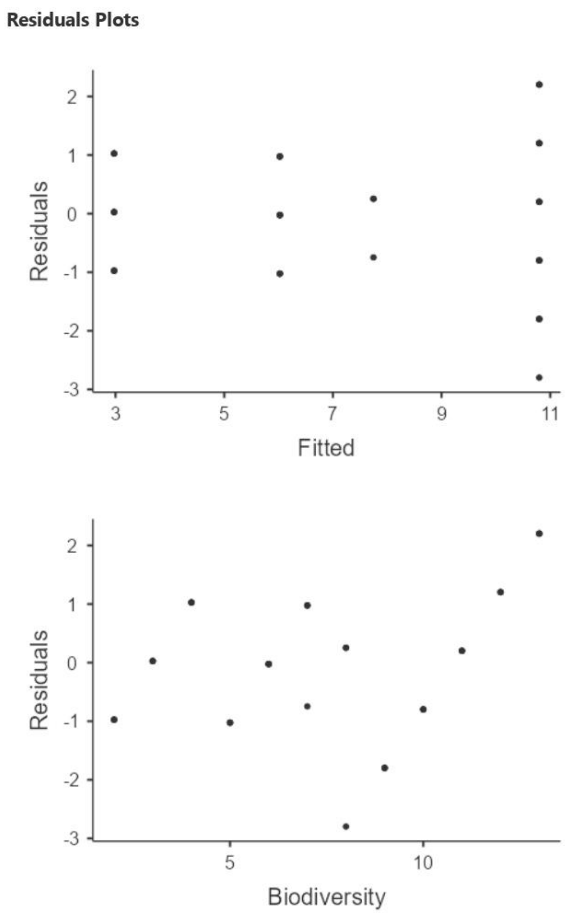
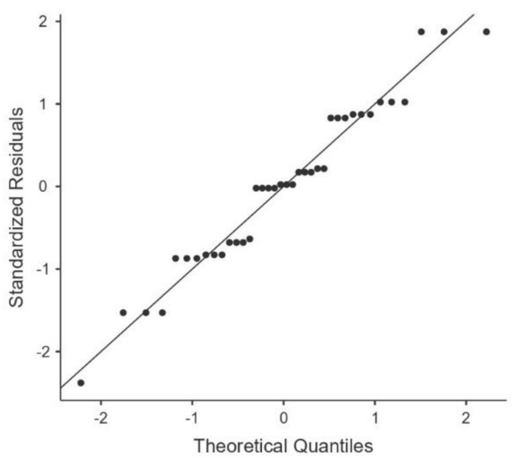


FIGURE 33: Q-Q Plot of Biodiversity



Multiple Linear Regression of Survival Rate

Model Fit Measures

Model	R	R^2
1	0.978	0.956

Model Coefficients - Survival Rate

Predictor	Estimate	SE	t	p
Intercept [a]	26.2	1.47	17.9	< .001
Post-project Maintenance:				
Yes – No	16.2	1.49	10.8	< .001
Natural Pest Management:				
Yes – No	26.7	1.48	18.0	< .001
Native Seedlings Use:				
Yes – No	22.9	1.49	15.4	< .001

[a] Represents reference level

Assumption Checks

Normality Tests

	Statistic	p
Shapiro-Wilk	0.974	0.511
Kolmogorov-Smirnov	0.0654	0.993
Anderson-Darling	0.235	0.775

Note. Additional results provided by *moretests*

Durbin–Watson Test for Autocorrelation

Autocorrelation	DW Statistic	p
-0.0537	2.04	0.766

Heteroskedasticity Tests

	Statistic	p
Breusch-Pagan	3.39	0.335
Goldfeld-Quandt	0.894	0.585
Harrison-McCabe	0.525	0.589

Note. Additional results provided by *moretests*

Collinearity Statistics

	VIF	Tolerance
Post-project Maintenance	1.01	0.986
Natural Pest Management	1.00	0.997
Native Seedlings Use	1.01	0.989

- Model Fit Measures:

The coefficient of multiple determination (R) is 0.978, indicating a strong positive correlation between the predictors and the Survival Rate variable. The coefficient of determination (R^2) is 0.956, which means that the independent variables ‘Post-Project Maintenance’, ‘Natural Pest Management’, and ‘Native Seedlings Use’ explain approximately 95.6% of the variance observed in the Survival Rate variable.

- Model-Specific Results:

The intercept represents the Survival Rate when all predictors are zero. In this case, the estimated intercept is 26.2.

Post-Project Maintenance: The predictor "Yes - No" is associated with a coefficient estimate of 16.2. This indicates that, all other factors being equal, if post-project maintenance is implemented (Yes), the survival rate of the trees in the reforestation project is expected to increase by 16.2% compared to when it is not implemented (No).

Natural Pest Management: The predictor "Yes - No" is associated with a coefficient estimate of 26.7. This suggests that, all other factors being equal, implementing natural pest management practices (Yes) is expected to increase the survival rate of the trees in the reforestation project by 26.7% compared to not implementing such practices (No).

Native Seedlings Use: The predictor "Yes - No" is associated with a coefficient estimate of 22.9. This indicates that, all other factors being equal, using native seedlings (Yes) is expected to increase the survival rate of the trees in the reforestation project by 22.9% compared to using non-native seedlings (No).

- Hypothesis Testing and Significance Testing:

In the provided regression results, all predictors (Post-Project Maintenance, Natural Pest Management, Native Seedlings Use) have p-values less than the significance level (0.05), indicating that they are statistically significant predictors of Survival Rate.

Therefore, we have evidence to reject the null hypothesis and conclude that these predictors have a significant influence on Forest Density.

- Normality Tests:

The Shapiro-Wilk test shows a statistic of 0.974 with a p-value of 0.511, suggesting that the residuals of the model approximately follow a normal distribution. Additionally, the Kolmogorov-Smirnov and Anderson-Darling tests also support the normality assumption, as they yield non-significant p-values.

- Heteroskedasticity Tests:

The Breusch-Pagan test statistic is 3.39 with a p-value of 0.335, indicating that there is no significant evidence of heteroskedasticity in the model. The Goldfeld-Quandt and Harrison-McCabe tests also confirm the absence of heteroskedasticity based on their non-significant p-values.

- Autocorrelation Tests:

The Durbin-Watson statistic is 2.04, suggesting no significant evidence of autocorrelation in the residuals. The p-value of 0.766 further supports this conclusion.

- Collinearity Tests:

The VIF values for each predictor (Post-Project Maintenance, Natural Pest Management, Native Seedlings Use) are all close to 1, indicating that there is no significant multicollinearity issue. Similarly, the tolerance values are all close to 1, suggesting that the predictors are not highly correlated with each other.

Overall, the regression analysis suggests that ‘Post-Project Maintenance’, ‘Natural Pest Management’, and ‘Native Seedlings Use’ are significant predictors of Survival Rate.

Implementing these practices is associated with a higher survival rate of the trees planted in the reforestation project, according to the estimated coefficients.

The Q-Q Plot and Residuals Plots below visualize the results of the assumptions of the multiple linear regression for the Survival Rate variable.

FIGURE 34: Residual Plots of Survival Rate

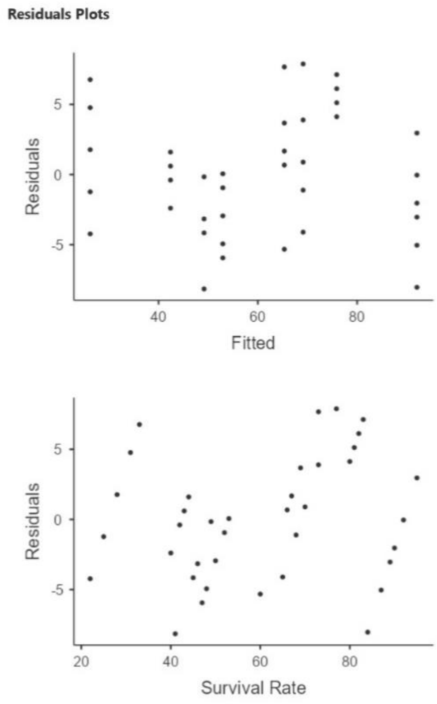
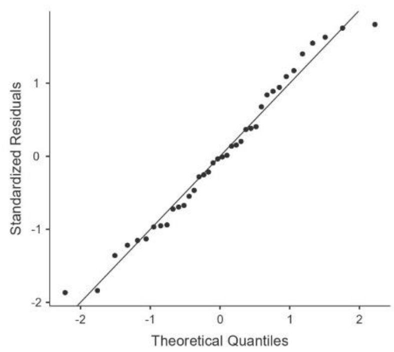


FIGURE 35: Q-Q Plots of Survival Rate



Discussion

Presentation of the Results

Summary and Interpretation

The statistical analysis of this research utilized mainly linear regression analysis. Through simple linear regression, we paired each independent variable with a dependent variable, and consequently determined a list of predictors for every dependent variable as follows. Then, the multiple linear regression determined the nature and strength of the relationships between the dependent variables and their predictors, both as a whole and each on its own.

For the three social variables: Local Hiring, Women Hiring, and Marginalized Hiring, the predictors determined are Community-Led Execution and Pre-Project Training, explaining 96.3% of the variance in the percentage of workers hired from the local community, 91.4% of the variance in the percentage of women hired, and 89.9% of the variance in the percentage of workers hired from marginalized groups in the community.

Moreover, Pre-Project Training showed a stronger effect on the local hiring variable, meaning when a training program on reforestation was implemented before the start of the project, the percentage of workers hired from the local community increased by 28.5%, the percentage of women hired increased by 11.81%, and the percentage of workers hired from marginalized groups increased by 10.89%. Whereas when all the planning and execution of projects happened through participatory and collaborative processes with the local community, the percentage of workers hired from the local community increased by 16.8%, the percentage of women hired increased by 6.81%, and the percentage of workers hired from marginalized groups increased by 6.11%.

When it comes to the last social outcome of reforestation, Income Generation, its predictors are Community-Led Execution and Tree Productivity Quota, explaining 68% of the variance in the number of individuals who secure income from the reforestation project, apart from job salaries. Community-Led Execution had a greater impact, with 38 more people expected to generate income when all the planning and execution of projects happened through participatory and collaborative processes with the local community, while planning at least fifty per cent of the tree species as productive or fruit-bearing resulted in an increase of 30 individuals generating income from the project.

Regarding the environmental outcomes, Carbon Sequestration's predictors are Tree Quota, Tree Species Requirement: Carbon Sequestering, and Stone Mulching, explaining 84.9% of the variance in the amount of carbon dioxide (CO2) sequestered by the reforestation site within the year following the completion of the reforestation project. Tree Quota showed the strongest effect, increasing this amount by 107 units when a minimum of 600 trees per hectare were planted, followed by similar amounts of increase (almost 82 units) through stone mulching and choosing at least twenty per cent of the tree species planted to be 'high carbon sequestering' species.

As for the variable Waste Disposal, the identified predictors are Recycling, Natural Pest Management, and Stone Mulching, explaining 96.4% of the variance in the amount of waste generated by the reforestation project and disposed of through conventional waste disposal methods. Among these, recycling exhibited the most pronounced effect, decreasing the amount by 13.26 tons, followed by Natural Pest Management, then stone mulching. When the reforestation projects did not include the use of any hazardous chemicals, and natural pest management was implemented instead, the amount of waste generated by the reforestation project and disposed of through conventional waste disposal methods decreased by 10.99 tons, and when stones were used as a protective layer over the soil surface around the planted trees, the amount decreased by 6.35 tons per reforestation project.

Concerning the variable Forest Density, the predictors determined are Invasive Species Removal, Tree Quota, and Native Seedlings Use, accounting for 88.8% of the variance in the number of trees per hectare that successfully survive and continue to grow after one year of the completion of the reforestation project. Planting a minimum number of six hundred trees per hectare showed the strongest influence, increasing Forest Density by 270 trees/hectare, followed by the use of only native seedlings with an increase of 202 trees/hectare, and the removal of invasive species contributing to an increase of 123 trees/hectare.

Concerning the variable Biodiversity, the predictors identified are Invasive Species Removal and Species Quota, explaining 84.8% of the variance in the number of species that successfully survive and continue to grow one year after the reforestation project. Planting a minimum number of seven species per project exhibited the strongest effect, leading to the survival of 4 to 5 more species, while the removal of invasive species resulted in the survival of 2 to 3 more species.

Finally, the variable Survival Rate's key predictors are Post-Project Maintenance, Natural Pest Management, and Native Seedlings Use, accounting for 95.6% of the variance in the percentage of planted trees that successfully survive and continue to grow one year after the completion of the reforestation project. The implementation of natural pest management techniques instead of the use of hazardous chemicals showed the most significant effect, increasing the survival rate by 26.7%, followed by the use of native seedlings only, which led to a 22.9% increase. Ultimately, including a phase after the end of the reforestation for project maintenance and follow-up increased the survival rate by 16.2%.

Unexpected Findings

While our primary focus was to investigate and analyze the relationship between circular measures and the outcomes of reforestation projects, our research uncovered additional findings that were both surprising and thought-provoking. These unexpected findings not only shed light on unique aspects of the research topic but also present intriguing implications for future studies and practical applications in the field of reforestation and environmental conservation. In this section, we delve into these unexpected findings, exploring their implications and discussing potential explanations for their emergence.

First, the combined influence of the independent variables (Post-Project Maintenance, Natural Pest Management, Native Seedlings Use) is extraordinarily high. They account for around 95.6% of the variance in Survival Rate, which indicates an extremely robust model. This is quite significant and could suggest that these three factors are critical for a reforestation project's success.

The large impact of Pre-Project Training on Local Hiring: The coefficient estimate associated with Pre-Project Training in the Local Hiring model was surprisingly high (28.5%). This suggests a very strong influence of pre-project training on the percentage of workers hired from the local community.

Community-Led Execution and its large effects: Across all models (Local Hiring, Women Hiring, Marginalized Hiring, and Income Generation), Community-Led Execution has consistently been a statistically significant predictor, leading to higher hiring percentages or income generation. The magnitude of this effect, however, varies across models, showing a particularly large impact on Local Hiring and Income Generation.

Income Generation Model's unique data behaviour: Many projects had a dependent variable (Income Generation) value of 0 in cases where circular measures (Community-Led Execution, Tree Productivity Quota) were not implemented. This 'all or nothing' behaviour is unusual in statistical data and underscores the vital importance of these measures for income generation in the context of these projects.

Marginalized Hiring: The fact that the average percentage of workers hired from marginalized groups in the reforestation projects is quite high (51.08%) is an interesting observation. It suggests that these projects are also playing a role in social inclusion, which might be a point to highlight in your discussion.

Survival Rate: The average survival rate of trees after one year (60.26%) suggests that almost 40% of trees are not surviving the first year, which could raise questions about the efficacy of the reforestation efforts or the quality of the care and maintenance given to the planted trees. This finding might warrant further discussion and investigation.

Reliability Assessment: The weakest association with the overall scale was for biodiversity (0.275), which is interesting given that biodiversity is a fundamental measure of the success of reforestation projects. This may suggest that your measure of biodiversity does not align well with the other measures in your scale, or that biodiversity is influenced by a variety of factors that were not captured in your study.

Income Generation: The mode of 0.00% for income generation is unexpected. This implies that some projects did not provide any additional income to their workers besides their regular payment. This might indicate that reforestation projects, while crucial for environmental sustainability, may not always significantly contribute to economic sustainability for their workers.

The Findings in Relation to the Research Question

The purpose of this study was to investigate the impact of implementing circular economy measures in the planning and execution phases of a reforestation project on both environmental and social outcomes. To address the research question and test the hypotheses, a comprehensive statistical analysis was conducted, primarily utilizing linear regression analysis. This analysis provided valuable insights into the relationships between the independent variables, which are the circular economy measures, and the dependent variables, which represent the environmental and social outcomes of the reforestation projects.

Regarding the social outcomes, the results revealed significant associations between the implementation of circular economy measures and the variables of local hiring, women hiring, marginalized hiring, and income generation. The predictors identified for these variables were Community-Led Execution and Pre-Project Training. The analysis demonstrated that when stakeholder engagement is taken into consideration, through training and collaborative processes for the local community, there were substantial improvements in the social outcomes of reforestation, with more people from the local community benefitting from job opportunities, as well as generating income.

In terms of the environmental outcomes, the analysis focused on Carbon Sequestration, Waste Disposal, Forest Density, Biodiversity, and Survival Rate. The predictors identified for these variables were Tree Quota, Tree Species Requirement, Stone Mulching, Recycling, Natural Pest Management, Invasive Species Removal, and Native Seedlings Use. The results demonstrated that the implementation of circular economy measures had a considerable influence on these environmental outcomes, with Carbon Sequestration increasing through Stone Mulching, Survival Rate increasing with Natural Pest Management, and so on.

These findings answer our research question: ‘What is the impact of implementing circular economy measures in the planning and execution phases of a reforestation project on the environmental and social outcomes of the reforestation project?’, by supporting our research hypothesis (H1), indicating that the implementation of circular economy measures in the planning and execution phases of a reforestation project positively impacts the environmental and social outcomes of the project.

The Findings in Relation to Existing Literature

As mentioned before, not much existing literature has focused on the integration of circular economy measures in reforestation. Thus, this was one of the reasons for conducting this research in the first place. Yet, recent studies have been concentrating on the importance of the circular economy in climate change mitigation, as it has attracted significant attention globally in the search for new long-lasting sustainable models for future generations (Khanna et al., 2022). Studies are also exploring the different applications of the circular economy in various sectors and industries, and how these applications benefit the industries.

For example, according to a paper on the relevance of the circular economy for climate change, the circular economy promotes business models and incentives that encourage the flow of resources and enhance circularity by enhancing resource efficiency. This aligns with the principles of Doughnut economics, which aim to meet the needs of all people within the boundaries of the planet (Khanna et al., 2022). This aligns perfectly with our research objectives, as we focused partially on the social aspects of reforestation that can be enhanced through the circular economy.

Moreover, to go into the specifics of the circular measures we implemented in our research, countless previous studies and projects in the domain of reforestation transitioned from deforestation to reforestation through similar techniques that focused on both the environmental and social aspects of reforestation. For example, the Republic of Korea's (ROK) experience with forest transition in the 1960s followed an integrated policy program that did not only focus on reforestation and land management, but also social development as an innovative approach that proved crucial to solving the problem (Park et al., 2017).

Further, in a study about reforestation in the Philippines, a set of indicators was created to measure the success of the reforestation projects, including both social and environmental success indicators. It emphasizes that reforestation is not only a tree planting activity, but as much a cultural activity as any other human endeavour, requiring a view expanded beyond the technical to include social and cultural aspects. Thus, reforestation efforts need to be carefully planned, implemented, and monitored over a sufficiently long time scale with stakeholder engagement and broader consideration of socio-ecological complexities (Le et al., 2014).

Some of the indicators in this study were similar to the ones used in our research, such as vegetation cover, species diversity, carbon sequestration, job opportunities, and fiscal return. Also, the study discusses the importance of an initial assessment of community capacity in planning and designing reforestation projects, as it can help identify strategic immediate actions and resources to ensure that the necessary inputs are made available to ensure communities have both the short- and long-term capacity required for the objectives to be met (Le et al., 2014). Furthermore, another study focuses on the capacity of communities to undertake reforestation, mentioning that social and human assets can be improved through capacity-building interventions that mobilize existing capital to achieve the desired objectives (Herborn et al., 2023). These two studies conform with the approach that LRI took through implementing pre-project reforestation training to better prepare and engage the local community in the reforestation activities.

Also concerning the social outcomes, a previous survey was done in the local community of a reforestation site, to which the majority of the respondents mentioned that the program is supporting the family's economy and contributing to the environment's development. The document mentions that the majority of labour for managing tree plantations is provided by adult males (38–57% of the total family labour time) followed by adult females (16–35% of the total family labour time), male children (17–25% of total family labour time), and female children (0–16% of total family labour time). This conforms with our results that suggest that community-led reforestation projects increase job opportunities for different members of local communities, including women (Bond et al., 2020).

In addition, a study about community participation in the management of forest reserves in the Northern region of Ghana suggests that when communities are excluded from the management of the forests in their area, it can lead to unsustainable resource management and poverty. The document recommends that the Forestry Commission initiate a formal collaborative agreement with all user groups from the local communities, involving them in the planning and implementation of management decisions, consequently leading to increased job opportunities. Also, when communities have little motivation to indulge in long-term activities that involve planting, which could be interpreted as a potential barrier to job creation in reforestation projects, these projects should be designed to provide immediate returns or benefits (Husseini et al., 2016). This study supports our findings regarding the Tree Productivity Quota and its influence on Income Generation for local communities.

The final study that supports our findings on a social aspect is about the Billion Tree Afforestation Program (BTAP) in Khyber Pakhtunkhwa Province (KPK), Pakistan. The program had a significant impact on the livelihood of the local community, the local residents have benefited the most from it, and it positively affected the economic conditions of rural households. The total net income in the three districts of KPK increased by 6.9 million USD, and social sustainability increased by 69%. The program also presented the locals with the opportunity of planting fruit trees and breeding livestock, while being entitled to 100% of the proceeds from these crops, which was a win–win solution for forest conservation and the fulfilment of human wellbeing, with the workers receiving financial support from the provincial government in the form of both salaries and profit. Additionally, the plantations provide employment mainly to migrant workers from regions in Northern Ghana (Khan et al., 2019).

When it comes to the environmental outcomes, the literature available on the potential of the circular economy to tackle the climate change crisis explains the impact of the CE on major important ecological processes that we shed light on through our research,

such as emissions reduction through carbon sequestration, as well as waste mitigation, and so on (Stefanakis et al., 2021).
For example, as our findings suggested that stone mulching increases the amount of carbon sequestered by the reforestation project, a field experiment was conducted for four consecutive years in the Eastern Himalayan regions (EHR), India that involved different mulch systems, as well as no mulch. The results showed that the mulched plots produced more crop biomass (both above and below ground), recycled more carbon in soils, and had a trend of relatively more soil organic carbon (SOC) pool, sequestration rate, and carbon retention efficiency than those of no mulch treatment. These results were seen despite differences among the mulch treatments, which were statistically non-significant after four cropping cycles. Also, another study conducted in the Loess Plateau of China found that stone mulching increased soil organic carbon (SOC) by 9.8% compared to non-mulched soils. The SOC content in the 0-10 cm soil layer under stone mulching was 17.8 g/kg, while it was 16.2 g/kg in non-mulched soils. The increase in SOC due to stone mulching was attributed to the improvement in soil water content and the reduction in soil erosion (Yadav et al., 2019).

Besides, a study conducted in the United States proved that planting a higher number of trees has the potential to increase the carbon sequestration capacity of forests as they are the largest terrestrial carbon (C) sink on earth, and their management has been recognized as a cost-effective strategy for mitigating greenhouse gas emissions. In the United States, forestland represents nearly one-third of the total land area, and forests store more than three decades of carbon dioxide (CO_2) emitted from economy-wide fossil fuels. The study states that the current tree planting efforts contribute ∼3 to 5% to live-tree C sequestration each year in the United States. If all understocked timberland were fully stocked in the United States, potential C sequestration capacity would increase by ∼20% (−187.7 MMT CO_2 ±9.1 MMT CO_2) per year (Domke et al., 2020).

Regarding natural pest management, our results found that avoiding the use of pesticides and replacing it with natural pest management reduces waste disposal and increases the survival rate of trees. Similarly, a study conducted in Southeast Asia has found that the intensive use of pesticides has resulted in significant biodiversity loss and peat oxidation, leading to surface subsidence and reversal of peatland systems from carbon sinks to carbon sources creating a large ‘‘biofuel carbon debt’’. Their use has also increased waste generation over the years (Biggs et al., 2015).

A different study in India proved that the use of pesticides contributes to soil pollution, and it can harm plants and animals by contaminating the soil. These chemicals can get deep inside the soil and poison the groundwater system. They can even kill more than just their intended targets, including the necessary micro-organisms in the soil. Hence, when pesticides are used for a while on plants in an area, they eventually leach into the soil, killing the micro-organisms living in the soil that break down organic material and aid in plants’ survival and growth. It can take years before microorganisms can once again live in soil that has had toxic chemicals applied to it (Mishra et al., 2016).

Besides, another study showed that stone mulching can as well contribute to reducing waste generation through weed control, as stone mulching creates a physical barrier that prevents weed growth, reducing the need for herbicides or manual weed removal, consequently decreasing the waste generated from packaging, empty containers, and other waste materials associated with weed control measures (Keesstra et al., 2018).

On another note, many studies have focused on the ecological impacts of the removal of invasive species, conforming with our findings in this regard that it positively affects the number of trees and species that successfully survive and continue to grow after the completion of the reforestation project. For example, a study evaluated the responses of the woody species and Megathyrsus maximus (an invasive grass species) to manual removal in a 20-year-old reforestation site. The number of new grass seedlings decreased drastically after the first year with repeated removals, indicating that one year of removal was sufficient to displace the grass. Based on this negative relationship between the invasive species and regeneration diversity, and also the strong release of woody regeneration one year after the first grass removal, there was evidence that Megathyrsus Maximus is slowing ecological succession in the study site. The weeding and repeated removals for at least one year allowed a consistent increase in woody species regeneration, accelerating succession (Mantoani et al., 2016).

Another very important circular measure we studied in our research was including a phase after the end of the reforestation for project maintenance and follow-up, which proved to increase the survival rate of the trees in the reforestation project. Previous studies on this finding were several, such as a document dedicated solely to the guidance for successful tree planting initiatives, which emphasizes the importance of monitoring and adaptive management in tree planting initiatives, and agrees with our findings by suggesting that variables such as the survival and growth rates of trees, the effectiveness of measures to control deforestation, and other outcomes of the reforestation projects are all affected by the monitoring phase in a reforestation project. It also mentions that most failed restoration programs result from a lack of planning and maintenance activity. Thus, small targeted projects with intensive maintenance are often more successful than projects planted over large areas. For example, one forest restoration project conducted by the Gunung Palung National Park (GPNP) office had an initial seedling survival rate of over 80%. Yet, all of the planting sites were burned because of the absence of adequate maintenance after the project. Moreover, another example that this document gives is about a reforestation site where on-site maintenance played a significant role in tree survival and growth, with one species having a survival rate of 97.7% on maintained sites vs. 73.8% survival on non-maintained sites (Brancalion et al., 2020).

Finally, when it comes to the importance of the use of native seedlings, which our research shows increases the survival rate of trees in the reforestation project, many studies have proved the same. One example can be a study that implemented a field experiment comparing planted seedlings of Acer platanoides (a non-native invasive canopy tree) and Acer saccharum (a common native tree) aimed to identify the benefits of using native seedlings in reforestation efforts and found that Acer saccharum seedlings had greater root, as well as greater winter survival, suggesting a physiological advantage over Acer platanoides during the winter months (Morrison et al., 2007).

Implications and Applications

The Research's Contribution to the Field

In the domain of reforestation projects, there has been an increasing interest in incorporating the principles of the circular economy, particularly given its potential to enhance both environmental sustainability and social outcomes. Despite this growing interest, there has been a noticeable gap in the literature about robust, empirical research that quantitatively examines the impacts of these measures. This study is aimed at addressing this gap, contributing significantly to the field by providing a rigorous, data-driven investigation into the tangible impacts of circular economy measures on the environmental and social outcomes of reforestation projects.

The first major contribution of this research is that it challenges the null hypothesis, providing solid empirical evidence that circular economy measures do have significant impacts on the environmental and social outcomes of reforestation projects. This confirmation provides a critical foundation for the theory that circular economy principles are not just theoretical concepts but can have practical, measurable impacts when implemented correctly in real-world scenarios. By directly linking these principles with tangible outcomes, this study bolsters the argument for the importance of circular economy measures within the broader field of environmental conservation, and specifically within reforestation projects.

Secondly, this study provides valuable insights into the specific circular economy measures that were shown to be predictors of successful outcomes. It identifies measures such as Community-Led Execution, Pre-Project Training, Tree Quota, Recycling, and Natural Pest Management as key elements that could enhance the success of reforestation initiatives. This detailed understanding of the specific strategies that work not only adds depth to our academic understanding but provides practical guidance for future projects. By outlining these specific measures, the study paves the way for future researchers and practitioners to design and implement reforestation initiatives that are more likely to be successful and sustainable.

Thirdly, an innovative aspect of this study is the connection it makes between environmental sustainability and social inclusion, particularly through the measures of local hiring, women hiring, marginalized hiring, and income generation. The study reveals that the principles of the circular economy can be leveraged to create a balance between environmental and social considerations. This balance is not just important for gaining community acceptance and participation, but it also directly impacts the success and sustainability of reforestation projects. This nuanced understanding of the interplay between environmental and social aspects is a significant contribution to the literature, as it broadens the traditional focus on environmental outcomes to include social outcomes.

Fourthly, this study extends the literature by providing robust quantitative assessments of the impact of circular economy measures. The ability of the study's identified predictors to explain a large proportion of the variance in each dependent variable underscores the role of circular economy measures as significant determinants of project outcomes. This clear quantification has been largely missing in previous studies, which makes this study's contribution especially valuable. These insights not only solidify the theoretical links between circular economy measures and project outcomes, but they also offer practical guidance for enhancing the success of reforestation projects.

Lastly, the findings of this research underscore the urgent need for further research into the integration of circular economy measures into reforestation projects. By providing a roadmap of effective measures and their quantifiable impacts, the study provides a solid basis for future research in this area. Moreover, by highlighting the important role of the local community and the impacts of training, this study calls for a broader focus on the social dimensions of reforestation, an aspect that is often overlooked in traditional conservation efforts.

In conclusion, this research contributes to the academic discourse by deepening our understanding of the impacts of circular economy measures in reforestation projects, as well as highlighting the importance of integrating these principles into future initiatives. By doing so, it offers a comprehensive, quantifiable perspective on the interplay between the circular economy and reforestation. As such, the contributions of this research are likely to have far-reaching implications for the design and implementation of future reforestation initiatives, as well as for the broader field of environmental conservation.

The Findings’ Applications in Real-world Contexts

The findings from this research have important implications for a wide range of real-world contexts. At the forefront is the potential to enhance the effectiveness of reforestation projects, which are increasingly seen as critical tools in global efforts to combat climate change, restore biodiversity, and create sustainable livelihoods.

Firstly, this research's findings emphasize the need to integrate circular economy principles into the planning and execution phases of reforestation projects, as they showed to be critical predictors of successful environmental and social outcomes of reforestation projects. In practical terms, this means that reforestation project managers can use these predictors as a roadmap for designing and implementing more effective and sustainable projects. For instance, the strong correlation found between Community-Led Execution and positive social outcomes suggests that reforestation projects should involve the local community from the earliest planning stages. By working collaboratively with local stakeholders and considering their needs and aspirations, project managers can ensure that the reforestation initiative is better aligned with the local context and has a higher likelihood of success. In terms of policy implications, these findings suggest that governments and funding bodies should prioritize community-led projects when allocating resources for reforestation initiatives.

Similarly, the Pre-Project Training measure was found to have a significant impact on both environmental and social outcomes. This indicates that investing in training initiatives before the start of a reforestation project can improve the project's effectiveness and sustainability. For example, training local community members in reforestation techniques can enhance their capacity to contribute to the project, resulting in increased local hiring, women hiring, and marginalized hiring. At the same time, trained community members are more likely to use sustainable practices, such as natural pest management and recycling, which can enhance environmental outcomes like carbon sequestration and waste disposal.

Considering environmental outcomes, the measure of Tree Quota can significantly improve the effectiveness of reforestation efforts. A practical application of this finding could involve policymakers setting mandatory minimums for tree plantings per hectare in all funded reforestation projects. This would help ensure a higher level of carbon sequestration and contribute more effectively towards climate change mitigation goals. Similarly, the importance of Recycling and Natural Pest Management as predictors of successful waste disposal outcomes suggests that these practices should be promoted in all reforestation initiatives. A practical application could be the development of 'green procurement' policies for reforestation projects, which prioritize the use of recycled and non-hazardous materials.

In conclusion, and on a broader level, these findings contribute to our understanding of how to create a more sustainable and inclusive economy. The identified correlations between circular economy measures and improved social and environmental outcomes suggest that these principles could be applied in other sectors, such as agriculture, manufacturing, and energy production, to promote sustainable development. This research, therefore, provides a valuable resource for reforestation practitioners, policymakers, and others working to promote a more sustainable and inclusive future.

Research Challenges

Research Limitations

In any research, it is crucial to acknowledge and critically evaluate the limitations that may affect the study's outcomes and conclusions. This section delves into the various limitations encountered throughout our research process, highlighting the boundaries and potential weaknesses that could impact the validity and generalizability of our findings. By openly acknowledging these limitations, we can provide a comprehensive understanding of the study's scope and shed light on areas where further research is warranted.

One limitation of this study is that it is restricted to projects executed by the NGO Lebanon Reforestation Initiative. This could potentially limit the generalizability of the findings, as these projects have the unique characteristics of their location, funding, and other features not found in other reforestation projects around the globe. Also, this study only considered environmental and social outcomes, which while significant, do not encompass the full spectrum of potential benefits of the circular economy approach in reforestation projects. For instance, the economic impacts of these projects, such as their effect on local economies or their potential to drive sustainable economic growth, were not considered.

On the other hand, the use of a quasi-experimental design, while practical and fitting for this research, has its limitations, as it inherently lacks random assignment of subjects to the treatment and control groups. Therefore, the results may be influenced by confounding variables that were not controlled for, limiting the generalizability of the results to the entire population of reforestation projects. What’s more is the selection bias due to the non-random selection of reforestation projects. Even though attempts were made to control for confounding variables, some variables may not have been identified or appropriately controlled for, potentially introducing bias into the study.

In addition, the sampling method, criterion purposive sampling, although suitable for this research, might limit the generalizability of the findings. Since this method is based on specific criteria, it may not accurately represent all reforestation projects, limiting the extrapolation of the findings to the larger population. The sample size also, while deemed sufficient for this research, is relatively small compared to previous similar literature in the field, which may limit the external validity of the findings.

When it comes to the confounding variables, although attempts were made to control for several (Project Date, Project Location, Project Size, Funding Source, Project Management, and Ecological Context), there may be other uncontrolled confounding variables that could affect the outcomes of the reforestation projects. These may include variations in the intensity of the implementation of circular economy measures, as well as other unmentioned variables.

Concerning the research methodology, there might be limitations of correlation, as correlation doesn't imply causation. Therefore, even though variables have shown strong associations, it doesn't mean one variable is causing the change in the other. Further, the binary nature of the predictors (Yes - No) may oversimplify the real-world situation. For example, the magnitude and method of implementing each measure (such as the extent of invasive species removal, the conditions of recycling, post-project maintenance variations in intensity and quality, etc.) can vary between projects and might influence the outcomes in a more nuanced way than simply whether or not the measure was implemented.

Given these limitations, while the findings of this study are robust and insightful, they should be interpreted with caution. Future research is needed to confirm these findings in different contexts and using different methodologies, and despite these limitations, this research has contributed to our understanding of the potential of the circular economy approach in reforestation projects and provides a solid foundation for further investigation.

Research Constraints

In the course of conducting our research, we encountered a few constraints that shaped our study's approach and methodology. These challenges were significant yet ubiquitous in the field of applied environmental research. As we navigated these obstacles, we found ourselves adapting our strategies and honing our techniques to ensure the validity and reliability of our results. The following section provides a comprehensive account of each constraint and details the measures we employed to mitigate its potential impact on our research.

- Time Constraints: Research is a time-consuming process and can often take longer than initially anticipated due to the complexity and unpredictability of scientific investigation. In our case, reforestation outcomes may take years, or even decades, to fully manifest, and it's challenging to capture all relevant data within a shorter time frame. Time constraints may also limit the amount of data that can be collected, analyzed, and interpreted within the research timeline. They may force the research to focus on more immediate, short-term impacts rather than long-term outcomes.

Thus, aware of the pressure exerted by the ticking clock, we prioritized our research activities meticulously, establishing clear milestones and deadlines to keep the research on track. We utilized modern data management tools to coordinate our efforts efficiently, enabling us to adhere to our timeline without compromising the quality of our work, and we set realistic goals for our research to focus on and reach.

- Data Availability: Comprehensive data from the projects was not readily available due to differences in record-keeping and a lack of standardized measurement techniques. Also, access to documents and records from the ministries in Lebanon for comparative purposes was more difficult than anticipated, as the country is passing through a socioeconomic crisis at the moment. Thus, many public entities are not able to work at full capacity. However, despite the challenges, we sought data from a wide range of sources, including public databases, and academic research. We also based our data collection mainly on the NGO itself, as we guaranteed full access to all the needed documents from its end.

- Geographical Constraints: The reforestation projects were implemented across diverse locations in Lebanon, most of which are remote and challenging to reach. This limited the frequency of site visits, and hindered our ability to build a relationship with the local community involved in the reforestation project. Direct, personal interaction with the community members is invaluable as it provides a nuanced understanding of their perspectives, experiences, and the real-time challenges they face in the context of the project.

However, it's important to note that while geographical constraints were a significant hurdle, they did not render the research invalid or irrelevant. It merely required us to find innovative ways to work around these constraints, utilize different data collection methods, and critically interpret the data we have at our disposal. This involved relying more heavily on digital communication methods with the employees of the NGO, who assisted every step of the way in data collection.

In conclusion, while the constraints we faced were significant, they were not insurmountable. The methodological choices we made and the strategies we adopted allowed us to navigate these challenges effectively. We believe these efforts have led to robust findings that can contribute meaningfully to the field of reforestation. Our experiences also underscore the importance of adaptability, collaboration, and meticulous planning in conducting high-quality research, particularly in complex, real-world settings like reforestation. We hope that the lessons we learned are valuable not just for our future work, but also for other researchers working in similar contexts.

Future Directions

Areas for Further Research

As we delve deeper into the exploration of our research project on reforestation initiatives, we acknowledge that this study, despite its valuable findings and contributions, is not exhaustive. The complexity of environmental conservation and sustainable development issues necessitates continuous investigation. Therefore, we consider this research as a stepping stone for future studies that can build upon and extend our findings. In light of this, we propose the following areas for further investigation:

- Long-term Impact Assessment: Our study predominantly focused on the immediate outcomes of reforestation projects. We propose that further research could delve into the long-term impacts of these initiatives. An examination of survival rate, carbon sequestration, biodiversity, and forest density beyond the preliminary stages of reforestation could offer valuable insights into the sustainability and efficacy of these projects over time. Such a longitudinal perspective would be integral to comprehending the full scope of reforestation's long-lasting environmental effects.

- Economic Evaluation: One significant aspect that could complement our study is an economic evaluation of reforestation projects. This line of research would assess the cost-effectiveness and prospective economic benefits tied to reforestation. Such a study could analyze the financial investments required for these initiatives, calculate the return on investment, and evaluate the economic value generated by reforestation efforts. An economic analysis would offer a comprehensive understanding of the economic implications and potential incentives for stakeholders and policymakers, thereby contributing to the discourse on the feasibility and financial sustainability of such projects.

- Comparative Analysis: We recommend expanding the scope of our research by conducting a comparative analysis of reforestation projects implemented in different regions or countries. This method of comparison, considering varying ecological, socio-economic, and policy contexts, could help identify factors contributing to successful reforestation efforts and the effectiveness of specific interventions. A comparative approach would enhance the generalizability of our findings and provide valuable insights for practitioners and policymakers globally.

- Stakeholder Engagement and Perception: An examination of various stakeholders involved in reforestation projects could offer a more nuanced and detailed understanding of these initiatives. By investigating the perspectives, experiences, and engagement of project managers, local communities, policymakers, and non-governmental organizations, further research can delve into the complexities of stakeholder dynamics. This could be achieved by conducting surveys, interviews, or focus groups. This approach would facilitate a more inclusive and participatory methodology for future reforestation initiatives.

- Policy and Governance Analysis: We also suggest an evaluation of the policy frameworks and governance structures surrounding reforestation initiatives. This would involve studying the impact of policy interventions, institutional arrangements, and regulatory frameworks on the implementation and success of reforestation projects. Such research could potentially identify gaps in policy frameworks and offer recommendations for enhancing the supportive environment for reforestation efforts.

In summary, the areas proposed for further research are aimed at addressing the gaps identified in our study and contributing to a more comprehensive understanding of reforestation practices. By exploring these avenues, future researchers can continue building upon our findings and make valuable contributions to the field of reforestation and environmental conservation.

Recommendations for the NGO

There are several potential development paths that the NGO Lebanon Reforestation Initiative could consider to enhance its reforestation projects' impact. These potential developments encompass a variety of strategic areas, including geographical expansion, community empowerment, socioeconomic sustainability, and research and innovation. Let's delve deeper into these future directions:

- Expansion of Project Sites: The NGO could consider widening the geographic reach of its reforestation projects to include different regions or countries. This expansion would address deforestation and environmental degradation on a grander scale, thereby making a more substantial contribution to global conservation efforts.

- Partnerships and Collaborations: Establishing strategic partnerships and collaborations with other organizations, such as governmental agencies, research institutions, and local communities, could be a significant step forward. Such collaborative initiatives could leverage collective expertise, resources, and knowledge-sharing, enhancing project outcomes and fostering more profound community engagement.

- Monitoring and Evaluation: The NGO could further bolster its monitoring and evaluation framework to track reforestation projects' long-term success and impact. Implementing robust monitoring systems to assess the survival and growth rates of planted trees, biodiversity recovery, carbon sequestration, and socioeconomic indicators can guide adaptive management and inform future decision-making processes.

- Policy Advocacy and Engagement: The NGO could engage more actively in policy advocacy at local and national levels. Collaborating with governmental and non-governmental stakeholders could promote supportive policies and financial incentives for reforestation and ecosystem restoration, impacting environmental policies, regulations, and funding mechanisms.

- Knowledge Exchange and Collaboration:

Active participation in knowledge exchange platforms, conferences, and networks is another potential development for the NGO. Sharing experiences, lessons learned, and best practices with other organizations and stakeholders involved in reforestation and conservation can foster collaboration and learning from similar initiatives worldwide.

In conclusion, the future holds immense potential for the NGO to enhance its impact on reforestation and conservation. By considering these potential developments, LRI can make strides in addressing environmental challenges, empowering communities, and fostering a circular future.

Conclusion

In this thesis, we have explored the critical transition from a traditional linear economy to a circular economy, with a particular focus on the application of this transition in the context of reforestation efforts. The linear economy, characterized by a "take-make-dispose" approach, has been the dominant economic model for centuries. However, this model has led to significant environmental, social, and economic challenges. These include the depletion of finite resources, environmental degradation, waste disposal issues, and social inequalities. The linear economy's assumption of abundant resources and easy waste disposal has proven to be unsustainable and detrimental to our planet and society.

In contrast, the circular economy presents a more sustainable and regenerative economic model. It aims to keep resources in use for as long as possible through strategies such as recycling, reusing, and repurposing. This model is designed to minimize waste and pollution while promoting sustainable resource management and economic growth. The three key principles of the circular economy are designing products for durability and reuse, optimizing resource use as efficiently as possible, and regenerating natural systems.

The application of circular economy principles to reforestation efforts has been a central theme of this thesis. We have discussed how these principles can be applied in various ways, such as choosing tree species that are well-suited to local conditions, employing natural pest management techniques, implementing a follow-up phase for maintenance, and so on. Which can enable us to significantly enhance the sustainability and effectiveness of reforestation projects. These practices not only contribute to the longevity and success of reforestation efforts but also help to optimize resource use and minimize waste, aligning with the core principles of the circular economy.

Further, we found that reforestation efforts that incorporate circular economy principles can have significant environmental benefits. Reforestation can mitigate climate change by absorbing carbon dioxide, a major greenhouse gas. It can also promote biodiversity by providing habitat for a variety of plant and animal species, and it can prevent soil erosion, reduce the risk of natural disasters, and improve water quality.

On another note, we delved into the role of non-governmental organizations (NGOs) in promoting the circular economy. NGOs play a crucial role in advocating for social and environmental justice, raising awareness, and implementing projects and programs to improve communities' livelihoods. The circular economy model can help NGOs maximize their use of resources, reduce waste, and promote sustainable practices, thereby benefiting their work. The work of NGOs like the Ellen MacArthur Foundation and the Rainforest Alliance exemplifies how these organizations can drive the transition to a circular economy and make significant contributions to reforestation efforts.

This research contributes to the existing body of knowledge on the circular economy and reforestation. It provides empirical evidence of the benefits of the circular economy in the context of reforestation, which can inform future research and policy development. It also highlights the need for a holistic approach to sustainability, which considers not only environmental but also social aspects.

Based on the findings of this research, several recommendations can be made for future actions to further promote and implement the circular economy in reforestation efforts. NGOs can use these findings to guide their advocacy efforts, develop and implement circular economy projects, and educate the public about the benefits of the circular economy. They can also use these findings to collaborate more effectively with businesses, governments, and communities to drive the transition to a circular economy.

For governments, the research emphasizes the need for policies and regulations that support the circular economy. Governments can use these findings to develop and implement policies that incentivize circular practices, such as tax breaks for businesses that reduce waste or use recycled materials. Whereas for local communities, the research shows how the circular economy can contribute to local economic development and environmental sustainability. Communities can use these findings to participate in reforestation efforts and advocate for policies that support the circular economy.

Finally, to overcome potential challenges or barriers to the circular economy, it is recommended to provide education and training on circular practices, foster collaboration among various stakeholders, and invest in research and development, as there are several areas where further research is needed to deepen our understanding and facilitate the transition to a circular economy.

In conclusion, while the research process was challenging, it was also a valuable learning experience. It provided insights into the potential of the circular economy, the importance of reforestation, and the role of various stakeholders in promoting sustainability. It also highlighted the need for further research in this area, providing a foundation for future investigations. As such, this research not only contributes to the academic field but also provides a roadmap for practical actions to create a more sustainable and equitable future.

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Annexes

Annex 1: List of Abbreviations

NGO: Non-governmental organization

IPCC: Intergovernmental Panel on Climate Change

EHR: Eastern Himalayan Regions

BTAP: Billion Tree Afforestation Program

KPK: Khyber Pakhtunkhwa Province

SOC: Soil organic carbon

CO2: Carbon dioxide

MMT: Mega metric tons

GPNP: Gunung Palung National Park

CO2: Carbon dioxide

VIF: Variance Inflation Factor

Q-Q Plot: Quantile-Quantile Plot

OPEC: Organization of the Petroleum Exporting Countries

IMF: International Monetary Fund

WEF: World Economic Forum
EPA: Environmental Protection Agency

RCRA: Resource Conservation and Recovery Act

WHO: World Health Organization

FAO: Food and Agriculture Organization

CE: Circular Economy

SDG: Sustainable Development Goals

UN: United Nations

GDP: Gross Domestic Product

IDAL: Investment Development Authority of Lebanon

MSW: Municipal Solid Waste

USD: United States Dollar

MOE: Ministry of Environment

AUB: American University of Beirut

LTA: Lebanon Tree Act

UNDP: United Nations Development Programme

ILO: International Labor Organization

UNHCR: United Nations High Commissioner for Refugees

WTO: World Trade Organization

USAID: United States Agency for International Development

IP: International Programs

EPR: Extended Producer Responsibility

PAYT: Pay-As-You-Throw

MFIs: Microfinance institutions

SMF: Sanabel Microfinance Network

MEVF: Middle East Venture Fund

LCPS: Lebanese Center for Policy Studies

LiF: Livelihood in Forests

LRI: Lebanon Reforestation Initiative

Annex 2: List of Figures

FIGURE 31: The Q-Q Plot of the Forest Density variable

FIGURE 32: The Residual Plots of the Biodiversity variable

FIGURE 33: The Q-Q Plot of the Biodiversity variable

FIGURE 34: The Residual Plots of the Survival Rate variable

FIGURE 35: The Q-Q Plot of the Survival Rate variable

Annex 3: Simple Linear Regression Tests Results

Simple Linear Regression Tests of Local Hiring

Model Fit Measures

Model	R	R^2
1	0.544	0.296

Model Coefficients - Local Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	69.9	3.04	23.03	< .001
Community-Led Execution:				
Yes – No	18.2	4.68	3.89	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.845	0.713

Model Coefficients - Local Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	58.2	2.52	23.10	< .001
Pre-Project Training:				
Yes – No	29.4	3.11	9.46	< .001

[a] Represents reference level

Simple Linear Regression Tests of Women Hiring

Model Fit Measures

Model	R	R^2
1	0.523	0.274

Model Coefficients - Women Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	27.59	1.31	21.14	< .001
Community-Led Execution:				
Yes – No	7.41	2.01	3.68	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.827	0.684

Model Coefficients - Women Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	22.7	1.12	20.25	< .001
Pre-Project Training:				
Yes – No	12.2	1.38	8.82	< .001

[a] Represents reference level

Simple Linear Regression Tests of Marginalized Hiring

Model Fit Measures

Model	R	R^2
1	0.510	0.260

Model Coefficients - Marginalized Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	48.27	1.22	39.69	< .001
Community-Led Execution:				
Yes – No	6.66	1.87	3.56	0.001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.825	0.681

Model Coefficients - Marginalized Hiring

Predictor	Estimate	SE	t	p
Intercept [a]	43.7	1.04	42.08	< .001
Pre-Project Training:				
Yes – No	11.2	1.28	8.77	< .001

[a] Represents reference level

Simple Linear Regression Tests of Income Generation

Model Fit Measures

Model	R	R^2
1	0.786	0.618

Model Coefficients - Income Generation

Predictor	Estimate	SE	t	p
Intercept [a]	16.3	5.80	2.81	0.008
Tree Productivity Quota:				
Yes – No	62.6	8.20	7.63	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.800	0.640

Model Coefficients - Income Generation

Predictor	Estimate	SE	t	p
Intercept [a]	20.5	5.23	3.91	< .001
Community-Led Execution:				
Yes – No	64.5	8.07	8.00	< .001

[a] Represents reference level

Simple Linear Regression Tests of Carbon Sequestration

Model Fit Measures

Model	R	R^2
1	0.348	0.121

Model Coefficients - Carbon Sequestration

Predictor	Estimate	SE	t	p
Intercept [a]	420.5	17.1	24.64	< .001
Tree Species Requirement: Carbon Sequestering:				
Yes – No	53.7	24.1	2.22	0.032

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.557	0.311

Model Coefficients - Carbon Sequestration

Predictor	Estimate	SE	t	p
Intercept [a]	387.7	18.3	21.22	< .001
Tree Quota:				
Yes – No	90.7	22.5	4.03	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.592	0.351

Model Coefficients - Carbon Sequestration

Predictor	Estimate	SE	t	p
Intercept [a]	410.4	13.3	30.80	< .001
Stone mulching:				
Yes – No	93.6	21.2	4.41	< .001

[a] Represents reference level

Simple Linear Regression Tests of Waste Disposal

Model Fit Measures

Model	R	R^2
1	0.685	0.469

Model Coefficients - Waste Disposal

Predictor	Estimate	SE	t	p
Intercept [a]	31.3	1.74	17.98	< .001
Recycling:				
Yes – No	-13.2	2.34	-5.64	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.337	0.114

Model Coefficients - Waste Disposal

Predictor	Estimate	SE	t	p
Intercept [a]	26.61	1.93	13.77	< .001
Stone mulching:				
Yes – No	-6.61	3.08	-2.15	0.039

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.698	0.488

Model Coefficients - Waste Disposal

Predictor	Estimate	SE	t	p
Intercept [a]	31.1	1.66	18.70	< .001
Natural Pest Management:				
Yes – No	-13.4	2.29	-5.86	< .001

[a] Represents reference level

Simple Linear Regression Tests of Forest Density

Model Fit Measures

Model	R	R^2
1	0.331	0.110

Model Coefficients - Forest Density

Predictor	Estimate	SE	t	p
Intercept [a]	422	55.9	7.56	< .001
Invasive Species Removal:				
Yes – No	135	64.0	2.11	0.042

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.666	0.443

Model Coefficients - Forest Density

Predictor	Estimate	SE	t	p
Intercept [a]	365	36.8	9.94	< .001
Tree Quota:				
Yes – No	243	45.3	5.35	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.543	0.295

Model Coefficients - Forest Density

Predictor	Estimate	SE	t	p
Intercept [a]	431	34.2	12.60	< .001
Native Seedlings Use:				
Yes – No	188	48.4	3.88	< .001

[a] Represents reference level

Simple Linear Regression Tests of Biodiversity

Model Fit Measures

Model	R	R^2
1	0.568	0.322

Model Coefficients - Biodiversity

Predictor	Estimate	SE	t	p
Intercept [a]	4.33	0.818	5.30	< .001
Invasive Species Removal:				
Yes – No	3.87	0.936	4.14	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.844	0.712

Model Coefficients - Biodiversity

Predictor	Estimate	SE	t	p
Intercept [a]	4.84	0.367	13.19	< .001
Species Quota:				
Yes – No	4.89	0.519	9.43	< .001

[a] Represents reference level

Simple Linear Regression Tests of Survival Rate

Model Fit Measures

Model	R	R^2
1	0.668	0.446

Model Coefficients - Survival Rate

Predictor	Estimate	SE	t	p
Intercept [a]	45.8	3.71	12.34	< .001
Natural Pest Management:				
Yes – No	27.5	5.11	5.38	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.599	0.358

Model Coefficients - Survival Rate

Predictor	Estimate	SE	t	p
Intercept [a]	47.9	3.89	12.34	< .001
Native Seedlings Use:				
Yes – No	24.6	5.49	4.48	< .001

[a] Represents reference level

Model Fit Measures

Model	R	R^2
1	0.483	0.234

Model Coefficients - Survival Rate

Predictor	Estimate	SE	t	p
Intercept [a]	49.8	4.36	11.41	< .001
Post-project Maintenance:				
Yes – No	19.9	6.01	3.31	0.002

[a] Represents reference level