Mapping and Valuing
Forest Ecosystem Services in Lebanon

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CO_2	Carbon Dioxide
FAO	Food and Agriculture Organization of the United Nations
GBA	Greater Beirut Area
GHG	Greenhouse Gases
IRENA	International Renewable Energy Agency
NDC	Nationally Determined Contribution
LAI	Leaf Area Index
LiF	Livelihoods in Forestry
LRI	Lebanon Reforestation Initiative
LWA	Leaf dry Weight per Area
MEA	Millennium Ecosystem Assessment
MoA	Ministry of Agriculture
MoPH	Ministry of Public Health
NO_x	Nitrogen Oxides
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NR	Nature Reserve
PA	Protected Area
PES	Payment for Ecosystem Services
PM_x	Particulate Matter
SBR	Shouf Biosphere Reserve
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Valuation
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollars
WHO	World Health Organization

I. Ecosystem Services Valuation of Lebanese Forests - Overview of Context, General Methodology and Results

1. Introduction and Objectives

Through direct and indirect services, forests are essential contributors to human wellbeing. In many ways, individuals and communities are dependent on these services to sustain their livelihoods and enhance their quality of life. They are essential to maintain resilience in face of shocks and stresses and to ensure prosperous futures. Although undoubtedly high in value, many of these services' values accrue as indirect or non-market benefits, making their contributions to human wellbeing often overlooked and unrecognized in public and private management decisions. As a result, forests are often degraded or lost along with their benefits – usually at immense social and economic cost to the many different groups and sectors that depend on forest ecosystem services.

Under the United States Agency for International Development (USAID) -funded "Livelihoods in Forestry" (LiF) project, the Lebanon Reforestation Initiative (LRI) NGO has developed a forest ecosystem services valuation study to monetarily represent this dependency on forest ecosystem services. This study aims to encourage the inclusion of forest services and their beneficiaries in decision making, and to make the case for the protection and expansion of these valuable natural ecosystems. Ecosystem valuation serves as a communication tool that enables a clearer understanding of the importance of forest services and thereby their conservation. Furthermore, by spatially mapping the distribution of services and value hotspots across the country, this study also aids in directing interventions towards key areas. Ultimately, the goal is to promote better-informed and more inclusive decision-making, that points towards optimal socio-economic and environmental outcomes and that supports sustainable livelihoods and economic growth.

With a clearer understanding of the value of forest services, comes the obligation to ensure that these values are integrated into public and private decision making. A key question becomes: How do we internalize ecosystem costs and benefits into the policies, markets and prices that drive people's economic behavior, and set-in place incentives to reward, encourage and enable forest restoration, conservation, and sustainable use? Therefore, and based on the results of this valuation, LRI will develop a Payment for Ecosystem services (PES) approach. This approach will present a model through which "payments" or rewards are provided to the groups that manage, use and act as stewards of forests, to ensure the continuity of forest services and increase their value. Considering the current economic crisis, the setbacks of COVID-19, and the devastating impacts of the Beirut blast, nature-based solutions are key to maintaining the ecosystem services that enhance people's quality of life and are an important source of livelihood income for an increasingly impoverished population.

Former studies on forest ecosystem functions and services in Lebanon have provided area-based valuations of services such as, in the Shouf Biosphere Reserve (Ecodit, 2015) or the Jabal Moussa Biosphere Reserve (Karam, 2016). Others have presented a Total Economic Valuation (TEV) of forest ecosystem services in Lebanon ranging from wood products to tourism and grazing (Sattout, Talhouk and Kabbani, 2005), yet the geographical distribution of these services and their values were not mapped. Additionally, a study by Amidi, Stephan and Maatouk (2020) valued the ecosystem services of old reforested sites from the perspective of the neighboring local communities' willingness to pay for the benefits of these sites. This study, developed by LRI, focuses on a selected set of services, and applies innovative techniques to quantify, valuate and map their distribution across Lebanon. These forest services are thereby highlighted in hotspots that are integral for conservation or expansion.

The following report presents the first outcome of this three-year-long project. The first part of this report describes the overall conceptual framework and methodology used for the ecosystem service quantification and valuation, as well as a compilation of the valuation results detailed in the following part. The second part presents an in-depth valuation of each of the selected forest ecosystem services.

The preparation of this study started in 2019 and was completed, in most part, during 2020. Many events occurred during this time in Lebanon that caused drastic changes to the social, financial, and economic situations in the country. To name a few, the devastating explosion that happened on 4 August 2020 in Beirut; the health, social and economic burden caused by the spread of COVID-19 pandemic that exacerbated an already difficult economic crisis in Lebanon; and the devaluation of the Lebanese Lira against USD. The influence of these changes on the values that are used in this report's valuation exercise were difficult to capture, and this study mostly reports values in 2019. However, a qualitative perspective on the expected changes on the value of each calculated service beyond 2019 are presented in their corresponding chapters.

2. Conceptual Framework for Forest Ecosystem Service Valuation

At a broader level, the current study draws on commonly-accepted international best practice in biodiversity and ecosystem valuation, and has a concern with ensuring that the study design is oriented towards maximizing policy and decision-making impact (Gómez-Baggethun and Barton, 2013; Berghöfer, et al., 2016). It adopts the definition of ecosystem services provided in the Millennium Ecosystem Assessment (MEA) (2005) as "the benefits people obtain from ecosystems". The MEA groups ecosystem services into four basic categories: Provisioning; regulating; cultural; and supporting services. It is generally agreed that the MEA framework presents an appropriate typology for describing, classifying, and valuing ecosystem functions, goods, and services in a clear and consistent manner (de Groot, Wilson and Boumans, 2002; Haines-Young and Potschin-Young, 2010).

This study explicitly seeks to consider all four categories of ecosystem services, as defined by the MEA. In so doing, it adopts the concept of Total Economic Value, which has now become the most commonly-used framework for identifying and categorizing environmental values (Pearce, 1992). The major innovation of TEV is to extend beyond the marketed and priced commodities to which economists had conventionally limited their analysis, and which largely excluded environmental costs and benefits. Instead, it incorporates the full gamut of economically important goods and services associated with different components of the natural environment and considers their complete range of characteristics as integrated systems – resource stocks, flows of services, and the attributes of the ecosystem as a whole (Barbier, 1994). Most ecosystem valuation frameworks use some variant of this basic TEV-MEA conceptual model (Pagiola, von Ritter and Bishop, 2004; Atkinson, Bateman and Mourato, 2012; Masiero, et al., 2019).

It is also now widely accepted that valuation studies are far more than just exercises to estimate the monetary worth of ecosystem services. They need to be designed, implemented, and delivered in such a way as to help decision-makers address and resolve real-world problems and challenges. The global initiative "The Economics of Ecosystems and Biodiversity" (TEEB) provides a particularly useful – and widely-applied – framework for linking economic valuation to the identification of policy instruments, to strengthen the conservation and sustainable use of natural resources in the real world (TEEB, 2008).

TEEB proposes a structured, three-tiered approach to ecosystem valuation, which the project adopts (TEEB, 2010). First, it is necessary to identify and assess the full range of ecosystem services affected and the implications for different groups in society. Second, the value of ecosystem services should be estimated and demonstrated, using appropriate methods. The third stage of TEEB, capturing the value of ecosystem services and seeking solutions, involves developing economically informed policy instruments. The current document reports on steps one and two of the TEEB framework. The subsequent PES work builds on the valuation study to address the third step.

There is now a consensus that the process of designing ecosystem valuation studies should not just seek to identify the 'best' methods to assess and value ecosystem services. Rather, it also needs to pay careful attention to framing the study context, purpose, and target audience, as well as to thinking through how the valuation results can be communicated effectively and used to improve decision-making in the real world (Gómez-Baggethun, et al., 2014; Berghöfer, et al., 2016). TEEB guidance recommends a series of generic steps for ecosystem valuation studies (TEEB - The Economics of Ecosystems and Biodiversity, 2013). These start with an initial scoping phase, followed by the main valuation exercise, which culminates in the communication of findings and recommendations to decision-makers. These considerations are now reflected in most international guidance. For example, the six-step protocol to guide valuation studies and assessments recently proposed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) recommends a similar process: Identify the purpose, scope the process, choose valuation methods, choose, and apply methods for assessing, integrating and bridging different valuation approaches, communicate, and review the process (IPBES, 2015; Pascual, et al., 2017).

3. General Methodology

This section develops the general methodology that governs the logic and flow of the valuation of forest ecosystem services, for all the services explored in this study's individual chapters. This methodology is adapted from a step-by-step approach proposed by Emerton (2014) that draws on a wealth of literature on ecosystem services valuation, documenting valuation approaches' fundamentals and evolution of best practices, as described in the section above. It is tailored to meet the objective of the current study, and to concretize the opportunities to use the results of the latter by the target audience, to accosting the challenges of forests' conservation and rehabilitation under the Lebanese context. **Figure 1** below illustrates the building blocks of this methodology.

Figure 1: *Methodology adapted from page 8 in Emerton (2014), "Guidelines for the Rapid Economic Valuation of Biodiversity and Ecosystem Services".*

This 10-step approach started by identifying forest conservation and restoration challenges, and existing forest protection mechanisms. It therefore championed as its core objective "making the case for forest conservation and resilience", by bringing new information about a range of forest ecosystem services that expose the benefits of sustainable forest management, and increased forest connectivity. This evidence quantifies the economic value of the identified services for numerous local and national beneficiaries, based on the geographical distribution of forest areas and the reach of the studied services. It thus constitutes a base for several optional models of PES schemes that intend to bridge the disparity in the economic burden undertaken by service providers and beneficiaries, and thus optimizing the balances towards forest conservation.

Following the first 4 steps that formulate this study's setting and purpose as described above, a valuation of the identified forest ecosystem services is then conducted. This valuation started in step 5 by confirming the validity of an existing or potential service in a certain location, through testing the reasoning for the existence of the supporting ecosystem structure, and biophysical environment. It then identified the most appropriate valuation methodologies that account for the category of the actual or potential service' beneficiaries, as shown in step 6. It concluded with data processing and calculation in step 7.

Working through steps 8 to 10 of this methodology, the economic values obtained in step 7 were analyzed and presented as 2019 equivalent values for each studied service. Their relevance to specific stakeholders was drawn up in each individual chapter. These targeted findings will be communicated to decision-makers to explore ways to employ them in practice, by investigating new economic instruments that operationalize them.

Ascertaining the spatial and biophysical scope, linkages, and attribution of services to a given forest ecosystem and beneficiary population, is an essential part of any ecosystem valuation exercise. In this study, mapping forest ecosystem functions is crucial for certain services to verify the existence of such actual or potential service, and has influenced the choice of services studied in this document. This verification step was completed using data generated through remote sensing and geographic information systems. The identification of 2019 forest areas and classes was done through remote sensing, by producing a forest area layer using Rapid Eye high resolution 2016 imagery, a combination of 2017 and 2018 high resolution World View 2 imagery for the section of Beirut and towards the North of Lebanon (all pre-mentioned imagery were provided through USAID support), Google Earth 2018 imagery, and by removing the 2019 forest fires previously mapped by Mitri, et al. (2020). Forest definition and forest classes are adopted from the CORINE landcover classification guidelines (European Environment Agency, 2019).

Steps 6, 7 and 8 express the value of forest ecosystem services in monetary and other terms. They draw on the standard 'toolbox' of ecosystem valuation methods that has come into common usage and is now widely accepted and applied. The question of how to place a monetary value on ecosystem services has long posed something of a challenge to economists. The easiest and most straightforward way to value goods and services, and the method used conventionally, is to look at their market price: What they cost to buy or are worth to sell? However, as many of the ecosystem services generated by forests have no market price (or are subject to prices which are highly distorted in regard to their real value), these techniques only have very limited application. A suite of methods has been developed over recent years with which to value ecosystem services that cannot be calculated accurately via the use of market prices (see, for example Pagiola, von Ritter and Bishop, 2004; Koetse, Brouwer and Van Beukering, 2015; Masiero, et al., 2019). These are now relatively well-known and commonly used by both economic and conservation planners. In addition to market prices, the ecosystem valuation 'toolbox' consists of five main categories of methods:

- Production function approaches: Attempt to relate changes in the output of a marketed good to a measurable change in the quality or quantity of ecosystem services, by establishing a biophysical or dose-response relationship between ecosystem quality, service provision, and related production.
- Surrogate market approaches: Look at the ways in which the value of ecosystem goods and services are reflected indirectly in people's expenditures, or in the prices of other related market goods and services.
- Cost-based approaches: Assess the market trade-offs or costs avoided maintaining ecosystems for their goods and services.
- Stated preference approaches: Ask consumers to state their preference directly (rather than looking at the way in which people reveal their preferences for ecosystem goods and services through market production and consumption, as in the approaches listed above) and;
- Benefit transfer approaches: Involve the transferral of value estimates from studies which have been carried out elsewhere to the service or site that is of current interest.

This valuation's data and applied methods are specific to each studied forest ecosystem service and detailed in the methodologies presented under the subsequent chapters.

Four forest ecosystem services were selected for valuation under step 5. The selection of these services accounted for 4 main factors:

- The service may present an opportunity to support the development of a policy instrument, such as the development of a reward system for the stewards of forests.
- The valuation of this service is perceived as highly important to guide decision-making, especially if this service accrue as a non-market benefit and its contribution to people's well-being is often concealed in public and private management decisions.
- The ability to apply the valuation exercise to a certain range of services in the time available to conduct the study.
- The lack of access to data due to COVID-19 restrictions, which prohibited the valuation of many highly important services.

This study acknowledges that many forest ecosystem services fulfill one or many of the above selection criteria. These services will be valued gradually and added as annexes to this report, once data and time permit.

Table 1 below highlights the selected services, the considerations that favored them, as well as the valuation methods applied to calculate them.

Table 1: Factors favoring the selection of the set of forest ecosystem services.

Forest Ecosystem Service	Ability to Prove Existence or Potentiality of Service under Lebanese Context	Availability of Plausible Economic Data & Methods for Valuation	Valuation Approach / Method	Strength of Relationship between Forest Ecosystem & Service Provision	Potential link to PES Approach	Potentiality for Service Enhancement through Forest Conservation & Resilience
Forest Tourism	Yes - Service concretized in Reserves	Yes	Market Price and simplified travel cost method	High	Yes	Yes – Ecotourism is further improved in protected areas – responsible tourism can be a channel for funding conservation and spreading environmental awareness
Carbon Sequestration and Storage	Yes – Plausible assumption of existence of service dependent on existence of forest ecosystem	Yes	Cost-based approach / Avoided Cost method	High	Yes	Yes – Forest conservation and expansion increase service and benefits to beneficiaries and service providers
Enhancement of Air Quality	Yes – Description detailed in relevant chapter	Yes – Methodology associating pollution with costs on health	Cost-based approach / Avoided Cost method	Medium to High	Yes	Yes – Healthier and larger forests contribute further to reducing air pollution and enhancing air quality
Forest Honey	Yes – Honey associated with existence of specific forest species	Yes – Direct market price	Market Price	High	Yes	Yes – Increasing areas of specific tree species can support increase in market share of niche product and provide opportunities for exportation

It is to note that although the previously mentioned four forest ecosystem services are presented separately in the following chapters, consideration is given to the need to avoid double counting.

The benefits from the four studied forest ecosystem services are also geographically summed to generate maps for these ecosystem services' hotspots aggregated by district. These maps are presented in the following section.

All the values that are presented in the following chapters are expressed in US Dollars (USD). They are meant to represent baseline values for the studied services in 2019[1]. The conversion rate from USD to LBP adopted in this study is 1507.5, since this report assumes that the fluctuations in the exchange rate took hold in 2020.

4. Summary of Valuation Results

The map presented in **Figure 2** highlights the hotspots of forest ecosystem services' values as demonstrated by the valuations conducted in this study. It allows for the comparison between the total value of 3 of the studied ecosystem services provided by the forests in each district. It excludes the value of the enhancement of air quality service since this value cannot be disaggregated by district (see chapter 4 for more details on the calculation of this service). Additionally, this map accounts for the value of Carbon sequestration and storage under scenario combination AC, which reflects the offset of CO_2 emissions from forest conversion to other land uses using a mix of renewable energy technology (further details on this scenario combination can be found in Chapter 3). Also, this hotspot map shows the number of services provided by the forests within each district, as well as the prevalence of each service as compared to the others. Although this map doesn't account for the total value of all possible forest services, it constitutes a tool that can be used as a starting point to recognize and bring forward forest areas of great importance within districts. Practitioners can build on this information to prioritize areas for conservation and to increase reforestation efforts and forest connectivity, thereby enhancing their resilience and protecting their services.

Table 2 summarizes the total values calculated for the 4 studied forest ecosystem services. In depth description of the calculation methods used to obtain these results can be found in the subsequent chapters.

[1] Exception to this claim is the value of Carbon sequestration and storage service. The calculated value of this service presented in the corresponding chapter refers to a cumulative incremental value of this service from a 2019 baseline value, covering the period 2020 to 2030.

Table 2: Economic value of the individual forest ecosystem services targeted in this study.

Forest Ecosystem Service	Economic Value (USD)
Forest Honey Provision	52,936,440
Forest Tourism	15,533,783
Forest Carbon Sequestration and Storage (under scenario-combination AC)	14,995,500
Forest Carbon Sequestration and Storage (under scenario-combination AD)	12,943,385
Enhancement of Air Quality	2,282,477

This study recognizes that the addressed services constitute but a part of the full range of forest ecosystem services that can support the development of potential PES scheme models, to name a few, pine nut provision; water quality and quantity regulation; slope stabilization; local climate and aesthetic value. Annexes to this report will be developed in the future to progressively cover these services.

Finally, ecosystem services valuations are based on the concept of a beneficiary's willingness to pay to receive a certain service, which makes this concept inherently subjective. This willingness to pay might be reflected in market transactions or interpreted through different behaviors. Therefore, certain valuation methods presented in the next chapters are easily relatable to actual markets. Others, however, can be perceived as serving to detect plausible hypotheses for the importance of forest ecosystem services.

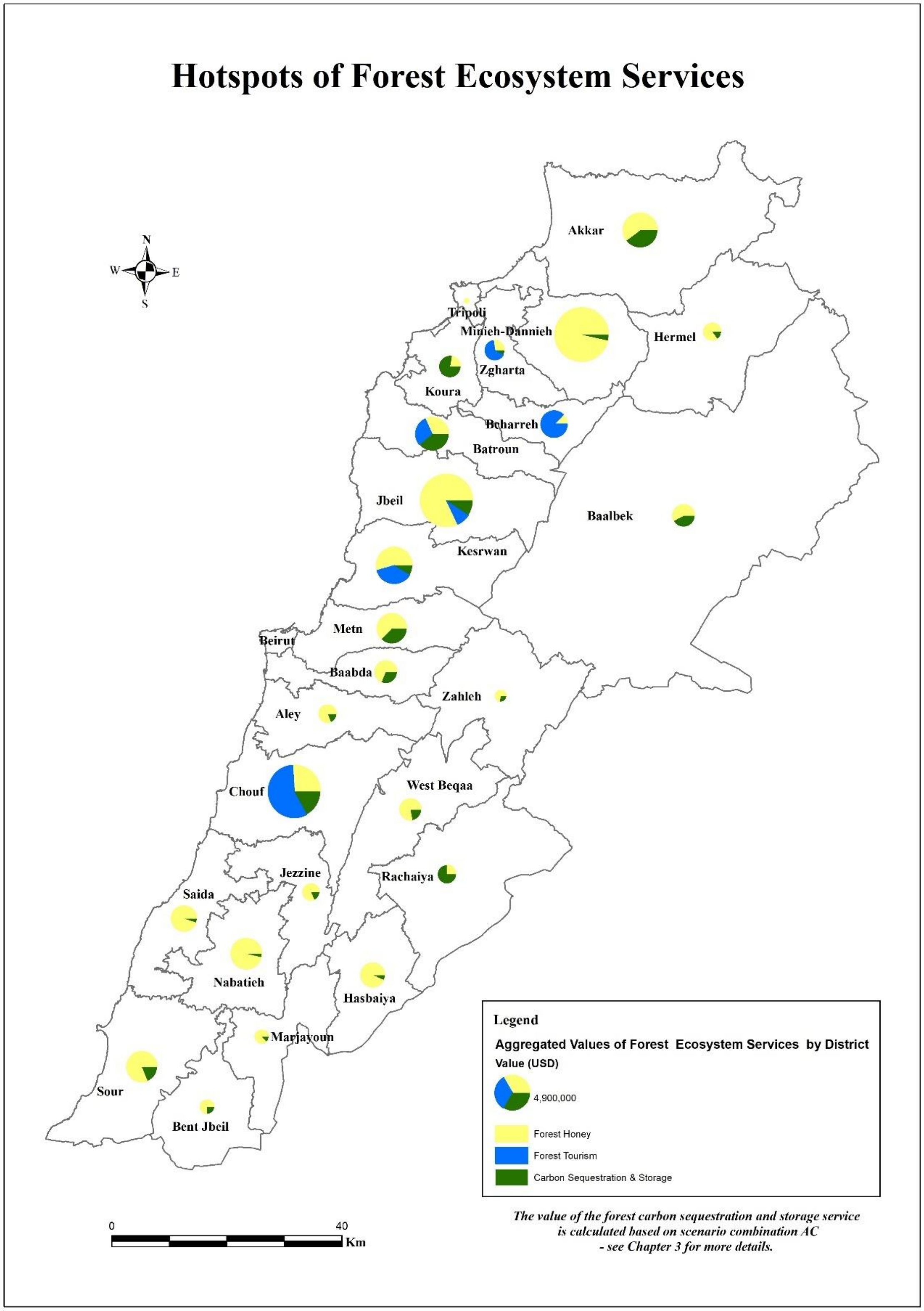

Figure 2: *Forest ecosystem services hotspots aggregated by district based on Carbon sequestration and storage service scenario combination AC.*

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II. Mapping and Valuation of forest ecosystem services: Honey provision, Tourism, Carbon sequestration and storage and Air quality enhancement

1. Forest Honey Provision

1.1. Introduction

Although not solely a forest product, honey is nonetheless an important one. For many beekeepers, forests provide important foraging grounds for their honeybees to collect food, as well as a convenient location to place their beehives (Bradbear, 2009). In turn, through the vital service of pollination, bees ensure the regeneration and conservation of forest biodiversity, therefore maintaining the forest ecosystem. Forests contain various types of species from trees to wildflowers and herbs that serve as food for the foraging honeybees (Bradbear, 2009). However, as the purpose of this study is to value forest ecosystem services in specific, it will only highlight the value of honey by bees that collect honeydew or a form of sugary liquid that is deposited by insects on trees. This distinguishes the forest honey value from that of the wildflower honey that can also be found outside forest areas. It is important to note that although forest areas are mixed ecosystems that contain more than just trees, this study focus on the honey directly linked to the existence of certain tree species to pinpoint the value added by forests or shrublands (Quercus spp.) that contain these species for honey production. Therefore, the term 'forest' honey will refer to that which is linked to the Oak, Cedar, Juniper and Fir species and is sold as such. This type of honey is typically rich in minerals and amino acids, possesses strong antibacterial properties and is therefore more expensive than other varieties (BLOMINVEST Bank, 2016). This honey is typically harvested between July and September. To obtain 'forest' honey, local beekeepers place their beehives in forest/shrubland areas in the spring and summer season to allow their honeybees to forage from the surrounding trees (ibid).

As a source of secondary income for almost 64% of local beekeepers, most of which are small scale producers with no more than 50 beehives, honey has the potential to provide additional livelihood support to vulnerable communities. Through several market channels, that include direct household sales, retail stores, and export markets, honey sales can generate revenue that would ripple along a value chain that includes but is not limited to beekeepers, distributers, exporters, retailers, and beekeeping service providers (LIVCD, 2017). With an export market that is largely untapped, and a local market that is mostly fed with imported honey products due to the shortage of local supply, the honey production value chain is one with expandable value (ibid). Considering the current economic crisis, the supplementary support provided by honey sales could offer increasingly needed financial support to struggling households.

Several studies have reported on the value of honey in Lebanon over the years. This value is often based on Ministry of Agriculture estimates of quantities of production multiplied by the market price of honey in that particular year. In 2005, the total value of honey was estimated at 14.37 million USD, this includes both forest, citrus and wildflower honey (Sattout, Talhouk and Kabbani, 2005). In 2013, the total value of honey production in Lebanon was estimated at 32 million USD. From this total amount, 23 million USD were considered as forest and shrubland honey (Hamade, 2016). In 2016, honey production rose to an estimated market value of 70 million USD (LIVCD, 2017). As years have passed, the market price, number of beekeepers and quantity of honey produced have varied.

Due to the important potential of honey as a source of livelihood support and a source of value generation and growth potential, the challenges that jeopardize this sector are important to overcome. As honeybees roam and forage for food 2 km away from their nesting area, thus creating a foraging field of approximately 12.6 km^2, reduced or fragmented forest areas can significantly affect the availability of food (Bradbear, 2009). In addition, the agricultural lands that may replace the forest areas use pesticides that are not only lethal for bees but also leave residues in honey that hinder local beekeepers from achieving safety standards and prohibit their access to international markets through exports (ACTED, 2018). Furthermore, as part of the mismanagement of forest areas, the haphazard use of harmful pesticides in Pine or Cedar forests to limit pest outbreaks could have an impact on bee mortality and quality of 'forest' honey (Stephan, 2021). Finally, as honey production fluctuates with the impacts of weather, more extreme weather conditions due to climate change could seriously hinder yield. This is especially true as many local beekeepers are amateurs and do not possess the technical skills or equipment to adapt (LIVCD, 2017).

In terms of policy, The Ministry of Agriculture's strategy (2015-2019) revolved around the need to increase the competitiveness of agricultural production by increasing productivity, while ensuring conformity with international sanitary and phytosanitary requirements, and thus facilitating access to international markets (ACTED, 2018). Through this strategy, that covers honey production among others, the MoA aimed at improving the good governance and sustainable use of natural resources as well as responding to the impacts of climate change. What this strategy thereby highlights is the importance of forest conservation for the continuity and expansion of the honey subsector.

With 10,057 registered beekeepers in Lebanon, according to data records obtained from the MoA for the year 2017 (Moghrabi, 2020), the value of this forest ecosystem service highlights a pathway for the sustenance and enhancement of a value generating sector that has the capacity to mitigate poverty. Conserving existing forests and reforesting areas with the honeydew producing species could help protecting the livelihoods of forest-dependent beekeepers and pave opportunities for financially struggling communities in a subsector with great potential.

1.2. Methodology

The average value of 'forest' honey that is presented in this chapter specifically corresponds to honey that is directly linked to forest areas or Fir, Cedar, Oak and Juniper trees. It is calculated by multiplying the average gross market price by an estimation of average yield of 'forest' honey production in Lebanon. Although beehives can be used for other purposes than honey production, including queen production or products like propolis, pollen, royal jelly and so on; this study assumes that all considered beekeepers are actively producing honey from their existing beehives. The equation used for the calculation of the total value of 'forest' honey in Lebanon in 2019 is presented in **Figure 3**.

Figure 3: *Formula used for total value of forest honey calculation.*

Average forest honey production

To differentiate the quantity of 'forest' honey produced from that of overall honey in Lebanon, this quantity is calculated using the yield from beehives that are in areas that contain the relevant tree species. To identify these areas, the districts map of Lebanon is overlayed with species suitability maps that were developed by Stephan et al. (2020) and that indicate regions that have high probability for the survival of the following species: *Cedrus libani, Juniperus excelsa, Juniperus drupacea, Abies cilicica, Quercus calliprinos, Quercus infectoria, Quercus brantii-look, Quercus cerris, Quercus cedrorum, Quercus kotschyna and Quercus ithaburensus*. The suitability maps were generated based on suitable environmental and biophysical conditions for the indicated species. In each of the selected districts, a certain percentage of 'forest' honey production is assigned based on personal communication with Stephan (2021) on the available tree species in each area, the existence in these areas of other types of honey sources like orange blossoms, as well as the climatic factors in each region that allow the production of honeydew. The remaining portions of the total honey production quantities are assumed to be either wildflower or citrus honey. The distribution, which amounts to approximately 60% of total honey production yield, is listed in **Table 3** below.

Table 3: Assigned percentage of 'forest' honey production yield per district – personal communication with Stephan (2021).

District	Assigned Percentage of 'Forest' Honey Production yield
Zahleh	20%
Rachaiya	20%
West Beqaa	80%
Baalbek	20%
Hermel	80%
Jbeil	90%
Metn	80%
Kesrwan	80%
Aley	50%
Chouf	50%
Baabda	80%
Akkar	50%
Tripoli	20%
Zgharta	50%
Koura	50%
Bcharreh	80%
Batroun	90%

District	Assigned Percentage of 'Forest' Honey Production yield
Minieh - Dannieh	80%
Nabatieh	80%
Bent Jbeil	20%
Marjayoun	20%
Hasbaiya	80%
Jezzine	50%
Sour	50%
Saida	50%

Although the overall number of beehives in Lebanon has witnessed a steady increase over the years as shown in **Figure 4**, it should be noted that the reported numbers are only based on registered beekeepers and that the actual total number might be higher with unregistered beehives and additional entries into the sector. This however does not necessarily indicate an increase in honey production yield, due to climate stresses, increasing use of pesticides and saturation of certain foraging areas due to the high quantity of beehives within them (Stephan, 2021).

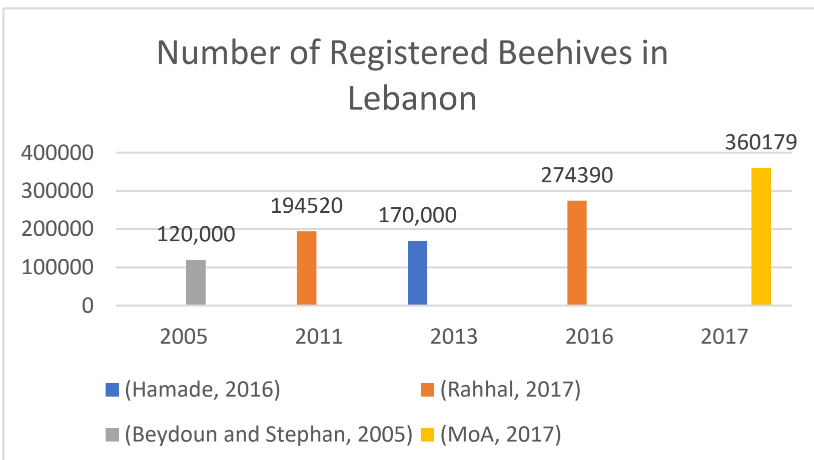

Figure 4: *Number of registered beehives across several years as reported by various sources.*

Most beekeepers in Lebanon are small-scale beekeepers with relatively small hives. The average yield of smaller scale hives is 7-10 kg (Hamade, 2016). According to Mr. Ramzi Al Moghrabi, Head of the Beekeeping Department at the Ministry of Agriculture, 'forest' honey production in Lebanon ranges between 4 kg/hive on a bad year to an average of 13 kg/hive on a good year (Moghrabi, 2020). Although production can sometimes reach 22 kg per hive on an excellent year, the average production of beehives in Lebanon is averaged at *8 kg per hive* in this study.

It is important to note that the quantity of honey produced in Lebanon varies from year to year and witness ups and downs that are related to climate conditions, pest invasions and so on. **Figure 5** provides a glimpse of total honey production in Lebanon as reported across the years through various sources; in the years without official sources, it is presented through FAO statistics estimates. In this study, the quantity of honey produced is based on the number of beehives as registered in 2017, to be able to spatially distribute the value per district. In 2019, the year in which most recent honey production data exists, official data reported a total production of 1,433 tonnes. According to the assumptions made in this study, 60% of the honey yield in 2019 can be attributed to ‘forest’ honey. However, for the purpose of highlighting an average value of ‘forest’ honey, and to be able to distribute the value spatially across Lebanon, this study relies on an assumption of production per beehive and on the number of beehives per district as reported by MoA (2017).

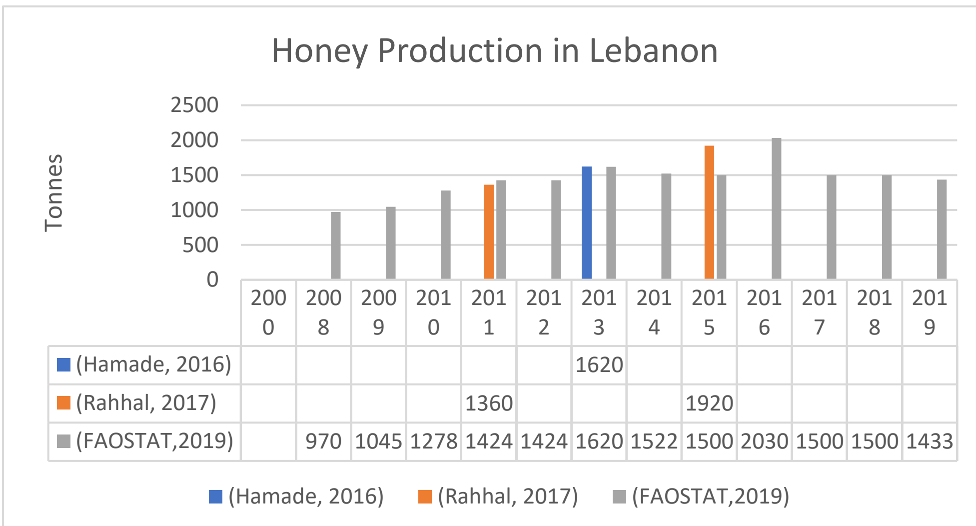

Figure 5: *Total honey production per year in Lebanon, as reported by several sources.*

Based on the percentages allocated to each honey district and the assumption on productivity per hive, the calculated total ‘forest’ honey production is estimated to be 1,765.544 tonnes. This is a yearly production estimate based on the MoA data from 2017, which is the latest official count of registered beehives to date.

Average Gross market price of honey

The market price of honey varies depending on the type of honey produced, whether wildflower, forest or citrus. However, the overall price range of honey remains somewhat stable despite high local demand as the low supply is compensated for by imports. Various sources have reported the price of ‘forest’ honey, with some placing it between 25-30$ (Hamade, 2016) and others between 30-50$ (BLOMINVEST Bank, 2016) with Oak honey usually at the lower end of that range and Cedar and Juniper honey at the higher end due to their rarity. For the purpose of this study and through an overview of available data and discussion with honey production businesses (both branded and unbranded), an average gross market price of 30$, specifically for honey associated with the four tree species (Oak spp, Cedar, Fir and Juniper), is selected. This covers a range of prices that include export prices of honey, averaged at 15$ (LIVCD, 2017), as well as the local prices of branded and unbranded 'forest' honey which range up to 45$ in 2019 (Stephan, 2021). The selected gross market price is used in this study since it considers the value accumulated across the whole value chain from the sale of 'forest' honey.

1.3.Results and Discussion

Using the abovementioned variables and assumptions, the total value of 'forest' honey in Lebanon is estimated to be 52,936,440 $ per year, based on the spatially distributed number of beehives and the market price in 2019.

It is important to note that many beekeepers across Lebanon transport their beehives during the summer and winter seasons to benefit from the various foraging grounds and to ensure bee population survival from the harsh seasonal weather. The calculations conducted in this study do not consider the multiple harvests that beekeepers conduct throughout the year due to the lack of data. Nonetheless, this transport of beehives could reveal a greater total value of 'forest' honey in Lebanon if beekeepers were to, for example, spend the winter season in Oak species foraging grounds, and the summer season in higher elevation sites with Cedar and Fir species; therefore, benefiting from two harvests instead of one. In **Table 4** , the total value of 'forest' honey in USD is listed according to its spatial allocation by district and with the corresponding estimated production yield in kg**.**

Table 4: Calculated total forest honey production in kg and its corresponding estimated potential value in USD per district in Lebanon.

District	Estimated total forest honey production (kg)	Estimated Value (USD)
Zahleh	11288	$ 338,640.00
Rachaiya	11040	$ 331,200.00
West Beqaa	48000	$ 1,440,000.00
Baalbek	37088	$ 1,112,640.00
Hermel	33920	$ 1,017,600.00
Jbeil	296944	$ 8,908,320.00
Metn	72816	$ 2,184,480.00
Kesrwan	94288	$ 2,828,640.00
Aley	32936	$ 988,200.00
Chouf	93736	$ 2,812,080.00
Baabda	43848	$ 1,315,440.00
Akkar	94944	$ 2,848,320.00
Tripoli	2568	$ 77,040.00
Zgharta	13608	$ 408,240.00
Koura	13384	$ 401,520.00
Bcharreh	11520	$ 345,600.00

District	Estimated total forest honey production (kg)	Estimated Value (USD)
Batroun	45696	$ 1,370,880.00
Minieh-Dannieh	367648	$ 11,029,440.00
Nabatieh	119040	$ 3,571,200.00
Bent Jbeil	18136	$ 544,080.00
Marjayoun	20776	$ 623,280.00
Hasbaiya	70824	$ 2,124,720.00
Jezzine	29016	$ 870,480.00
Sour	100176	$ 3,005,280.00
Saida	81304	$ 2,439,120.00

In the map presented in **Figure 6**, the ‘forest’ honey values are presented proportionally across the districts. This map demonstrates key areas in which ‘forest’ honey presents a high value. The map also highlights areas in which the Cedar, Oak, Fir and Juniper species can potentially exist, thereby pointing to a potential diversity of tree species on which beekeepers can rely for the diversification of production. As these areas are suitable for the existence of these key tree species, they present an opportunity for the beekeepers in these areas to benefit from them as foraging grounds. Therefore, conservation and reforestation projects can be directed towards these areas to capitalize on this valuable prospect.

In the context of the Lebanese economic crisis and the devaluation of the local currency, the value of ‘forest’ honey based on 2019 value has obviously dropped in local markets when compared to the new lira to dollar value. Nonetheless, ‘forest’ honey sales still provide an income addition when sold locally at higher conversion rate prices and have the potential to generate fresh dollar revenues when sold internationally. The export market for the ‘forest’ honey product is still largely untapped and can be enhanced with further marketing, and quality assurances. More importantly, the link that exists between the tree species/forest areas and the honey value is unchanged, thereby demonstrating the need to conserve and expand these areas. The values presented in this study highlight the need to integrate this value in land management decisions to support the continuity of this service.

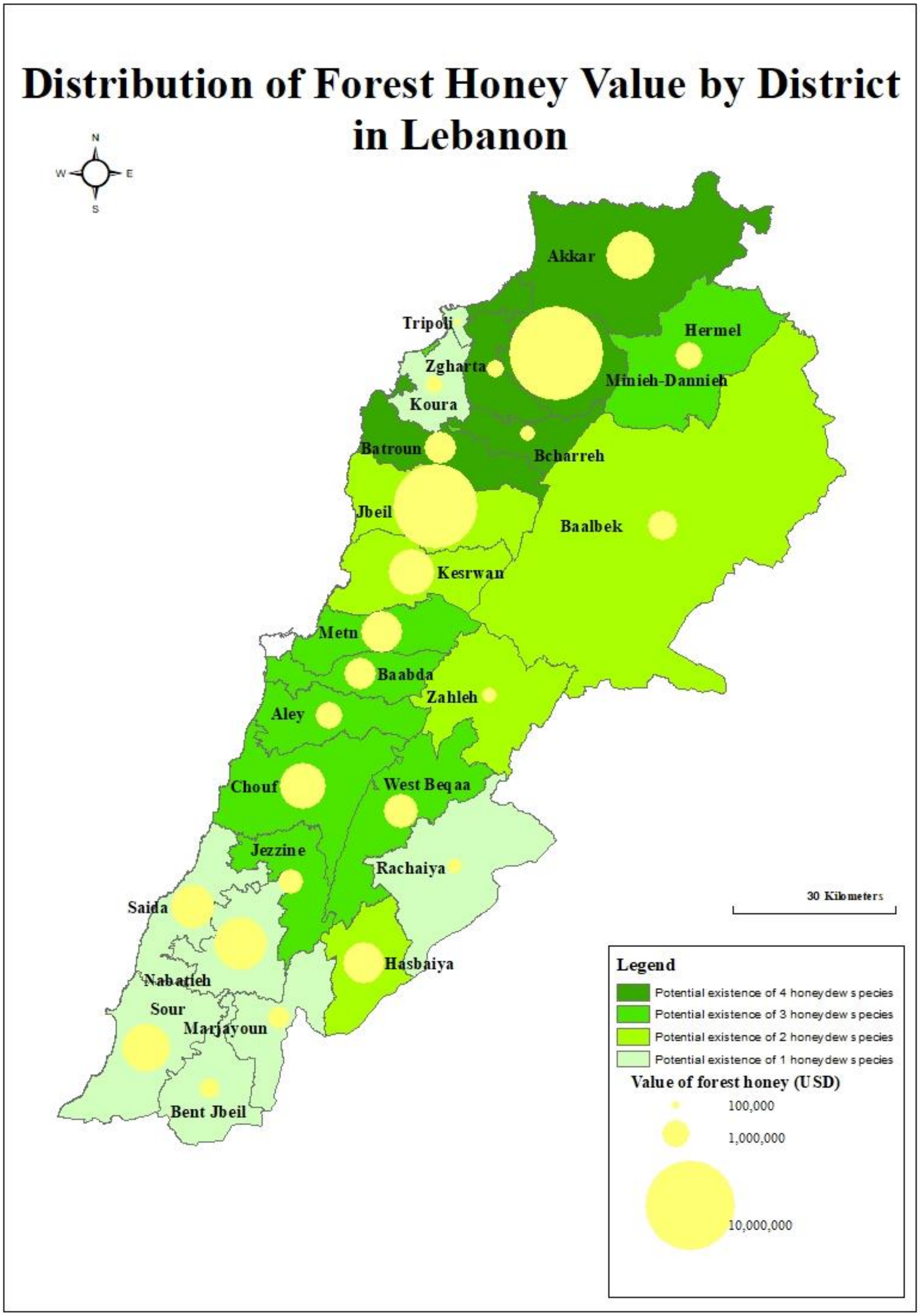

Figure 6: *Distribution of calculated forest honey values in Lebanon by district.*

1.4. Conclusion

This chapter aimed to estimate the value of 'forest' honey production in Lebanon, thereby highlighting the ecosystem service provided by forests for honey provision. It only took into consideration honeydew honey, that is predominately foraged for in forests or shrublands containing Oak species and is sold as such. Considering various assumptions, this chapter estimated the average value of forest honey in Lebanon to be 52,936,440 $, based on 2019 value.

As the majority of honey sales in Lebanon occur through direct personal household sales, beekeepers and their respective households pocket a large portion of the revenue. For larger scale beekeepers, this value ripples to various beneficiaries along the honey value chain.

Despite the Lebanese economic crisis and the devaluation of the local currency, the revenues generated through local sales at higher conversion rates and the potential for fresh dollar revenues through export markets maintain the ability of this service to provide valuable livelihood support to vulnerable communities. In this chapter, the value of 'forest' honey provision in Lebanon was also disaggregated by district and overlayed with areas in which certain tree species are potentially available, thereby highlighting possible forest honey product diversification. The spatially distributed values point to key areas in which this forest service is relied on and benefited from. Essentially, they validate the need to maintain these livelihood supporting values through conservation and reforestation. Integrating these values and their importance to beneficiaries is therefore necessary in land use management decisions. This would also provide the opportunity to restore full value to the sector should the market eventually regulate. With the increasing challenges faced by forests due to climate change, fires, and deforestation, it is crucial to consider the significant value of forest honey in Lebanon in policy, economic and land management plans so that forests continue to be able to provide this service.

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2. Forest Tourism

2.1. Introduction

As a space for relaxation, discovery, adventure, education, and even spiritual connection, forests provide a valuable service of forest tourism. According to the MEA, this is a cultural service that enriches the lives of the beneficiaries and generates considerable income and employment to local communities (Millennium Ecosystem Assessment, 2005). Forest-based tourism depends on intact natural resources to generate revenue and is therefore an important tool for conservation and sustainable development (Naidoo and Adamowicz, 2005).

Due to their distinguished wealth in biodiversity compared to other countries in the Arab region, richness in fauna and flora, and the moderate Mediterranean climate, Lebanon's forests are an attractive tourism destination, in their own right, and as side attractions on larger tours in the region. The cultural services provided by Lebanese forests are not limited to non-consumptive use values such as tourism, recreation, and education, but also possess passive use values due to the patriotic and religious value of the Lebanese Cedar tree or *Cedrus libani* (Sattout,Talhouk and Caligari, 2007). It is also well-recognized that nature tourism provides considerable psychological benefits, helping to sustain and improve people's physical and mental wellbeing, decrease stress, and promote positive social interactions (Buckley, et al., 2019).

Over the years, and especially in years of political stability, nature-based tourism in Lebanon, within nature reserves and protected areas, has been increasing (Ministry of Environment/UNDP, 2011). The benefits of forest tourism are expected to ripple, not only locally but also throughout the national economy, as Lebanon's tourism sector is projected to provide a 23.7% total contribution to the GDP by 2028 (World Travel and Tourism Council, 2018). Although Lebanon's forest-based tourism cannot be limited to certain regions in specific, it can most accurately be portrayed in nature reserves and protected forests. The reason is twofold: the record keeping adopted by nature reserve managements, and the facilitated access to recreational and cultural activities within these areas.

Lebanon has eighteen Nature Reserves (NA), some of which are marine, and most are forests. These reserves encompass rich biological diversity with a wide variety of mammals, reptiles, birds and endemic fauna and flora. They are also aesthetically pleasing landscapes that create opportunity for outdoor activities. They were established and are managed under the supervision of the Ministry of Environment and contain most of the remaining symbolically significant Cedar forests of Lebanon. Among them, those that are forests include: Horsh Ehden Nature Reserve, Tannourine Cedar Forest Nature Reserve, Shnaneer Nature Reserve, Bentael Nature Reserve, Al Yammouneh Nature Reserve, Shouf Cedar Nature Reserve, Houjeir Valley Nature Reserve, Karem Shobat Nature Reserve, Nature Reserves of Ramiyah, Kafra, Beit Leef and Dibil and Jaj Cedar Nature Reserve. In addition, there are several protected area (PA) forests such as Cedar of God Forest in Bcharreh and biosphere reserves like Jabal Moussa Biosphere Reserve (Samaha, 2020).

These nature reserves and protected areas employ individuals from the local community and create space for ecotourism guides and local businesses to engage in activities within their grounds. In addition, and due to the emblematic nature of the Cedar tree and Lebanese forests, many souvenir shops and restaurants have capitalized on this cultural significance and based their establishments within proximity of nature reserves/protected forest areas.

This chapter aims to value this contribution to the local economy by estimating the value generated by forest nature reserves/ protected forest area visitors. The value of forest tourism, demonstrated through the value generated, will thereby present an estimation of how much the existence and protection of these forests has the potential of creating local wealth. Some studies have suggested that through sustainable forest management practices and community engagement policies, forest-based tourism even presents an opportunity for poverty alleviation (Schreckenberg and Luttrell, 2009). In the current economic crisis, supporting and enhancing forest-based tourism could present means of uplifting local livelihoods while also conserving valuable cultural and natural national assets.

The value of forest tourism in Lebanon therefore also highlights the importance and potential that conservationist environmental policies can hold for forest areas across Lebanon. With targeted policies, investments and effort, cultural services from forests can be benefitted from throughout Lebanon while also serving the conservation of forest areas. In addition, the value of forest tourism points to the potential of reforestation and the expansion of forest areas to bring about opportunities for ecotourism and related expenditures that in turn generate income and support the livelihoods of communities.

Considering the economic, social, and environmental benefits of forest tourism, the threats faced by existing forests cannot be ignored (Ministry of Environment/UNDP, 2011). As temperatures rise and bring about longer periods of drought, species migration, pest infestations and devastating fire seasons, the enhancement and restoration of forest cover across Lebanon is integral to maintaining forest tourism in the long term (Ministry of Environment/UNDP, 2011). This is necessary not only to ensure the continuity of the forests themselves but also the livelihoods that are dependent on them.

The following study undertakes a rapid assessment of the economic value of a cultural ecosystem service provided by forest nature reserves and protected forest areas across Lebanon. It does so by conducting interviews with several nature reserve managers, and a nationwide online survey of nature reserve/ protected areas visitor expenditure.

2.2. Overview of Forest Tourism Values in Lebanon

Not many studies have valuated the cultural services provided by forests in Lebanon. Providing an overarching perspective on rural tourism, that includes nature-based tourism, one study analyzed domestic visitors' needs, preferences, and expectations in Lebanon (Ghadban, et al., 2017). It did so by assuming that rural tourism revenues provide great contributions to local economies and can therefore uplift communities. Interestingly, it found that most visitors are motivated to engage in rural tourism to relax and escape to nature; a trend that was also observed under COVID-19 restrictions. Although the aforementioned study conducted a Willingness to Pay (WTP), it was mostly centered on visitor preferences for a rural tourism trip (Ghadban, et al., 2017).

One study on Mediterranean forests valued forest tourism in Lebanon through the net revenue generated by environmental clubs that organize recreational activities in Lebanese forests, including the donations collected at the entrance of the three forest/biosphere reserves and protected areas of Shouf Biosphere Reserve, Cedar of God Forest in Bcharreh and Horsh Ehden Nature Reserve (Sattout, Talhouk and Kabbani, 2005).

On a more targeted scale, the Shouf Biosphere Reserve conducted an ecosystem services valuation study in which tourism services within the SBR region were valued (Ecodit, 2015). This included visitor entrance fees, lodging, the restaurants run by the reserve and the other restaurants within the biosphere. The total forest tourism within the biosphere reserve was valued as 712,500$, based on a range of 60,000-70,000 visitors per year. It also valued the symbolic value provided by the Cedar trees that exist in the reserve through the several emblematic loans and Cedar adoption initiatives that SBR has launched (Ecodit, 2015).

Another area specific study was conducted by the Jabal Moussa Biosphere Reserve, in which the benefit transfer method was used with an average of 52$ spending per person, based on a previous study conducted by SBR, to obtain a value of ecotourism for its biosphere reserve (Karam, 2016). Finally, in the Cedar of God Forest in Bcharreh, a WTP survey was conducted in 1996 through which an average of 7.5 $/visit was revealed by participants as to how much they are willing to pay to conserve the Cedar Forest and similar forests in Lebanon as well (Darwish, et al., 1996 cited in Sattout, Talhouk, and Kabbani, 2005).

This study focuses on forest tourism in specific. In other words, recreational and cultural activities that would have not existed in the region had the forest not existed. It calculates the monetary value generated by visitors of forest nature reserves and protected forests across Lebanon, both within the reserve and in the surrounding area. It assumes that by visiting the managed forest, the visitors contribute to the local economy by generating income for the nature reserve and thereby its staff and workers, in addition to the restaurants, bars, souvenir shops in the town that contains the forest. The value generated is an average estimation of total value of forest tourism across Lebanon and per nature reserve/protected area.

2.3. Methodology and Results

For this valuation, a combination of market prices and a simplified travel cost method is used to assess the ecosystem services related to recreation in forests across Lebanon. In addition to obtaining data directly from reserve managers/protected areas through a questionnaire (Annex 1), an online survey was developed in September 2020 to collect empirical data on the expenditure of visitors and visitation behavior. This survey was undertaken through a google form questionnaire that was distributed virtually through social media (Annex 2). Respondents were randomly selected but had to have visited a forest reserve/protected area in Lebanon between 2016 and 2019. The year 2019 was chosen as the last year since prices in 2020 are distorted by the extreme inflation occurring in Lebanon and would therefore not reflect an accurate valuation of the income generated. The questionnaire was divided into three sections. The first section contained questions about the respondents' visit to the nature reserve/protected area starting with details about their overall trip (e.g., duration and when they visited, what activities they participated in, both in the nature reserve/protected area and in the surrounding area, and modes of transport). The second section asked the respondent to give a close estimation of how much they spent on different activities both within the reserve/protected area and in the surrounding region. Respondents were provided with monetary ranges to select from to make the recollection of expenditures simpler. In the last section, the respondents were asked a few demographic questions to complete a brief profile (see Annex I for survey questionnaire).

A select number of nature reserves/protected areas are used in this study due to their record keeping, and the facilitated access to recreational and cultural activities within their areas. They include the following: Bentael Nature Reserve, Horsh Ehden Nature Reserve, Tannourine Cedar Nature Reserve, Cedars of God Forest Bcharreh, Jabal Moussa Biosphere reserve and Shouf Cedar Nature Reserve. Since some nature reserves and protected forests are excluded, the actual total value generated by forest tourism in Lebanon is expected to be higher.

The forest tourism survey received 227 responses that were distributed across seven NR/PA. The survey included all official forest nature reserves and protected areas in Lebanon[2]. Reserves that received two or less responses were removed from the calculations. The Jaj Cedar Nature Reserve was removed from this calculation due to the lack of record keeping, and therefore the number of visitors per year is not available. The average response rate per NR/PA is 31 responses. They are distributed somewhat evenly as demonstrated in **Figure 7** below.

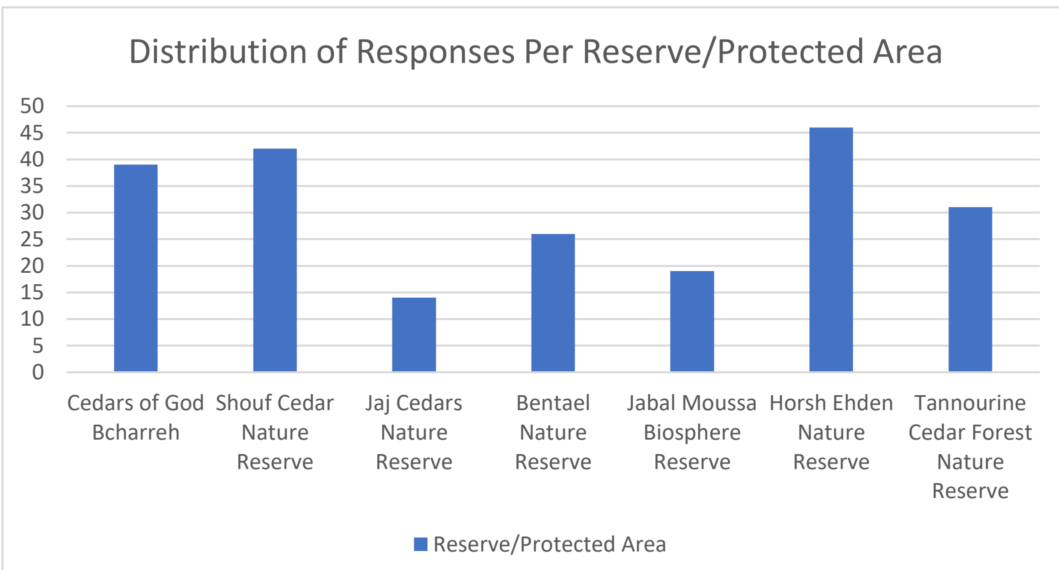

Figure 7: *Distribution of forest tourism survey responses by nature reserves in Lebanon*

Most of the responses were received for visits that occurred in 2019 as presented in **Figure 8**. As expected, the least responses were received for 2016 since it was the least recent.

[2] Cedars of God Forest (Bcharreh), Horsh Ehden Nature Reserve, Bentael Nature Reserve, Tannourine Cedar Forest Nature Reserve, Jaj Cedars Nature Reserve, Shouf Cedars Nature Reserve, Yammouneh Nature Reserve, Jabal Moussa Biosphere Reserve, Shnaneer Nature Reserve, Houjeir Valley Nature Reserve, Nature Reserves of Ramiyah, Kafra, Beit Leef and Dibik.

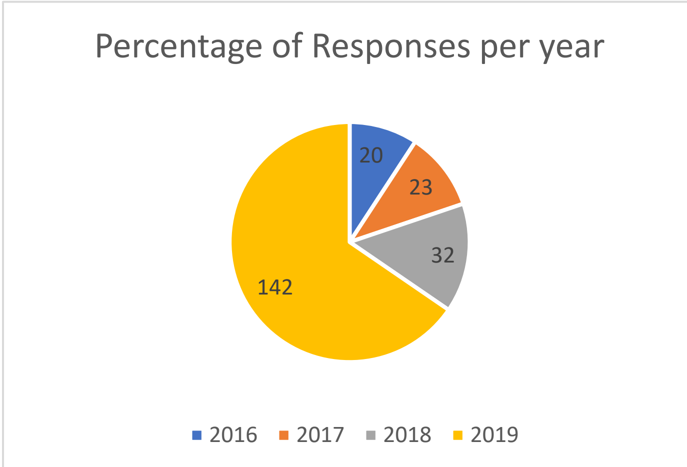

Figure 8: Percentage of responses per year in the forest tourism survey.

Most visitors were in groups of 1 to 12 people. Most groups were made of family and friends and visited the nature reserve by rental car or owned vehicle.

As presented in **Figure 9** below, 91% of the visitors listed the forest nature reserve/protected area as the primary destination of their trip.

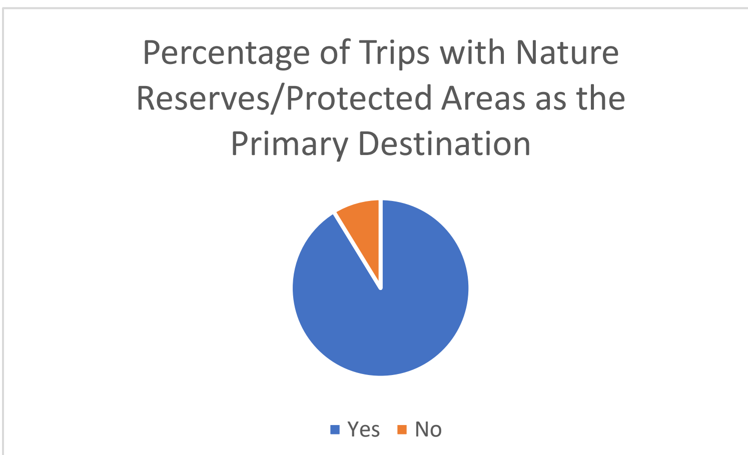

Figure 9: Percentage of forest tourism survey responses that indicated the forest nature reserve/protected area as the primary destination of their trip.

It is important to note that as with most online surveys, and especially due to the constrictions witnessed in Lebanon in the past year, several assumptions are made. The survey was distributed in September 2020, yet the values requested ranged from 2016 to 2019, and relied on respondents having accurate memories of their visits. In addition, since expenditure ranges were provided in the survey instead of exact values, the average local value generated lies within a scale of values and could therefore actually be slightly higher or lower. Finally, the survey asked respondents about their expenditures in the NR/PA and the surrounding area, whereby the surrounding is defined as the town containing the protected forest/nature reserve. This therefore excludes the value generated in neighboring towns that could also be benefiting from visitors of the nature reserve / protected area. The average total value generated does not account for the variation in prices across towns, and the variety in available activities across regions. For example, Horsh Ehden Nature Reserve is surrounded by a lot of restaurants, bars, and souvenir shops, while Bentael Nature Reserve is not, and therefore there is more opportunity for visitors to generate value in Ehden than in Bentael. Finally, the expenditure is presumed to be per individual visitor based on the survey results, but it could in some cases reflect group expenditures.

2.3.1. Total value of forest tourism in Lebanon

To estimate an average local value generated per visitor of the NR/PA the following equation, exhibited in **Figure 10** , is utilized.

Figure 10: *Formula used to calculate the total value of forest tourism in Lebanon.*

whereby the average expenditure per visitor is calculated as the sum of the weighted means of each expenditure category.

The weights are assigned based on the number of responses received for each range of expenditure and include cases of 0 spending. In other words, the number of responses to each range of expenditure within each of the categories listed below determined the importance of the expenditure category within the overall average. The means of each category are then summed to generate the total average expenditure per visitor. The average expenditure on entrance fees per person is calculated based on the range of entrance fees as reported by the NR/PA managers in the questionnaire. The entrance fee ranges from 3000 to 8000 LBP, or 2 to 5.3 USD (1 USD = 1500 LBP). In **Table 5**, the calculated weighted averages are listed alongside their corresponding categories and summed to generate a total average expenditure per visitor. It is accordingly assumed that NR/PA visitors spend an estimated 67.85$ per visitor per NR/PA.

Table 5: Results of forest tourism survey on expenditure calculated as weighted averages per category of spending.

Category of Expenditure	Weighted Average (USD)
Restaurants or bars within the surrounding area	19
Grocery store/ supermarket	8.6
Hotel or accommodation	12.1
Camping fees/equipment	4.3
Rental of recreation equipment (e.g snowshoes, bicycles, ATV)	5.3
Guide and tour fees	6.5
Souvenir, clothes, supplies and other retail	8.4
Average entrance fee expenditure	3.65

Total Average expenditure per visitor	67.85

The average number of NR/PA visitors per year is calculated as a weighted average to all the forest nature reserves as reported by their managers. An ascending weight of 10% is given to each year to account for the increasing trend in NR/PA visitors. Whereby the number of visitors in 2016 are given a weight of 10% of the total number of visitors to the NR/PA, 2017 with 20%, 2018 with 30% and 2019 with 40%. **Table 6** shows the number of visitors to each NR/PA as provided by nature reserve / protected area managers.

Table 6: Number of visitors to forest nature reserves/protected areas as reported by their managers based on a distributed survey.

Number of Visitors / Year	2016	2017	2018	2019
Tannourine Cedar Forest Nature Reserve	14,703	15,860	16,953	21,077
Horsh Ehden Nature Reserve	8,000	10,000	12,000	18,000
Shouf Cedar Nature Reserve	85,966	91,020	105,173	118,083
Bentael Nature Reserve	2,150	2,459	1,800	3,550
Cedars of God Bcharreh	58,605	59,244	66,078	62,648
Jabal Mousa Biosphere Reserve	18,247	20,182	28,647	29,711

Hence, the average number of visitors to all forest NR/PA's in Lebanon combined is estimated to be 228,943 visitors /year.

Therefore, the formula in

Figure **10** is used, considering the aforementioned variables, to calculate the total yearly value of forest tourism generated in Lebanon. As shown in **Figure 11**, an estimated value of 15,533,783$ is generated by the selected NR/PA across Lebanon per year, both within forest nature reserve/protected areas and their surrounding areas (Values are in 2019 USD).

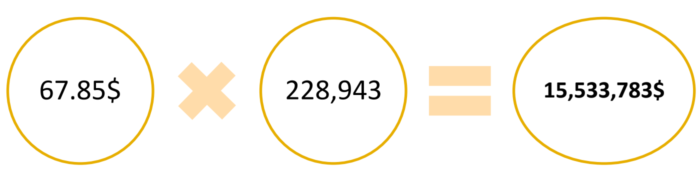

Figure 11: *Formula used to calculate the total value of forest tourism in Lebanon.*

2.3.2. Distribution of expenditures across Nature Reserves/Protected Areas

To visualize the value generated by forest tourism within and around each of the previously mentioned forest NR/PA's individually, an average expenditure value is also generated for each. For each of the six forest nature reserves/protected areas, a weighted mean of each expenditure category is calculated using the responses to each expenditure range listed in the distributed online survey. The sum of the weighted means of each expenditure category is calculated to estimate an average total expenditure per visitor. This average is then multiplied by the average number of visitors provided by the targeted nature reserve/protected area managers.

In **Figure 12**, the number of responses that are used to weight the means of the expenditure categories are presented as percentages of the total responses received for each forest NR/PA. Although they provide only a glimpse of the expenditure habits of forest NR/PA visitors, this method is useful to understand the behavior and interests of visitors and encourage the development of these value generating activities.

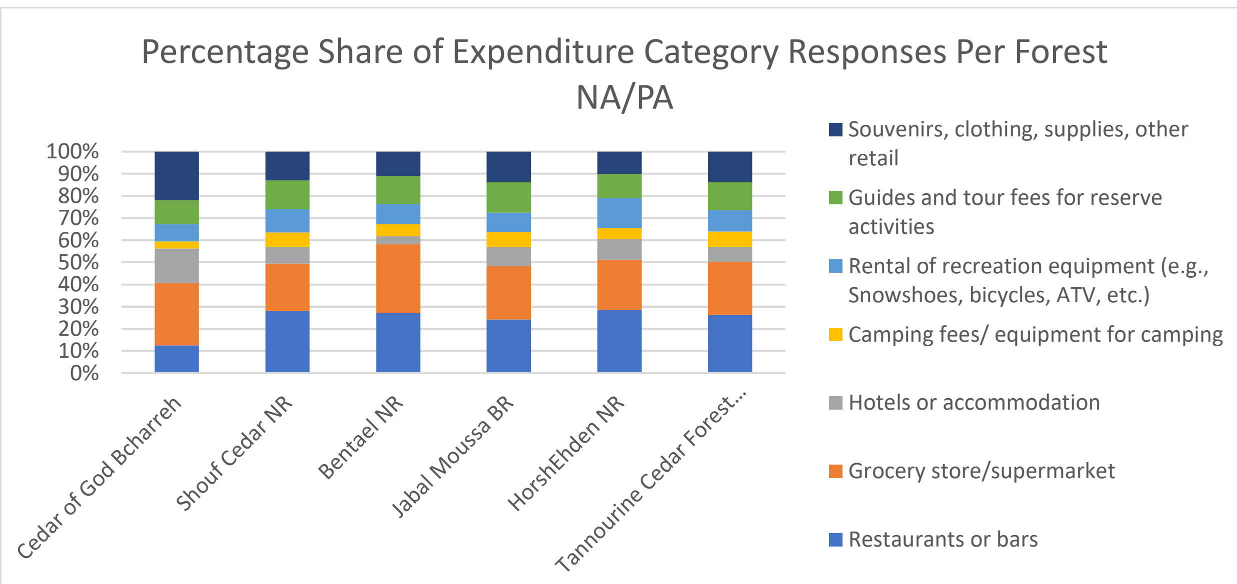

Figure 12: *Percentage of response share to each expenditure category in distributed forest tourism survey, divided per forest nature reserve/protected area.*

The calculated value generated by forest tourism within each of the selected forest NR/PA is presented in **Figure 13**. The generated map also includes the forest connectivity corridor developed under a collaboration between the USAID/LRI project and the UNDP/SLMQ project in 2015. The developed forest connectivity corridor is a 500 m wide potential strip that is designed as a strategy to expand the existing forest cover by linking existing forests, especially important conservation spots such as Horsh Ehden Nature Reserve and Yammouneh Nature Reserve in the northern part of Lebanon and expands across the high mountains of Mount Lebanon to reach forests in West Beqaa and Rachaiya districts. This corridor is added to the map to project forest locations (that exist or might be planted) that might provide potential future value from forest tourism for their surrounding communities, if they are managed and protected in a similar manner as the studied NR/PA.

It is important to note that the calculated forest tourism values presented in this study offer only a glimpse of the actual forest tourism value generated in Lebanon; in reality, the value might be much greater. On one side, the study does not take in consideration events and various free activities and services that are offered in these managed areas in addition to the paid services. On the other, as it only examines the value generated in six selected forest NR/Pas, it excludes forest tourism values that are generated in non-managed forests, and in the nature reserves that do not keep records. Additionally, as the number of visitors increase each year, so is the value that forest tourism is expected to generate.

Finally, as the presented values rely on 2019 values, they assume a level of normalcy in the country. This overlooks the ramifications of Covid-19 with travel restrictions, as well as the dire economic situation in Lebanon. Although, despite covid-19 restrictions, there were some indications of a growing trend of restoring to local nature-based tourism, which still allowed this service to provide somewhat of an income to local communities in which the NA/PAs exist. Nonetheless, this service can be considered as a potential value generating source that can be strengthened as covid-19 restrictions ease.

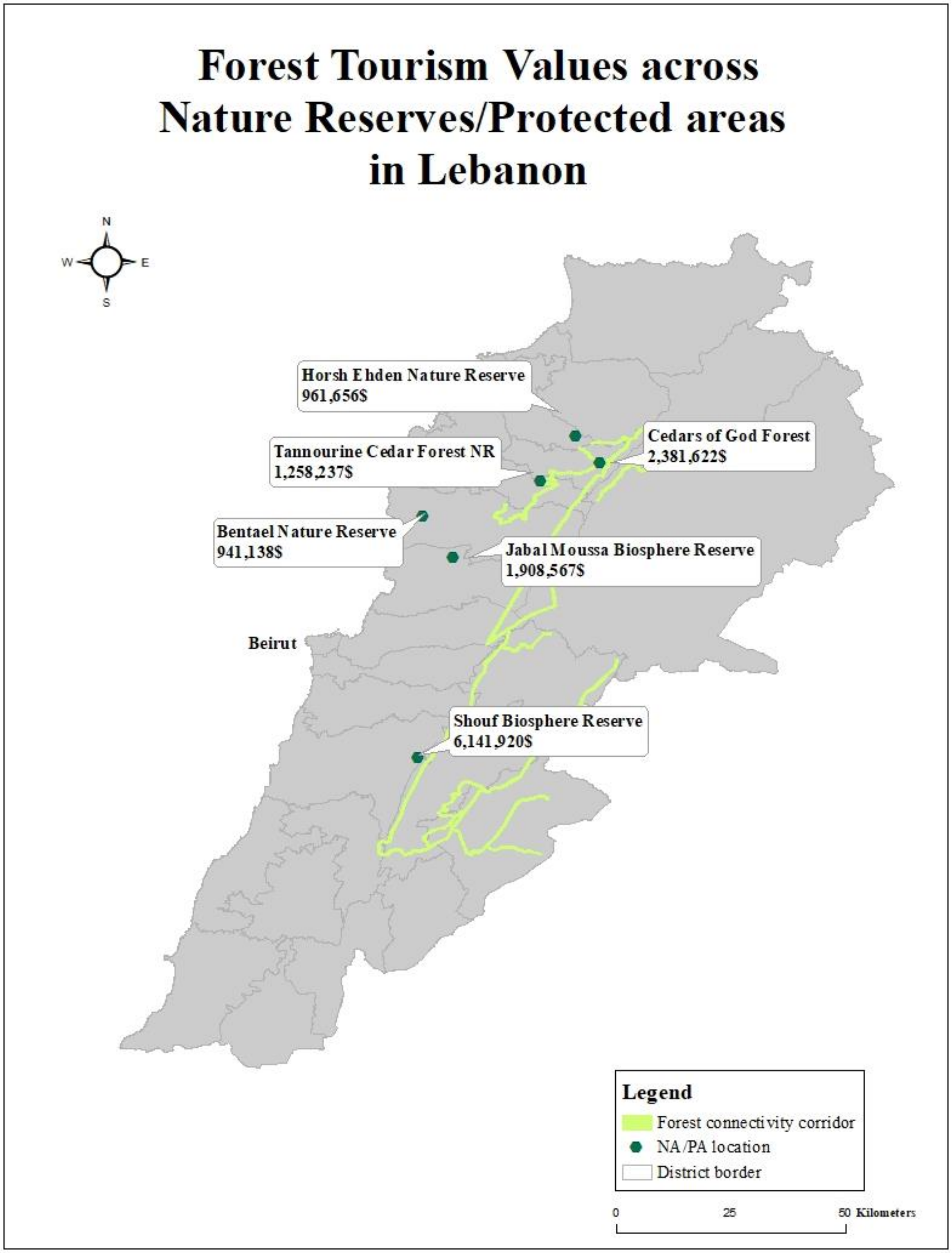

Figure 13: Calculated values of forest tourism in Lebanon distributed across selected nature reserves/protected areas.

2.4. Conclusion

The purpose of this chapter is to present an estimation of the value generated by forests through tourism in and around the areas in which the managed forests exist. The value of forest tourism in Lebanon was calculated based on data collected from NA/PA visitors and managers. Six forest nature reserves/protected areas were selected due to data availability. The overall value generated by forest tourism was estimated to be 15,533,783$ distributed across spending within and around NA/PA in restaurants, bars, souvenir shops, etc. This chapter also estimated the value generated within each of the NA/PAs individually, thereby highlighting the role of these existing forests in generating value, while also shedding light on their potential. The values presented in this study highlight the potential of forest tourism in generating values that are not only distributed at a local scale, but that also ripple throughout the national economy. It presents the cruciality in conserving and sustainably managing these valuable forest areas that possess great potential. This becomes even more crucial as the economic crisis worsens, and the needed livelihood support can potentially be found within forest areas. The values presented hint at the need for conservation policies and investments, as well as sustainable ecotourism initiatives. As nature-based tourism is a growing tourism category in Lebanon (MoE, 2001), its contributions to the overall tourism sector create a significant impact on the local economy. This is especially true as in 2017 the World Travel and Tourism Council calculated that travel and tourism contributed a total of 18.4% of Lebanon’s GDP and generated 17.9% of total employment (World Travel and Tourism Council, 2018). These figures consider the indirect and induced impacts of tourism such as secondary and support industries and other income, employment, and spending multipliers, which almost triple the economic contribution over and above the direct spending that was calculated in this chapter. The value generated by forest tourism as demonstrated in this study encourages the management of existing forest not only from an administrative perspective, but also through the generation of forest management and conservation plans that ensure the continuity and maintenance of these values.

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3. Forest Carbon Sequestration and Storage

3.1. Introduction

The targets of Lebanon's Nationally Determined Contribution (NDC), to mitigate greenhouse gas (GHG) emissions at the national level and adapt to the adverse impacts of climate change up to year 2030, were updated and submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021, as part of Lebanon's commitment to an international effort to combat climate change and develop Lebanese people's resilience towards its negative impacts. The updated reduction targets were set conditional to the assumptions in two scenarios: Scenario 1 sets the mitigation target to 20% by 2030 relative to a Business-As-Usual baseline scenario, untied to any international support to achieve this reduction; while Scenario 2 increases the target to reach 31% by 2030 if international support is provided to fund additional interventions (MoE/UNDP, 2021). Both scenarios rely on optimized practices in key sectors such as energy, water, agriculture, and forestry to project these drops in emissions (ibid). Yet, despite the key role of existing and replanted forest areas to act as Carbon sinks and support achieving the discussed targets, forests in Lebanon face persistent area losses (Global Forest Watch, 2020) due to various natural stressors such as climate change, and more prominent and fast implemented anthropogenic interventions such as land use shifts towards urbanized settlements or agriculture (Masri, Khawlie and Faour, 2002). These land use changes are in many cases facilitated by the ownership type of the forest areas which is approximately equally divided between private (including religious groups) and public (Darwish, 2012), and land exploitation laws that fail to protect the green cover over unclassified private lands, which are still dominant in Lebanon (Masri, Khawlie and Faour, 2002). However, it is worth noting that not all forest types and uses face the same level of land conversion risk since existing environmental laws, when implemented, protect declared reserves and protected areas from exploitation and coniferous forests from felling, regardless of land ownership (IOE-UOB, 2016).

Considering all the above, this chapter aims at calculating the economic value for conserving the Carbon stocks in Lebanese forests, seeing their supporting role in reducing the financial burden for nearing Lebanon's NDC emissions reduction target by 2030 under scenario 1. This computation favors scenario 1 over scenario 2 since it considers the former more reflective of the cost directly or indirectly absorbed by the Lebanese population and economy to reduce GHGs, through undertaking the cost of implementation of new strategies to meet Lebanon's NDC target, even with the absence of external funding. It hence represents, in part, a closer framework for Lebanese people's willingness to pay to avoid the "social cost for Carbon[3]" and provides a better representation of the value of the Carbon already stocked in Lebanese forests. Additionally, scenario 2 incorporates a large uncertainty associated with the provision of external funding to Lebanon, which is less probable due to the current global economic condition post COVID-19 pandemic.

[3] "The monetized damages associated with an incremental increase in Carbon emissions, generally referred to as the social cost of Carbon (SCC)" (Greenstone, Kopits and Wolverton, 2013).

3.2. Methodology

This section describes the methodology adopted to calculate the economic value of conserving the Carbon sequestered and stored in Lebanon's 2019 forests, to contribute to nearing Lebanon's NDC scenario 1 GHG emissions reduction target by 2030. This value is solely recognized from the perspective of a projected amount of CO_2 that might be emitted due to assumed future annual trends of areas of forests converted to agriculture and urban settlements during the period 2019-2029, and the cost for alternative mitigation measures needed to compensate the forest Carbon sequestration and storage service lost due to these land use changes. It therefore represents a hypothetical incremental value of the forest Carbon sequestration and storage service from a 2019 baseline value of this service provided by the total existent forest area. This baseline value would have been most calculated in the literature by either: Considering the total value of Carbon sequestered and stored in existing forests equal to an avoided cost, the social cost of Carbon (Waigner and Ervin, 2017); or attributing this value using a Carbon price adopted from existing Carbon markets (Sonwa, Nlom and Neba, 2016). However, this chapter calculates an incremental value of this service from the cost of two replacement measures, to give an insight on the value of the loss of a forest service due to forest conversion to other land uses. Moreover, and to this study's knowledge, in Lebanon, there is neither a value previously calculated for the local social cost for Carbon, nor examples of values of Carbon credits traded in international markets, and the transfer of such values from other countries and markets is not assumed in this study to reflect the current national environmental and economic situations. Hence, the sub-sections below describe one hypothetical future scenario for forest conversion to other land uses during the period 2019-2029, and 2 others for replacement mitigation measures undertaken during the period 2020-2030. All values are distributed geographically and presented in section 3.3.

3.2.1. General Assumptions for All Scenarios

This sub-section presents the main assumptions that govern all proposed scenarios for the calculation of the forest Carbon sequestration and storage service as follow:

- The Lebanese government is committed to work towards reaching its 20% GHG emissions reduction target by the year 2030 despite the current national financial and economic hardships.
- The Lebanese government is working towards implementing all the adaptation and mitigation strategies proposed under the NDC scenario 1 for all sectors.
- The loss of forested areas due to land conversion to other land uses is perceived as an additional source of emissions that would need to be compensated to enhance the likelihood of nearing the 2030 reduction target.
- The forest land use change to another land use type is permanent for at least 20 years.
- An increase in renewable energy generation and reforestation are two of the most likely mitigation measures to be adopted to compensate the emissions from forest land use change based on existing strategies adopted by the Ministry of Water and Energy and the Ministry of Agriculture (MoE/ UNDP, 2021).

- The conversion of forested areas to other land uses occurs between 2019 and 2029, while the compensation for the hypothetical CO_2 emissions from this conversion takes place between 2020 and 2030.

3.2.2. Forest Land Conversion and Associated CO_2 Emissions

This sub-section describes the method used to calculate the projected CO_2 emissions under one developed scenario for forest land conversion to other land uses. This hypothetical scenario is referred to in this study as scenario A.

This scenario assumes the following:

a- The average forest area shifting to other land uses each year during the period 2019-2029 is 115 Ha. This value is calculated by using the average area of forest and other wooded lands converted to settlements between the years 2000 to 2018, as provided by MoE/UNDP/GEF (2019) and considering that 56.38% of this average concerns forest ecosystems solely. The 56.38% correction factor reflects the percentage of total forest area compared to the total area of forest and other wooded lands combined, as reported by the Forest Resources Assessment report of FAO in 2010 (UNDP-CEDRO, 2016), and assumes equal probability of conversion to settlements between forests and other wooded lands. This study recognizes that the 115 Ha considered under scenario A does not reflect but part of the area of forest that might have been converted to other land uses based on previous trends, however, it adopts this value for the lack of data in Lebanon regarding the total yearly forest area change to all other land use types. Also, this study adopts a constant average forest area lost per year and not an average percentage year to year forest area loss since there is a discrepancy between the definition of forest used in MoE/UNDP/GEF (2019) and the one used in this study.

b- The areas of forests lost are converted to either croplands or settlements under scenario A. Additionally, this study considers any shifts to other land uses during the targeted period, as a transition to one of the 2 land uses previously mentioned, especially that the average forest area shifted to other land uses (115 Ha) and adopted in this study is based on data for forest areas shifted to settlements, which highly likely refers to privately owned forest areas. These assumptions thus presume that future forest land conversion trends, especially on private lands, will partly imitate previously observed trends (conversion to settlement), yet they are likely to respond to the current and mid-term food security concerns (conversion to agriculture), as well as to the national economic and financial hardships that are currently observed and are likely to continue to be felt in the coming years.

c- A conversion of forest lands to croplands is favored over that of settlements in the targeted period. This hypothetical conclusion is based on a previous observation when a drop in the annual growth of GDP in Lebanon from 9.2% between 2006-2010 to 0.8% between 2015-2018 (FAO, 2020) coincided with a drop of 66% in the average area of forest land converted to settlement between the previously mentioned periods (data from MoE/UNDP/GEF (2019)), and on an assumption that this drop will be compensated for in agriculture activity that responds to the current and foreseen need for household income support. Another example that indicates a slowdown in construction activities when economic and financial hardships are dominant in the country is the drop in construction permits requests by 38.5% between January 2018 and January 2019 and that of 64.6% between January 2019 and January 2020 (Bank Audi, 2020).

d- Croplands are divided between perennial and annual crops to imitate existent agriculture practices. Also, the cultivation of perennial crops is maintained slightly higher than that of annual crops under scenario A, since the cost of inputs to maintain the production from such crops is lower than that needed for annual crops, especially if traditional practices are adopted (FAO, 2020). This is highly likely under the current and foreseen national economic circumstances and the devaluation of the national currency. Yet, this assumption also presumes that some success in meeting part of the priorities set in Lebanon's national agriculture strategy 2020-2025 will be observed, such as increasing agriculture exports and enhancing access to agriculture production inputs (Ministry of Agriculture, 2020).

e- Similar trends are observed for the distribution of forest areas lost to urban settlements and agriculture between different forest types.

f- This study does not account for CO_2 equivalent emissions produced due to changes in the use and management of the new land use types.

To calculate the projected CO_2 emissions from the conversion of 1 ha of distinct types of forests to perennial and annual croplands and to urban settlements based on scenario A, the following equation is applied:

Yearly CO_2 to be mitigated /1ha of distinct forest type = C1 + C2

Where

C1= Sum of stored Carbon stock expressed in tonnes of CO_2 released from the conversion of 1 ha of forest type to other land uses as per the distribution enforced in scenario A.
C2= Carbon stock expressed in tonnes of CO_2 that would have been sequestered in one year due to forest type growth if the corresponding area would have remained forest during that year.
Carbon stocks for a "forest remaining a forest" and the ones lost from a "forest converted to cropland" are obtained by applying the equations given in worksheets 3B1a and 3B2b of volume 4 of the IPCC (2006) guidelines. The default parameters used in these equations are presented in **Table 7** below.
These Carbon stocks are then expressed as CO_2 emissions using the below equation deduced from IPCC (2006) volume 4 chapter 2 p11 conversion method:

$$CO_2 \text{ (tonnes ha}^{-1} \text{ yr}^{-1}) = \text{C stock (tonnes ha}^{-1} \text{ yr}^{-1}) * (-44/12)$$

Table 7: Conversion parameters from IPCC 2006 guidelines reference tables.

Conversion Parameter	Value (s) Used in Equations	Source
Above-ground biomass (tonnes d.m. ha^{-1})	130	Table 4.7 IPCC 2006 default value
Carbon fraction (**CF**) [tonnes C (tonnes d.m.)$^{-1}$]	0.47	Table 4.3 IPCC 2006 default value
Above-ground biomass growth (tonnes d.m. ha^{-1} yr^{-1})	1.5	Table 4.9 IPCC 2006 default value
Ratio of below-ground biomass to above-ground biomass (**R**) (tonnes of root / tonnes of shoot)	0.27	(FAO, 2005 cited in MoE/UNDP/GEF, 2019, p.73)
Carbon stock in biomass after one year (**ΔCG**) (tonnes C ha^{-1})	2.1 Perennial	Table 5.9 IPCC 2006 default value
Basic wood density **D** (tonnes m^{-3})	0.5 Coniferous Forest 0.58 Broadleaved 0.54 Mixed Forest	(FAO, 2005 cited in MoE/UNDP/GEF, 2019, p.73)
Biomass Carbon loss (**L**) (tonnes C ha^{-1} yr^{-1})	63 Perennial	Table 5.1 IPCC 2006 default value
Litter Carbon stocks of mature forests (tonnes C ha^{-1})	20.3 Needleleaf evergreen 28.2 Broadleaf deciduous	Table 2.2 IPCC 2006 default value
Soil organic C stocks (**SOC_{ref}**) for mineral soils (tonnes C ha^{-1} in 0-30 cm depth)	38	Table 2.3 IPCC 2006 default value
Land use **F_{LU}** – Native Forest	1	Table 5.10 IPCC 2006 default value
Tillage **F_{MG}** – Native Forest	1	Table 5.10 IPCC 2006 default value
Input **F_I** - Native Forest	1	Table 5.10 IPCC 2006 default value
Land use **F_{LU}** - cropland	1 Perennial 0.8 Annual	Table 5.5 IPCC 2006 default value
Tillage **F_{MG}** - cropland	1 Perennial 1 Annual	Table 5.5 IPCC 2006 default value
Input **F_I** - cropland	1.37 Perennial 1 Annual	Table 5.5 IPCC 2006 default value

The conditions adopted for the calculations under scenario A are summarized in **Table 8** below.

Table 8: key parameters under scenario A.

Condition	Value	Method of calculation	Data Source (s)
Average forest area converted to other land uses each year between 2019 and 2029 (Ha)	115	56.38% of the average area of forest and other wooded lands converted to settlements between years 2000-2018	MoE/UNDP/GEF, 2019 UNDP-CEDRO, 2016
Yearly percentage of forest area lost and converted to croplands (%)	66	Hypothetical conclusion: a) Drop in the annual growth of GDP in Lebanon from 9.2% between 2006-2010 to 0.8% between 2015-2018 coincided with a drop of 66% in the average area of forests and other wooded lands converted to settlements between the previously mentioned periods b) areas not converted to settlements will be replaced by ones converted to croplands to respond to food security concerns and the need for household income support	FAO, 2020 MoE/UNDP/GEF, 2019
Yearly percentage of forest area lost and converted to settlements (%)	34	Percentage of average forest area lost in a year and not converted to croplands	Assumption stating that all forest areas lost are solely converted to one of 2 land uses under scenario A: Urban settlements and agriculture
Distribution of forest area converted to settlement per forest type (percentage / year)	10 % Coniferous Forest 81 % Broadleaved Forest	Average area type of forests and other wooded lands converted to settlements for the period 2000-2018 compared to the average	MoE/UNDP/GEF, 2019

Condition	Value	Method of calculation	Data Source (s)
	9 % Mixed Forest	area of forests and other wooded lands converted to settlements for the same period. This study recognizes a discrepancy between the definition of forest used in the reference source and that of this study.	
Distribution of yearly forest area converted to other land uses per forest type (percentage / year)	10 % Coniferous Forest 81 % Broadleaved Forest 9 % Mixed Forest	Similar distribution to forest area type lost due to settlements	Assumption based on existing forest laws that govern the use of different forest types
Distribution of croplands per type (percentage)	52 % Perennial 48 % Annual	The opposite distribution of croplands divided by types calculated based on average distribution for years 1998, 2013, 2014 and 2015 from “a cropland remaining cropland”. An opposite distribution from previous trends for croplands divided by type was adopted since perennial crops are favored over annual crops under scenario A, for presumably needing lower maintenance costs	MoE/UNDP/GEF, 2019 table 51 p.72 FAO, 2020
Annual volume of fuelwood gathering per ha of forest type (m^3/ha)	- 0.03 (m^3/ha) for coniferous forest - 0.016 (m^3/ha) broadleaved and mixed forests	Volume of fuelwood gathering per forest type in 2015 divided by the corresponding total forest type area for forest area remaining forest in 2015. Broadleaved and mixed	MoE/UNDP/GEF, 2019 table 51 p.72

Condition	Value	Method of calculation	Data Source (s)
		forests total areas are added to calculate fuelwood gathering in non-coniferous forest. A margin of error is recognized in this computation since the volumes calculated in the reference report include fuelwood collected from shrublands as part of the value presented for non-coniferous forests	
CO_2 emissions from the change of 1 ha of forest type to settlement (Gg) / ha	- 0.246 Gg/ha Coniferous Forest - 0.224 Gg/ha Broadleaved Forest - 0.235 Gg/ha Mixed Forest	Calculated based on 2015 data. Total CO_2 emissions per forest type divided by total area of forest type change to settlement. The calculation method in reference source of 2015 data uses IPCC 2006 guidelines	MoE/UNDP/GEF, 2019 table 70 p.93

The workflow governing the calculation of CO_2 emissions under scenario A is presented in **Figure 14Error! Reference source not found.** below:

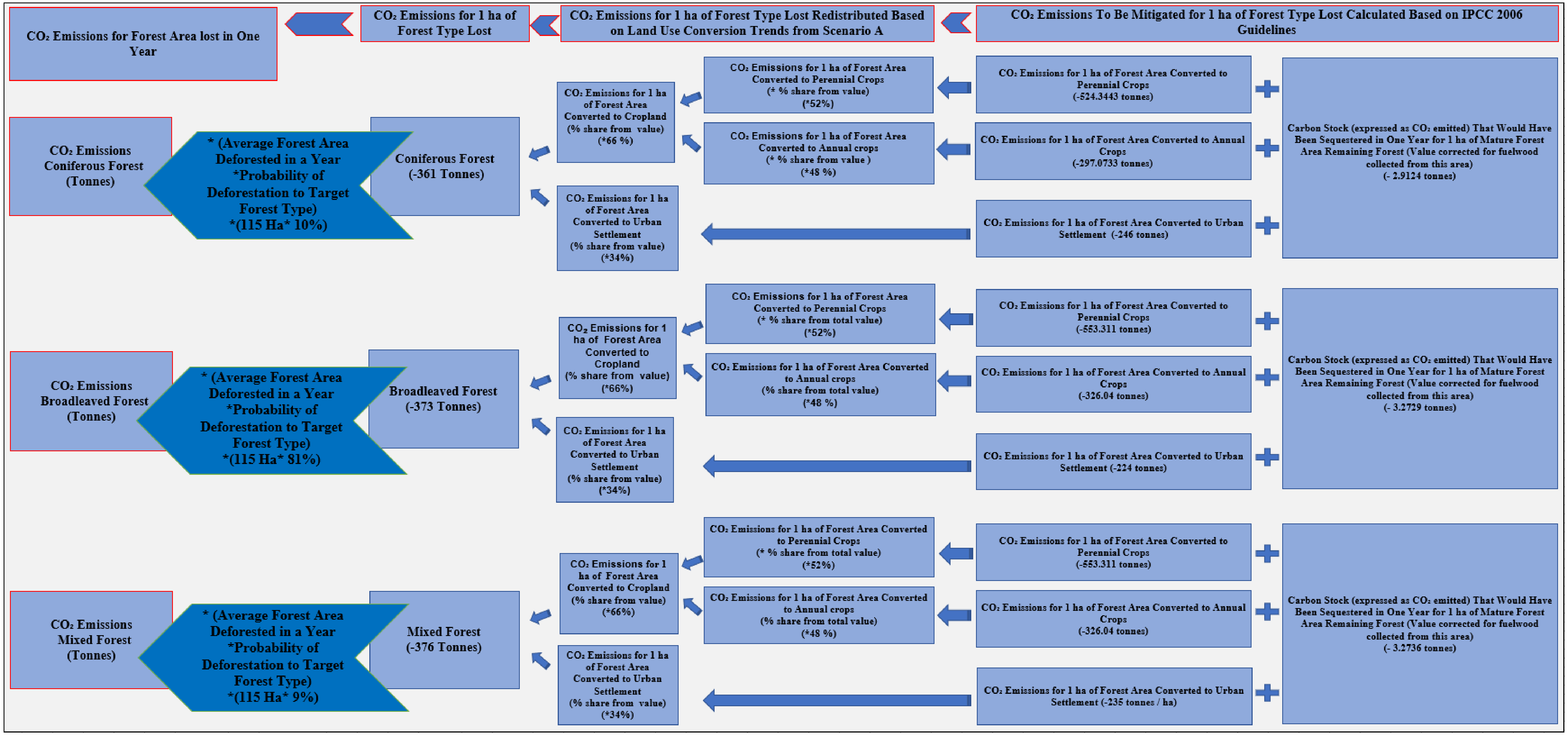

Figure 14: *Workflow of Scenario A for CO_2 emission calculations.*

3.2.3. Replacement Mitigation Measures Scenarios and Associated Costs

This sub-section presents two replacement mitigation scenarios used to attribute a cost to the mitigation of 1 tonne of CO_2 emitted in the atmosphere:

a) Scenario C replaces the same amount of electricity generated by a likely-used pollutant energy technology mix (mainly plants run with combined cycle gas turbine and using gaseous fuel) and leading to the emissions of 1 tonne of CO_2, by electricity produced through a combination of renewable energy sources. It attributes the relative cost of producing this quantity of clean energy to the cost of 1 tonne of CO_2 to be mitigated. It considers the calculated value valid for the period 2020 to 2030.

b) Scenario D compensates for the release of 1 tonne of CO_2 in the atmosphere by planting trees that will allow the sequestration of the same amount of Carbon and attributes the cost that is willed to be paid for reforesting that area to the cost of 1 tonne of CO_2 to be mitigated.

Both scenarios assume that the total offset of CO_2 emitted from the forest area lost in one year will take place in the year that follows. The calculated costs in both scenarios are expressed in 2019 USD value.

The computation of the cumulative incremental value of Carbon stored and sequestered in the 2019 existing forest cover area (per type) based on these 2 scenarios is discussed in sub-section 3.2.4.

3.2.3.1. Scenario C

This scenario considers that renewable energy sources are gaining territory in Lebanon and that they would form a plausible replacement method if need to mitigate CO_2 emissions from other sources arises. One significant indication of this claim is the development of the National Renewable Energy Action Plan (NREAP) 2016-2020 (MoE/UNDP, 2015) as well as the recommendations of IRENA renewable energy outlook for Lebanon report, that compliments the updated NDC targets (IRENA, 2020).

The assumptions adopted in scenario C are backed with information and figures provided in UNDP (2017) report, unless otherwise stated. They are as follow:

- The increase in electricity generation through a mix of renewable energy sources (wind and solar PV) will lead to actual additional mitigation of CO_2 emissions. This assumption is supported by 3 main factors:

    a. Lebanon's public main electricity producer's existing generation capacity is slightly higher than half of Lebanese population's highest electricity demand that can reach 3000 MW.
    b. Fuel is the dominant power source used in power stations in Lebanon thus an increase in electricity generation using this source will lead to an increase in emissions. Hence, the use of renewable energy sources give opportunity for GHG emissions mitigation.

c. The total capacity to be produced from both wind and solar large-scale PV energy sources by 2030 is 750 MW[4] according to the target set in the NREAP. This target leaves room to higher shifts to renewable energy sources to replace existent polluting ones, especially since electricity demand in Lebanon is foreseen to increase by 3.5% each year (MoE/UNDP, 2021) due to national circumstances.

- The cost for mitigating 1 tonne of CO_{2e} emissions using wind and solar large-scale PV energy sources is divided between 60% contribution from wind and 40% contribution from solar. This is based on a similar contribution for the generation of the 750 MW previously mentioned and assumes to imitate the current energy market capacity to meet demand under the NREAP.

- The reduction cost of one tonne of CO_{2e} emissions by using wind energy is assumed at 42.5 $ (UNDP, 2017, p.21) while the same reduction using large-scale solar PV is assumed at 27 $ ((UNDP, 2017, p.22). Both costs are expressed in 2017 USD. These values reflect relative costs (cost premium) to generate the same amount of electricity from a baseline pollutant energy technology mix mainly run using natural gas and assumed to be highly likely implemented in Lebanon (ibid). They are calculated presuming a scenario that imitates the current risk environment in Lebanon with no funding support or policies to minimize the risks for investment in renewables and embed the costs of installation of renewable energy systems, costs of operations and management, as well as financing costs. Since all the latter costs are calculated from average values between 2017 to 2030[5] under the UNDP (2017) study, this scenario will express the reduction cost of 1 tonne of CO_{2e} emissions from wind and solar in 2019 USD equivalent value and will consider this value as constant for the period 2020 - 2030.

- The CO_{2e} emissions are considered equal to the Net CO_2 emissions in this calculation as the quantity of the other GHGs emitted from energy generation are negligible compared to CO_2 (MoE/UNDP/GEF, 2019).

- The calculated cost will be assigned similarly between different forest types.

The costs of abatement of 1 tonne of CO_2 using renewable energy technology expressed in 2019 USD are provided in **Table 9**.

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[4] According to the IRENA (2020) renewable energy outlook for Lebanon report, a target of 1000 MW of energy produced from wind and that of 2500 MW from large scale solar PV, totaling 3500 MW, were identified to support reaching the updated NDC 2020 targets associated with renewable energy use by 2030, yet this study uses the total value of 750 MW set in the NREAP since it considers the latter an official document.

[5] The devaluation of the Lebanese Lira starting year 2020 and the decrease in Lebanon's central bank USD reserves are foreseen to inflict changes to these costs during the period 2020-2030. However, the correction of these values to account for the current national economic circumstances would acquire an in-depth study of the renewable energy market in Lebanon which is outside the scope of this study.

Table 9

Table 9: Cost of abatement of 1 tonne of CO_2 emissions in 2019 USD value.

	Cost of Abatement of 1 tonne of CO_2 (2017 USD value)	**Cost of Abatement of 1 tonne of CO_2 (2017 LBP value)**	**Cost of Abatement of 1 tonne of CO_2 (2018 LBP value)**	**Cost of Abatement of 1 tonne of CO_2 (2019 LBP value)**	**Cost of Abatement of 1 tonne of CO_2 (2019 USD value)**
Wind	42.5	42.5 *1507.5 = 64,068.75	64,068.75 – (0.056*64,068.75) = 60,480.9	60,480.9 – (0.07*60,480.9) = 56,247.237	56,247.237 / 1507.5 = **37.3**
Large-scale solar PV	27	27 *1507.5 = 40,702.5	40,702.5 – (0.056*40,702.5) = 38,423.16	38,423.16 – (0.07*38,423.16) = 35733.5388	35733.5388/ 1507.5 = **23.7**
Calculation Method / Data Source	Direct values / (UNDP, 2017)	Cost in 2017 USD * Conversion rate to LBP in 2017 / (Banque Du Liban, 2019)	Cost in 2017 LBP deflated using % change of consumer price index from year 2017 (5.6%) / (IMF, 2018)	Cost in 2018 LBP deflated using % change of consumer price index from year 2018 (7%) / (IMF, 2019)	Cost in 2019 LBP / Conversion rate to USD in 2019 / (Banque Du Liban, 2019)

The cost attributed to the mitigation of 1 tonne of CO_2 emissions released from forest loss in 2019 USD value under scenario C, is presented in **Table 10**.

Table 10: Cost of abatement of CO_2 emissions using a combination of renewable energy sources expressed in 2019 USD.

Renewable Energy Technology	**Cost of Abatement of 1 tonne of CO_2 (2019 USD)**	**Contribution of Energy Source to Total Cost (%)**	**Cost of Abatement of 1 tonne of CO_2 Corrected for Energy Sources Contribution (2019 USD)**
Wind	37.3	60	22.38
Large-scale Solar PV	23.7	40	9.48
Wind & Solar	-	100	**31.86**

Hence the cost of mitigating 1 tonne of CO_2 emitted due to forest land conversion to other land uses in a certain year between 2019 and 2029 is given at 31.86$ under Scenario C.

3.2.3.2. Scenario D

This scenario is developed using the following assumptions:

- All CO_2 emitted due to the conversion of a forest area in a year will be compensated with reforestation in the next year.
- Areas suitable for reforestation are available.
- Reforestation is done using one-year old tree seedlings, reflecting the current dominant reforestation practices in Lebanon.
- Reforested sites will be protected for at least 20 years.

The avoided cost that would have been invested to offset 1tonne of CO_2 through reforestation used under this scenario is provided by the Lebanon Reforestation Initiative. It is estimated at 27.5$ (2019 USD) per tonne of CO_2 removal. This value is adopted from the average cost paid by one private sector company - Advanced Car Rental - in 2019, for LRI to plant a mix of different tree species in suitable reforestation sites to mitigate part of this company's car fleet CO_2 emissions during that same year. This value is deemed representative of a willingness to pay from a private sector company to sequester and store Carbon in forests and is applied to all forest types. This study acknowledges that reforestation provides a set of ecosystem services beyond the Carbon sequestration and storage service, and thus the indicated cost might embed the values of multiple forest services. However, considering that the sole indicated purpose for payment for reforestation under the "LRI-Advance Car Rental" agreement is the mitigation of CO_2 emissions, this scenario solely attributes this full avoided cost of reforestation to mitigate CO_2 emissions to the value of forest ecosystems' Carbon sequestration and storage service. 27.5$ per tonne of CO_2 offset will be considered constant from the period 2020-2030. This study acknowledges that the reported value might be but an indication to a possible willingness to pay to offset Carbon emissions using reforestation. Also, this value might not be valid for the upcoming years due to the current financial hardships that the private sector in Lebanon is enduring. Yet, a correction to this value cannot be put forward under this study considering the complexity of future predictions based on the current unstable economic and financial situations in Lebanon.

3.2.4. Carbon Sequestration and Storage Service Accounting for NDC 2030 Target

This sub-section details the estimation of the cumulative incremental value of the Carbon sequestration and storage service per forest type, from a 2019 total value of this service. The adopted calculation method is meant to showcase the importance of forest conservation to contribute to nearing the 20% GHG reduction target by 2030 under the emissions and mitigation scenarios previously discussed. Hence the cost of offsetting CO_2 emissions from forest area conversion to other land uses happening every year starting 2019 till 2029 is accounted as part of the total Carbon sequestration and storage service value of the 2019 forest area. An average annual forest area converted to other land uses of 115 Ha (discussed in previous sections of this chapter) is adopted starting from a baseline 2019 forest cover.

Equation 3 is applied to 2 scenario combinations by using the described values of emissions and costs previously generated and discussed under each scenario. These combinations are Scenario

AC (scenario A and scenario C) and scenario AD (scenario A and scenario D). The elements constituting equation 3 are presented below:

$$Vs = (\sum_{n1}^{n11} EF) * Ca \qquad (3)$$

Where

Vs= Cumulative value of Carbon sequestration and storage service per forest type starting from a 2019 forest cover. This is an incremental value to that of the Carbon sequestered and stored in the 2019 forest cover which will not be converted to other land uses in the period 2019-2029.

n1= Year 2019

n11= Year 2029

EF = CO_2 emissions from forest area type lost in one year (see figure 19 for calculation method) according to scenario A.

Ca: Avoided cost of mitigation measure to offset 1 tonne of CO_2 released in a certain year and mitigated in the next year.

This calculation recognizes a margin of error to Vs since the implementation of a mitigation measure (reforestation or clean electricity produced responding to energy demand) in a said year to offset the emissions of the previous year would still be providing that service in the following years. However, this will partly compensate for the CO_2 that would have been sequestered by the growth of trees in the forest area converted to another land use starting a said year and throughout the studied period, which is not accounted for in this equation. Yet, the calculated cost will still be reflective of a higher boundary value as Carbon released from forest cover shift to other land uses is much higher than the value of Carbon sequestered in a mature forest (see figure 19 detailed values for comparison per ha of forest type).

3.3. Results and Discussion

This section presents the results of the computation of the cumulative incremental value of forest Carbon sequestration and storage service from a 2019 value of this service, based on the 2 scenario combinations previously discussed in sub-section 3.2.4. This calculation adopts as a baseline, the forest areas mapped in the 2019 forest cover used in this study. The total CO_2 emissions calculated from the projected forest area conversion trends to settlements and croplands between 2019 and 2029 under scenario A, by applying the workflow in figure 19, are presented in **Table 11Table 11**.

Table 11: CO_2 emissions from forest conversion to other land uses under hypothetical scenario A between 2019 and 2029.

Total forest area projected to be converted to other land uses during the period 2019 – 2029 (Ha)	**1,265**

Total forest area projected to be converted to other land uses during the period 2019 – 2029 distributed per forest type (Ha)	**Coniferous: 126.5** **Broadleaved: 1,024.65** **Mix: 113.85**
CO_2 emissions per 1 ha of forest type lost under scenario A (Tonnes) (see figure 19)	**Coniferous: -361** **Broadleaved: -373** **Mix: -376**
Total CO_2 emissions from the projected total forest area converted to other land uses under scenario A during the period 2019-2029 (Tonnes)	**- 470,668.55**

The cumulative incremental value of the Carbon sequestration and storage service from that provided by the 2019 forest cover remaining forest, is calculated for the total mass of CO_2 projected to be emitted during the period 2019-2029 under scenario A, by applying the avoided mitigation costs that would have been inflicted between 2020 and 2030 for 1 tonne of CO_2 emitted, previously discussed under scenarios C and D. The results of this calculation are presented in **Table 12**.

Table 12: Results of the calculation of the cumulative incremental value of the Carbon sequestration and storage service from a 2019 value under scenario-combinations AC and AD.

Projected CO_2 emissions associated with the total forest area assumed to be converted to other land uses under scenario A (Tonnes)	**- 470,668.55**
Avoided cost of mitigating 1 tonne of CO_2 using a mix of renewable energy technology under Scenario C (2019USD)	**31.86**
Avoided cost of mitigating 1 tonne of CO_2 using reforestation under Scenario D (2019 USD)	**27.5**
Cumulative incremental value of the Carbon sequestration and storage service from a 2019 baseline value, covering the period 2020-2030, and calculated based on scenario combination AC (2019 USD)	**14,995,500**
Cumulative incremental value of the Carbon sequestration and storage service from a 2019 baseline value, covering the period 2020-2030, and calculated based on scenario combination AD (2019 USD)	**12,943,385**

The geographical distribution of the cumulative incremental value of the forest Carbon sequestration and storage service from a 2019 baseline value is mapped using ArcGIS. This mapping exercise applies the equations in **Figure 14** (scenario A) for emissions from forest area conversion by forest type to each forest type area for the period 2019-2029 and multiplies these emissions by the mitigation costs for 1 tonne of CO_2 calculated under scenarios C and D, respectively. A map presenting the distribution of these values by district for the 2 scenario-combinations AC and AD is generated and is shown in **Figure 15**. This map serves as a guidance to spot the districts presenting the highest values for the studied service and thus to advocate for the conservation of their corresponding forest areas. It is to be noted that the high values observed for forests in certain districts might be reflective of large forest areas that exist in these districts but more importantly of forest types that are most at risk of conversion to other land uses under the assumptions adopted in scenario A (i.e., broadleaved forests are designated as having the highest risk of land conversion under scenario A – 81%).

As previously discussed in this chapter, the calculated values of the Carbon sequestration and storage service under scenario combinations AC and AD use costs for mitigating CO_2 emissions that do not account for the current and future national economic and financial situations. However, these values, although varying in the future, can be used to flag a sure benefit to Lebanon in keeping Carbon stored in forest ecosystems, and by reasoning, to conserve these ecosystems. So, these values might be used as an indication to support the case for stressing on implementing or updating certain forest protection and land use laws, especially if these forest land conversion trends are foreseen to increase in the future.

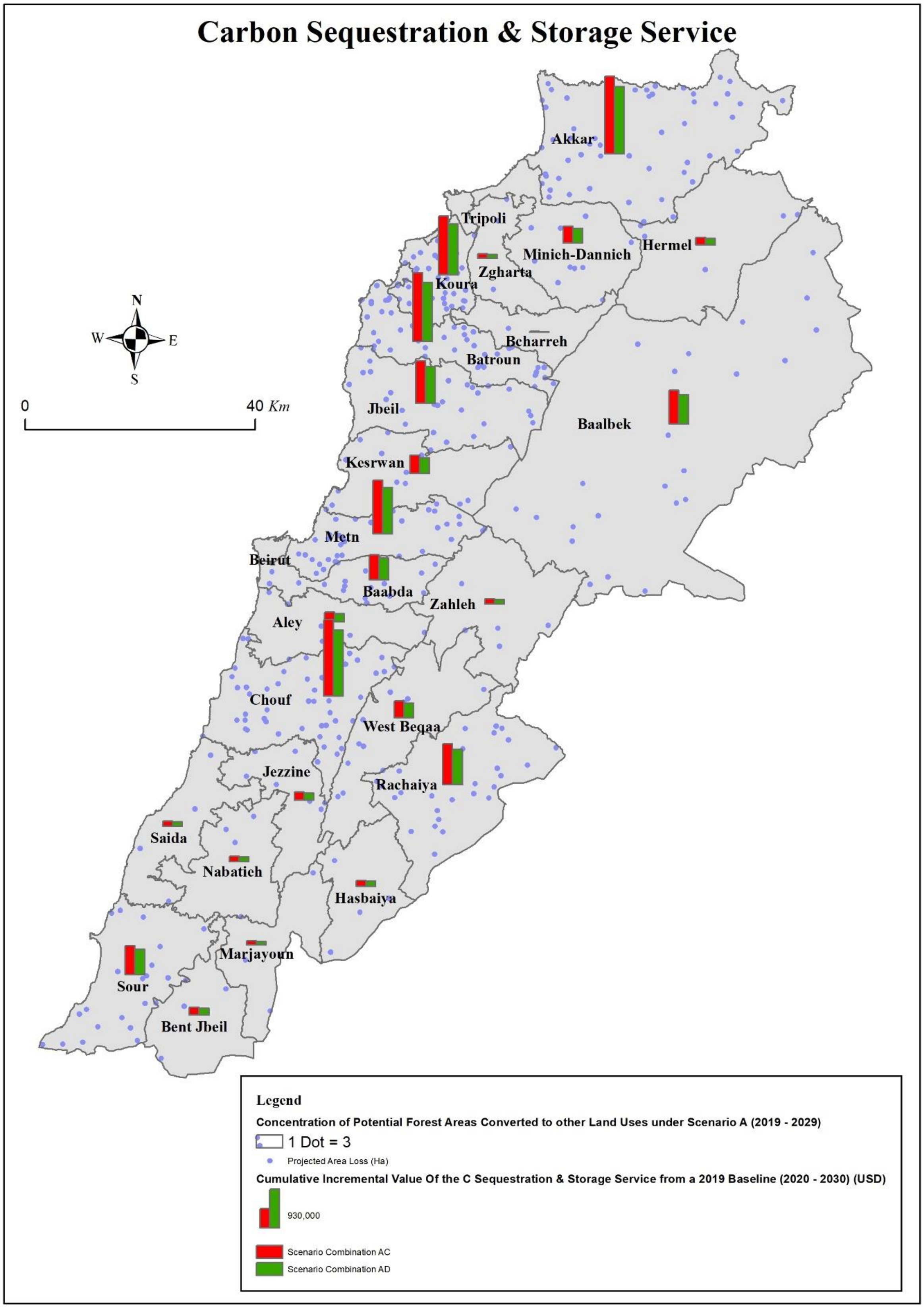

Figure 15: *Cumulative incremental value of the forest Carbon sequestration and storage service from a 2019 baseline value, calculated for the period 2020-2030, distributed between districts.*

3.4. Conclusion

This chapter aimed at computing the monetary 2020-2030 cumulative incremental value of the Carbon sequestered and stored in Lebanese forests, compared to a 2019 baseline value of this service provided by the 2019 conserved forest cover. It hence calculated a value ranging between 12,943,385$ and 14,995,500$ from the replacement of this service through reforestation and renewables over the course of 11 years, respectively, depending on hypothetical projected forest land use shifts to agriculture and urban settlements. This financial burden will be undergone by the Lebanese Government, and thus by the Lebanese population, if Lebanon will seek to nearing its 2030 NDC target under scenario 1. However, the calculated values can also be perceived as indicative numbers to communicate the importance of international private and public funding support towards forests' conservation and expansion in Lebanon. Such investment goes beyond conserving the role of forests as Carbon sinks, to continuously benefitting from the full set of services that these forests provide and that contribute to support vulnerable developing countries to adapt to climate change.

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4. Enhancement of Air Quality

4.1. Introduction

Cities are the main hubs for economic activities and administrative, educational, and social services in Lebanon. This centralization of economies rendered living in, or commuting within and to these areas, vital for the Lebanese population to access services. Consequently, about 88% of people in Lebanon were estimated to dwell in urban areas in 2014 (UN Habitat, 2018) with a share exceeding 40% residing in the Great Beirut Area (GBA) (El Khoury, et al., 2016). Additionally, travel demand has also been concentrated in and towards these cities. In the absence of reliable public transportation means, the land transport sector in Lebanon became dominated by large with private passenger cars which constituted around 85% of total road motorized vehicles in 2012 (MoIM, 2013 cited in MoE/UNDP/GEF, 2015 p.2). This reliance on individual transportation eloquently explains the observed traffic jams at cities' entrances, notably for the GBA, where daily flows of passenger cars can record 230,000 units from the Northern coastal highway and 85,000 from the Southern one (MoE/URC/GEF, 2012 cited in IPTEC, 2016 p.9).

Yet, these land travel dynamics in Lebanon are not without a cost. The land transport sector's footprint heavily marks air quality in cities and around roads from direct and indirect greenhouse gas emissions (MoE/UNDP/GEF, 2015) with the latter forming part of the indicator pollutants for air quality. Additionally, the high population density in Lebanese cities, especially in GBA, and the elevated daily average road travel time that is estimated at about 16% of a person's day-hours in Lebanon (Arab Weekly, 2016 cited in Malaeb, 2018 p.16) indicate a potential high risk of exposure to air pollution from transportation by a significant part of the population, leading to possible negative impacts on people's well-being. In fact, a wide-reaching breadth of literature has been investigating the correlation and relationship's pattern between the exposure to changed levels in ambient air flagship pollutants, namely nitrogen oxides (NO_x), sulfur dioxide (SO_2), Ozone (O_3), and particulate matters (PM_{10} and $PM_{2.5}$), and the number of hospital admissions associated with respiratory and circulatory systems' diseases. These studies established, through a variety of statistical models and tests, reasoning for potential important associations between higher admissions' probabilities and higher air pollutants' levels (Ko, et al., 2007; Ab Manan, Noor Aizuddin and Hod, 2018; Anenberg, et al., 2018; Sanyal, et al., 2018). In Lebanon, studies investigating correlations between different concentrations of air pollutants and diverse health effects in Beirut and other cities and towns in the North reached comparable conclusions (Melki, 2018). These correlations can often be translated into economic losses on the health sector and on the general well-being of people from the interruption of their daily activities; for instance, one recent study by Farrow, Miller and Myllyvirta, 2020 estimated a 2% equivalent of Lebanon's 2018 GDP as inflicted loss by air pollution resulting from the combustion of fossil fuels in Lebanon in the indicated year.

Recognizing the weight of degraded ambient air quality on health and human well-being, the World Health Organization (WHO) has set threshold concentrations for flagged air pollutants to guide government air pollution mitigation strategies that aim at reducing these pollutants' levels in the atmosphere (WHO, 2003). A variety of approaches championing technological and nature-based solutions are often advanced to address this challenge, with emphasis on the role that trees and forests in highly polluted areas or located near emission sources can play to enhance air quality

(Nowak, Crane, and Stevens, 2006; The Nature Conservancy, 2016). This emphasis takes root from the bidirectional exchange mechanisms that naturally exist between trees and their local ambient atmosphere. Ambient air quality is thus affected by the influence of trees on local air flows, and their ability to capture gaseous and solid air pollutants through their leaves, trunks, branches, and roots. Although, it is to be acknowledged that certain tree species, under specific conditions (i.e., dense tree rows inside urban canyons; species emitting biogenic volatile organic compounds), might have a counter-effect on air quality and exacerbate air pollution in cities (Grote, et al., 2016).

Considering the above, this chapter attempts to build the case for the existence of a potential air quality enhancement service provided by the existing tree cover located near land transport emission sources in Lebanon. It estimates a hypothetical economic value of this service provided by trees (stands of single trees or forming a part of a forest area) at proximity to roads, by removing air pollutants from the atmosphere, namely NO_x emitted from vehicle tailpipes. It aims at highlighting the possible key role of existing trees in highly polluted locations to reduce the costs undertaken by the Ministry of Public Health (MoPH) to subsidize hospitalized diagnosis of a set of circulatory and respiratory diseases, as well as to avoid part of the costs encountered by a vulnerable group of patients due to hospitalization and loss of wages. This calculation constitutes but a part of the total potential hypothetical value of this air quality enhancement service provided by the pre-mentioned tree cover, since it only tackles the costs covered by one health coverage scheme and omits to consider others such as private insurances, due to inaccessibility of relevant data. It nonetheless supports the discourse for conserving and increasing the green cover, particularly at well-designed key locations near air pollution sources such as roads, inside and outside urban areas. It attempts to highlight the potential critical role of this nature-based solution to protect and enhance the quality of life of the Lebanese people, especially with new challenges arising from the current economic crisis and COVID-19, and the increasing stress on household income and on the national economy.

A very important note that needs to be stressed on in this chapter, is that the calculation of the value of air quality enhancement service, although presented in detail and through numbers in the following sections, is only meant to showcase the possible likelihood of a hypothesis. Thus, these numbers should not be communicated as actual benchmarks of financial benefits from the air quality enhancement service. They should be regarded as an indication to part of the negative influence of the air pollution from the transportation sector on health, as a signal to the potential additional burden on the livelihoods and well-being of a vulnerable group of the Lebanese population that might be highly likely influenced by this air pollution, and as an indication to the supporting and often unrecognized role that trees can play in avoiding the intensification of that burden.

4.2. Methodology and Results

This section details the stepwise methodology adopted in this chapter to estimate a hypothetical value of air quality enhancement service for the existing tree cover strategically located in the main cities and around highways and busy roads in Lebanon, and specifically associated with pollutant emissions from land transport. It attempts to build the rationale around the avoided cost to multiple stakeholders, potentially served by existing trees, by decreasing, through their absorption mechanism, the levels of NO_x emitted by privately owned passenger cars.

Figure 16Error! Reference source not found. below illustrates the steps undertaken to calculate the value of the air quality enhancement service. A detailed description for the data, assumptions and limitations related to each calculation step is presented in subsections 4.2.1 to 4.2.6.

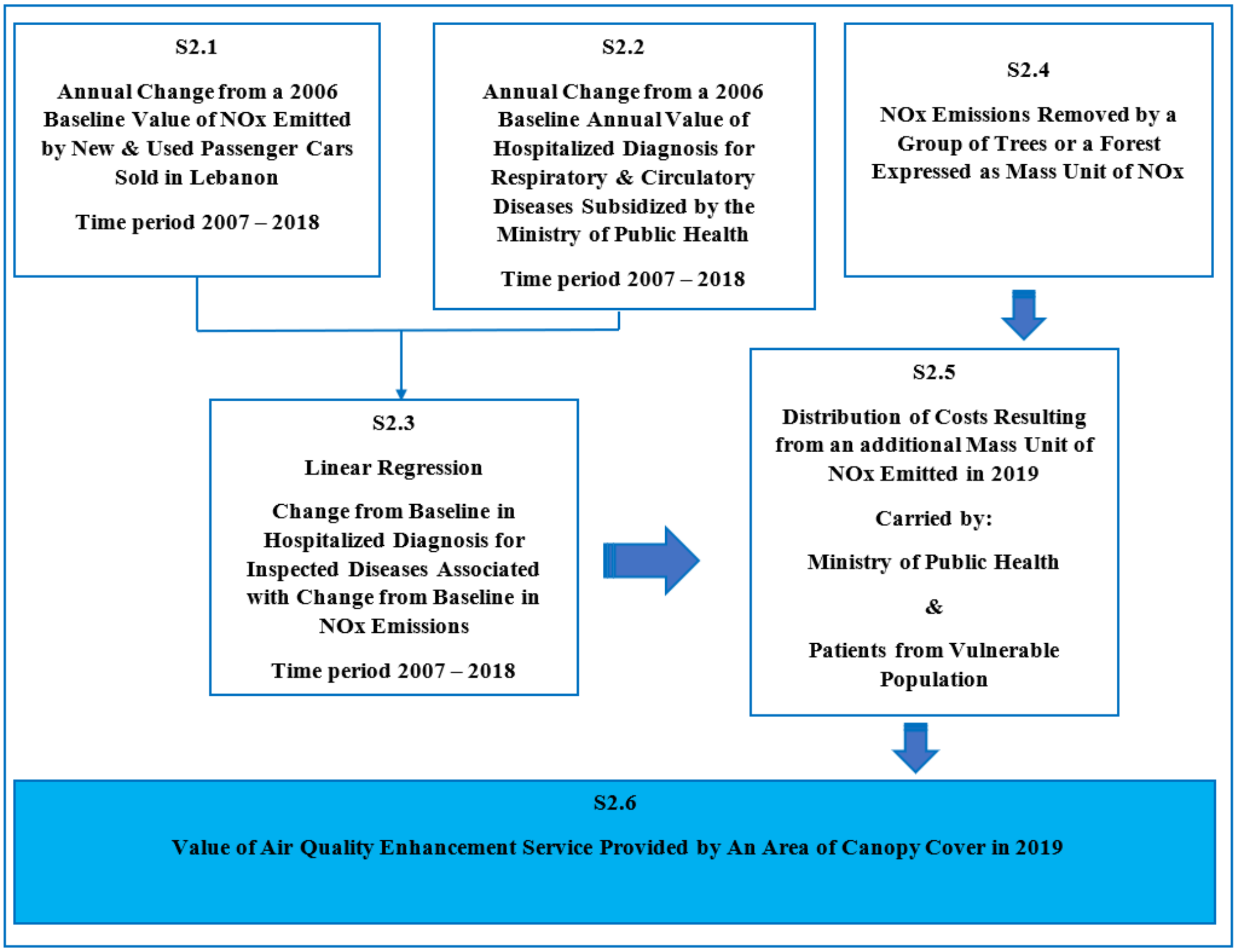

Figure 16: *Steps for the calculation of the air quality enhancement service.*

This study assumes that the variation of emissions from passenger cars' tailpipes is representative of the main changing trend of these emissions from land transport over the years due to the below:

a- Passenger cars are the most dominant land transport mean in Lebanon and their yearly numbers entering in circulation continuously increase starting 1994 onwards (see figure 14 in MoE/UNDP/ GEF, 2019, p 43; and table 14 in this chapter for references).

b- The yearly increase in the number of commercial vehicles entering in circulation is minimal compared to that of privately owned passenger cars (see figure 14 in MoE/UNDP/ GEF, 2019, p 43).

Also, this calculation uses the impact of NO_x emissions from passenger cars as proxy to that of other air pollutants emitted through vehicle tailpipes and that affect the respiratory and circulatory systems, as practiced in numerous epidemiological studies (WHO, 2013), as it is very difficult to single out the effects of one type of pollutant on health from the impact of other ambient air pollutants (ibid), or to limit the assumed high levels of air pollution around busy roads to one specific pollutant and pollution source.

4.2.1. Emissions of Nitrogen Oxides from Passenger Cars

The computation of tailpipe NO_x emissions from new and used passenger cars sold in Lebanon between 2007 and 2018 is done using a constructed scenario providing lower boundary NO_x emissions from these cars. The 2007-2018 timeframe is chosen since data for the number and distribution of passenger cars sold in Lebanon during this period are available from open sources. The constructed scenario aims at reflecting the general map of the car market in Lebanon based on the yearly number of cars sold during the indicated period, their related brands, models, engine sizes, and the average tailpipe NO_x emissions reported by the relative car manufacturers for car models under controlled conditions, corrected for real time driving conditions. It however reflects a minimum estimate of NO_x emissions from these passenger cars, since it assumes optimal technological solutions installed in these cars to reduce the level of pollutants emitted in the atmosphere, continuous car maintenance, and the use of fuel with a quality comparable to the European standards adopted in a certain year. Data is collected from secondary sources or estimated based on supported assumptions. The total NO_x emissions assumed during the studied period result from a 3-step calculation:

1. Value of tailpipe NO_x emitted from new passenger cars sold in Lebanon for each year in the indicated period.
2. Value of tailpipe NO_x emitted from used passenger cars imported and sold in Lebanon for each year in the indicated period.
3. Total value of NO_x emitted from new and used passenger cars sold in Lebanon for each year in the indicated period corrected for real time driving conditions.

Changes in NO_x emissions due to cars aging over the studied period are not considered in this calculation.

4.2.1.1. NO_x emissions from new passenger cars sold.

Figure 17 below illustrates the flow of computation of tailpipe NO_x emissions for a certain year from new cars sold in this particular year.

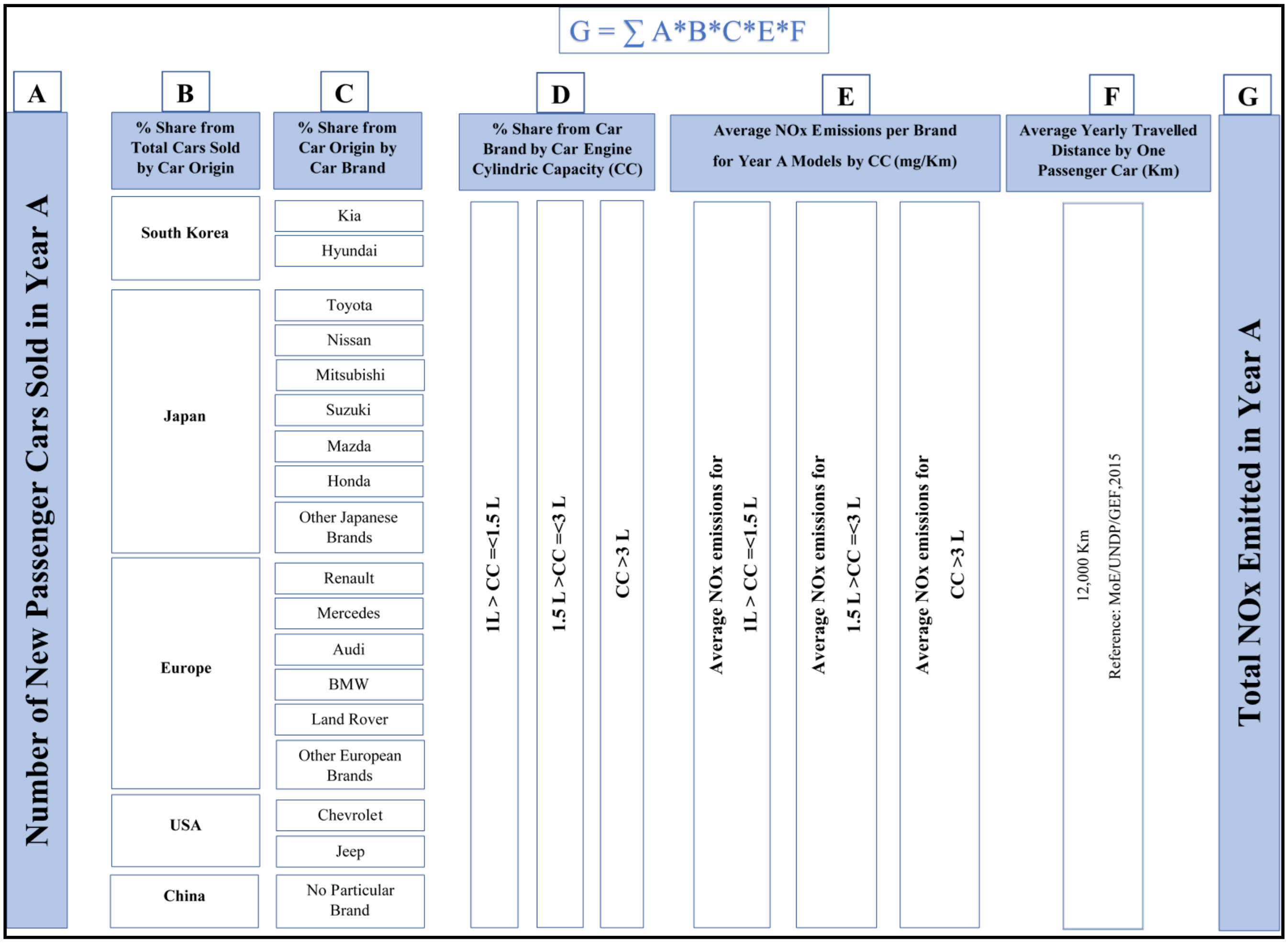

Figure 17: *Calculation of NO_x emissions from new passenger cars sold in a particular year.*

The calculation framework introduced in figure 17 above is governed by a set of assumptions to compensate for the unavailability or inaccessibility of detailed data when applicable. These assumptions are presented in **Table 13**.

Table 13: Assumptions applied to the computation of NO_x emissions from new passenger cars.

Assumption	Reasoning Supporting Assumption	Implication of Assumption on Calculation	Reference
All new passenger cars sold in Lebanon during the studied period use gasoline	A 2001 Lebanese law & a 2002 decree that restrict the use of diesel in motorized vehicles to heavy-duty vehicles only.	NO_x emissions for car models running on diesel are not included in NO_x calculation	MoE/UNDP/ GEF, 2019
NO_x emissions from the Japanese and European cars brands	Assumption based on the dominance of the listed brands in car sales	Emissions for other Japanese & European brands	

listed in figure 17 are representative of the other European and Japanese brands available on the Lebanese market		(Additional to the ones specifically listed in figure 17) are calculated from the average values of the Japanese & European brands listed in figure 17, respectively.	
Average NO_x emissions for US cars other than Chevrolet are represented by Jeep brand	Assumption based on popularity of Jeep brand in Lebanon	Value of NO_x emissions for other US brands for a particular year is taken from Jeep brand emissions values in that year	
Emissions for Chinese cars are assumed equal to the value of Chinese standard of maximum permitted emissions level for NO_x for gasoline passenger cars corresponding to a certain production year. No differentiation for emissions exists between different engine sizes	Lack of reported NO_x emissions per car brand from manufacturers. Thresholds for maximum emissions set by the Chinese Government are assumed to be respected by Chinese cars' manufacturers	Value of NO_x emissions for all new Chinese passenger cars in a certain year is equivalent to the value of the Chinese standard of NO_x emissions for gasoline cars applied in that particular year	Transportpolicey .net, 2018
2011 constitutes a benchmark year for the shift in consumer demand towards small size cars	Statement found in several references regarding the dominance of sales of small cars in recent years	Distribution of car sold by engine size from 2011 to 2018: 90% (1L<CC<1.5L) and equal distribution of remaining 10% between medium and big engine size cars	Byblos Bank, 2019. Cochrane, 2020
Distribution of engine size for number of new cars imported reflect the distribution of sold cars per engine size	Distribution of cars imported per engine size reflect market demand for these cars	Distribution of new cars sold per engine size is taken from the distribution of new cars imported by engine size for	Data adapted from Ministry of Finance, 2011 Table 2 p.7 of car specifications at imports

		the years 2008 till 2011	assuming equal average cost for imported cars
The higher boundary of the value of NO_x emitted by a certain car brand for a certain year is equal or lower to the value of NO_x emitted from that car brand reported for the previous year	Euro standards are becoming more restrictive with time for the maximum threshold NO_x emissions	In case emissions' values for a certain brand in a certain year are not available in the consulted emissions database, the value of the previous reported year of the same brand is adopted	

Since the dataset used to apply the computation framework presented in **Figure 17** is exhaustive to be added to this chapter, **Table 14Table 14** below provides a list for the data sources used for each data type.

Table 14: Data sources for the calculation of NO_x emissions from new passenger cars.

Data Type	Data Source
Number of new passenger cars sold in a particular year	Year 2007: BLOMINVEST Bank, 2018 & CEIC, 2014 Years 2008 - 2009: BankMed, 2013 & CEIC, 2014 Years 2010 till 2015: BankMed, 2016 Years 2016-2017: BLOMINVEST Bank, 2018 Year 2018: Brite, 2018
Distribution of new passenger cars sold per country of origin and brand in a particular year	Year 2007: Assumption (Average values from 2008 till 2010) Years 2008 till 2010: BankMed, 2013 Years 2011 till 2015: BankMed, 2016 Years 2016 – 2017: BLOMINVEST Bank, 2018 Year 2018: Brite, 2018
Distribution of new imported cars per engine size	Years 2007 till 2010: Assumption based on data adapted from Ministry of Finance, 2011 Table 2 p.7 Year 2011 to 2018: Assumption
Passenger car model (series) per car brand sold in the Lebanese market	Consulted websites: - Kia (https://www.kia.com/lb/main.html) - Hyundai (https://www.hyundai.com/lb/en/utility/downloads) - Toyota (https://toyotalebanon.com/) - Nissan (https://en.nissanlebanon.com/vehicles/brochures.html) - Mitsubishi (http://www.mitsubishilebanon.com/models.php) - Suzuki (https://gabsleb.com/suzukimodels.php?id=#tab7) - Mazda (https://www.mazdalb.com/) - Honda (https://www.honda-mideast.com/en-lb) - Renault (http://www.renault-liban.com/en/range.html)

Data Type	Data Source
	- Mercedes (https://www.mercedes-benz mena.com/en/passengercars.html) - Audi (https://www.audi-lebanon.com/me/web/lben/models/q3/q3.html) - BMW (https://www.bmw-lebanon.com/en/topics/fascination-bmw/xdrive/introduction.html) - Land Rover (https://www.landrover-lebanon.com/en/) - Volkswagen (https://models.volkswagen-me.info/lebanon/) - Chevrolet (https://www.chevroletarabia.com/lb-en) - Jeep (https://jeep-beirut.com/en/gargour-automotive-co-sal)
Tailpipe NO_x emissions reported by car manufacturers for car brands and models under controlled conditions	Emissions Finder, 2014
Chinese standard tailpipe emissions for passenger cars	Transportpolicey.net, 2018
Average yearly travelled distance by a personally owned passenger car in Lebanon	MoE/UNDP/GEF, 2015

4.2.1.2. NO_x emissions from imported used passenger cars sold.

The calculation of tailpipe NO_x emissions from used cars imported and sold in Lebanon during the period 2008 till 2018 is completed using equation 1 below:

$$NOx\ emissions\ in\ year\ Z = \sum_{Z-1}^{Z-8} NOx\ emissions \quad (1)$$

This equation is based on the decision of the Lebanese customs to enforce a condition on the allowed age of imported used cars to Lebanon, allowing imports only for car models first time manufactured up to 8 years backward from the year of import (MoE/UNDP/GEF, 2015).
Since no data can be found by this study on the distribution of sold imported used cars in a certain year by model year, one key assumption is applied:

- An equal distribution for the number of cars sold in year z by model years z-1 to z-8 is initially assumed. A year to year % discount on each share is then adopted starting from the oldest to the newest model or vice versa, equal to the difference in percentage between used and new passenger cars sold in year z. This discount assumes that demand of used versus new cars reflects the consumers preference for car age (model) in a certain year. An illustrative example is presented in **Table 15:** Illustrative example for distribution of 2013 used cars sold by model years**Table 15**. The calculation of NO_x emissions for each share is done using the same framework given in **Figure 17** for new passenger cars.

Table 15: Illustrative example for distribution of 2013 used cars sold by model years.

Distribution of Used Imported Cars Sold in 2013	**Model Year**								**Sum (Used Cars Sold in 2013)**
	2012	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	
Equal share distribution	3,875								**31,000**
Difference in % of used versus new cars sold in 2013 (discount in favor of new passenger cars)	**- 0.98%**								
Distribution discounted with 0.98% in favor of new models	3,875	3,837.025	3,799.422	3,762.188	3,725.318	3,688.81	3,652.66	3,616.864	29,957.29
Distribution corrected based on total used car sold	4,010	3,970	3,932	3,893	3,855	3,817	3,780	3,743	**31,000**

Additional assumptions adopted in this calculation are presented in **Table 16Table 16**.

Table 16: Assumptions applied for the computation of NO_x emissions from used passenger cars sold.

Assumption	Reasoning Supporting Assumption	Implication of Assumption on Calculation	Reference
Car importers in Lebanon respond to the actual car demand of the Lebanese market	The average percentage of used cars sold between 2009 till 2012 equals 90% of the total used cars imported, calculated after correcting for the percentage of new passenger cars sold from total imported passenger cars.	The percentage of used cars sold from the total number of cars imported fluctuates slightly during the studied period.	Total passenger cars imported from 2007 till 2010: Ministry of Finance, 2011 Table 4 p.9 Total Passenger cars imported starting 2011 onwards: BLOMInvest, 2018; Byblos Bank, 2019 Used Passenger Cars sold from 2009 till 2014: BLOMInvest, 2015. New passenger Cars sold from 2009 till 2014: BankMed, 2013 & CEIC, 2014 & BankMed, 2016
The used passenger cars sold in a certain year from used cars imported in preceding years are considered a small share of the total used cars sold in that year	High percentage of sales from imports	The NO_x emissions of used passenger cars sold in a certain year from used cars imported in preceding years are not accounted for in this calculation.	
The distribution of the shares of used cars sold per car brands for the years 2008 till 2018 is assumed to be like the ones figuring for the model years when first	The distribution of brands per year for new passenger cars sold is considered representative of the success of certain brands in a certain year based on design.	Share of used cars sold from a model year (for z-1 for instance) have equal distribution per brands & engine size as for new passenger	

Assumption	Reasoning Supporting Assumption	Implication of Assumption on Calculation	Reference
manufactured (new passenger cars sold)		cars of the same year (z-1)	
The distribution of the shares of used cars sold per car brands for the years 2000 till 2010 is assumed like the ones figuring for the average model years 2008 till 2010 when first manufactured	The shift in market demand for smaller cars did not pick up before 2011 (Byblos Bank, 2019).	For the model years 2000 till 2007, the distribution of brands per year is adopted from the average of years 2008 till 2010	

The data used to apply equation 1 are presented in **Table 17**.

Table 17: Calculation details for NO_x emissions from used imported passenger cars sold.

Data Type	Calculation Method	Data Source
Total number of used imported passenger cars sold in a year	2007-2008 & 2015 till 2018 values: Calculated as % of used cars sold from total cars imported based on: Average % cars sold from imported cars for 2009 till 2014 minus % of new cars sold from total cars imported in a particular year. 2009 till 2014: Direct value from source	Total passenger cars imported from 2007 till 2010: Ministry of Finance, 2011 Table 4 p.9 Passenger cars imported starting 2011 onwards: BLOMINVEST, 2018; Byblos Bank, 2019 2009 till 2014: BLOMInvest, 2015.
Distribution of each share of used model year sold (z-1 to z-8) per car brand (%)	Year 2000 till 2007: Assumed equal to average distribution per brand for years 2008 till 2010. Years 2008 till 2018: Assumed like brands distribution for new	Assumptions

	passenger cars sold in each respective year	
Distribution of engine size for car sold from a model year (z-1 to z-8)	Years 2000 – 2007: Assumed equal to average distribution of used cars sold per engine size from 2008 till 2010. Years 2008 till 2010: Assumed equal to the % distribution per engine size of used cars imported in the indicated years. Year 2011 till 2018: 90% share estimated for small engine size and 5% for each of the medium and big engine size categories	Year 2000 till 2007: Assumption based on change in demand trend starting 2011 (Cochrane, 2020; Byblos Bank, 2019) Years 2008 till 2010: % share of imported used cars per engine size is adapted from Ministry of Finance, 2011 Table 2 p.7 of car specifications at imports, assuming percentage share in LL billion reflective of % share of number of cars imported & distribution of imported cars per engine size reflects market demand and hence engine size distribution of sold vehicles. Years 2011 till 2018: Assumption based on change in demand trend towards small engine size cars starting 2011 (Byblos Bank, 2019 and Cochrane, 2020;)
Tailpipe NO_x emissions reported by car manufacturers for car brands and models under controlled conditions	- Calculated average value in mg/km per car model and engine size for years 2000 till 2014. - Value calculated in 2014 is adopted for 2015 till 2018 as considered to be reflective of the latest NO_x emissions Euro standard applied.	Emissions Finder, 2014
Chinese standard tailpipe emissions for passenger cars	Direct value from Chinese standards 3, 4 & 5 for gasoline passenger cars	Transportpolicey.net, 2018
Average yearly travelled distance by a personally owned passenger car in Lebanon	12,000 Km/year	MoE/UNDP/GEF, 2015

4.2.1.3. Change from Baseline of Annual NO_x Emissions from Passenger Cars During the Period 2007-2018

The change in passenger cars' NO_x emissions in an indicated year between 2007 and 2018 compared to a 2006 total baseline value of these cars' emissions is calculated as: The sum of emissions from the total number of new and used passenger cars sold preceding that year, starting with 2007, and of the total emissions from new and used passenger cars sold in the said year. These numbers are corrected, preceding addition, by an increased rate of 33% to reflect the discrepancy between the NO_x emissions for car models reported by car manufacturers under controlled conditions, and the actual emissions for these models tested under real driving conditions (Transport & Environment, 2018). This calculation assumes that cars sold in previous years will still be in circulation, adding to the number of cars sold and emissions generated in a certain year, and affecting the concentrations of NO_x in the ambient air around roads. Baseline NO_x emissions for vehicles circulating on the Lebanese roads in 2006 is adopted from MoE/UNDP/GEF, 2015 and estimated at around 37.39 Gg (p.28, calculated from Figure 17 parameters in indicated reference). It is however to be noted that the calculation method for the 2006 baseline differs from the one adopted in this study. It is based on the default NO_x emission factors for fuel provided by the Intergovernmental Panel on Climate Change (IPCC), and accounts for the high probability in Lebanon to take out the technologies that regulate emissions and that are initially built-in vehicles during manufacturing, before selling these vehicles (ibid). This baseline value is not added to the calculation. However, it is used to compare total NO_x emissions from land transport until 2006 with available reported NO_x concentrations in GBA and other cities before and after 2006.

Table 18Table 18 presents the annual change from the 2006 baseline of NO_x emitted by new and used imported passenger cars sold starting 2007 with a 33% correction for real driving conditions.

Table 18: Difference from baseline of NO_x emissions from passenger cars sold.

Year	NO_x Emissions in Tons (Difference from 2006 Baseline – value rounded)
2007	30.11
2008	86.41
2009	151.05
2010	212.72
2011	251.64
2012	282.89
2013	305.82
2014	327.42
2015	351.36
2016	376.13
2017	401.37
2018	**423.21**

4.2.2. Change from baseline in MoPH Subsidized Hospitalized Diagnosis for Respiratory & Circulatory Diseases

Annual MoPH subsidized hospitalized diagnosis for respiratory and circulatory diseases for the period 2006 till 2018 are compiled from MoPH statistical bulletins (MoPH, 2018 - statistical bulletins from 2006 till 2018 available at: https://www.moph.gov.lb/en/Pages/8/327/statistical-bulletins). The difference in the number of yearly admissions from the 2006 value by category of disease is then calculated for each year between 2007 and 2018. **Table 19** below shows the results of this computation.

4.2.3. Correlation between NO_x emissions and hospital admissions

As previously noted in the main introduction to this chapter, a significant number of studies has been testing the correlation between an increase in air pollutants' concentrations and changes in hospitalization statistics for a set of respiratory and circulatory illnesses. These studies are often designed as to investigate the influence of a specific increase (often 10 µg/m^3) in one or multiple air pollutants' concentrations on changes in the relative risk of hospitalization for these diseases, using statistical functions (see Ab Manan, Noor Aizuddin and Hod, 2018 for a thorough review of 175 related epidemiological studies). Additionally, specific considerations are often given for 3 key factors to ensure the plausibility of the proposed study design and its associated results: Meteorological conditions; hospital admissions collected for a distinct group/ population over a studied timeframe; and short or long-term repetitive exposure of the target group to high concentrations of studied air pollutant(s) (ibid).This sub-section adopts a simpler approach to explore the pre-mentioned association, shaped by the limited specificity of the available dataset.

This approach seeks to shed light on the link between air pollution and health in a specific context without claiming an equal level of precision as to the results from specifically designed epidemiological studies. It builds its plausibility by using proxies and assumptions to build the case around the previously mentioned key factors, and to frame the context of this investigated relationship. It does not attempt to identify an excess concentration dose by which a higher risk on hospital admissions for specific diseases can be observed. It rather gives an indication on the effect of high levels of air pollution amplified by transportation on the increase in hospitalized diagnosis by category of circulatory and respiratory diseases. Hence, this computation uses NO_x emissions from passenger cars as proxies for concentration levels of these pollutants in cities and near busy roads since data for concentrations were not accessible for recent years. However, this study considers that NO_2 concentrations starting 2007 onwards are highly likely to be almost at, or exceeding 40 µg/m^3, a threshold above which long-term exposure to NO_2 concentrations is suspected to have negative impacts on health (WHO, 2013). This assumption is backed by the concentrations of NO_2 reported for the GBA from 2004 till 2014 that are either nearing or above this level (MoE, 2017, Figure 3), as well as by the concentration levels recorded in Zahleh and El Hadath in 2014 that exceeded this level by 10 and 9 µg/m^3 respectively (MoE, 2017). Hence this study considers that any addition to the baseline NO_x emissions of 2006 previously reported contributes to NO_2 concentrations above 40 µg/m^3. The choice of 2006 as a start year (baseline) in

this computation is not meant as to present a minimum threshold value for which NO_x concentrations are at a level where no increase in hospitalization for the studied categories of diseases can be statistically inferred to. In fact, 2006 was marked by a war in Lebanon, during the second half of the year, which gives reasoning to assume that NO_x emissions were generated from multiple sources during that year (adding to common sources of emissions) and likely resulted in high concentrations of NO_x in the atmosphere. 2006 is thus chosen as a start date (and not a reference point) with records for NO_x emissions representing one point in time preceded and followed by continuous build-up of NO_x pollution levels in the atmosphere. This choice of baseline year is solely due to the availability of data for emissions and hospital admissions starting this date. As previously stated, NO_x emissions in this calculation are considered as proxies for other air pollutants that affect the respiratory and circulatory systems since it is very unlikely to single out the effects of one type of pollutant on health from the impact of other ambient air pollutants.
The three previously noted key factors are addressed in this study by adopting the following arguments:

a) Meteorological conditions. This study is not measuring the concentrations of NO_x in a particular moment in time, but rather adopts changes in NO_x emissions' yearly values based on a fixed average travelled distance by passenger cars in circulation. The latter inherently assumes an equal distribution of emissions and exposure probability per km of distance travelled, per time unit, over one year. Consequently, the impact of meteorological conditions on the speed of dispersion of NO_x emitted from passenger cars in circulation in one year, and thus on the main changing trend of NO_x concentrations due to these emissions over different times in a said year, as well as on the yearly pattern of people's exposure to these concentrations, is assumed to have less influence compared to that of the quantities of pollutants emitted. The natural alternation of these meteorological conditions under a Mediterranean climate in between seasons over the course of one year, as well as the several year-period considered, give plausibility to this assumption. Although, this study recognizes a margin of error to this claim as dominant summer weather conditions over the eastern Mediterranean, such as in Lebanon, are shown to increase the accumulation of pollutant concentrations (Dulac, et al., 2016).

b) Identification of a distinct group/population to study. The dataset for recorded hospitalized cases used in this correlation concerns specific categories of circulatory and respiratory diseases, which frames this dataset to a share of the population that initially suffers from these diseases. Additionally, the hospitalized diagnosis for these diseases in the used dataset only concern the ones subsidized by the Ministry of Public Health. This type of health coverage is used by a share of the Lebanese population who cannot afford any of the coverage costs or are not eligible for any of the other health coverage types such as the National Social Security Fund (NSSF) or private insurance companies (World Bank, 2017). The percentage of the uncovered Lebanese population who would potentially have recourse to this last resort to subsidize their health bill was reported at 52.3% in 1998 (Ammar, 2003, p.33) and at 33.8% in 2019 (CAS/ILO, 2020, p.79), hence ranging from 1,180,809 persons in 1998 (based on total population – including Palestinian residents in 1998 given in World Bank, 1998 and corrected for 200,000 estimated Palestinian residents in Lebanon in 1997, value reported in Lebanese Palestinian Dialogue Committee, Central Administration of statistics and Palestinian Central Bureau of Statistics, 2018, p.9.) to 1,536,757 persons in 2019 (based on total Lebanese population in 2019 given in MoPH, 2019 – Statistical Bulletin 2019, p.13). Considering the 2 types of vulnerabilities – existing health condition and disadvantaged economic conditions - that characterize the group of people for which the hospitalized diagnosis records are investigated in this correlation, a targeted, and relatively highly unchanged group of studied people is thus assumed.

c) Short or long-term repetitive exposure of target group to high concentrations of studied air pollutant(s).This study assumes a high likelihood of long-term repetitive exposure of a major part of the target group to high concentrations of NO_x during the studied period (2007-2019) due to a combination of numerous factors: The percentage of the Lebanese population residing in or daily commuting to major cities is very high; high traffic on roads in and at cities' entrances; high average road travel time of a person's day-hours in Lebanon (see the introduction of this chapter); and the locality and nearness of the sources of NO_x emissions used in this correlation to the people circulating on roads.

Hence, based on all that preceded, the impact of repetitive long-term exposure to built-up NO_x concentrations around busy roads in and outside cities, on the increased need for hospitalization for a vulnerable group of Lebanese population is investigated using the following variables, tested for their correlation with Spearman's Rank Correlation Coefficient (R_s):

- X: An independent variable that is equal to the change in passenger cars' NO_x emitted between 2007 and 2018 compared to a 2006 total baseline value (see sub-section 4.2.1.3)
- Y: A dependent variable that is equal to the change in MoPH subsidized hospitalized diagnosis for respiratory and circulatory diseases between 2007 and 2018 compared to a 2006 baseline value (see sub-section 4.2.2)

R_s is chosen since the studied datasets do not present a normal distribution. R_s values exceeding 0.8 are tested for their statistical significance using the probability value (p-value). The simple linear regression assumption for the corresponding datasets is tested through residual plots and linear regression equations are then thus generated for each correlated dataset presenting $R_s>0.8$ with strong and very strong significance value. **Table 20Error! Reference source not found.** below presents the categories of circulatory and respiratory diseases that show high correlation with NO_x emissions.

Table 19: Difference from 2006 baseline in number of MoPH subsidized hospitalized cases per category of disease.

Category of Disease	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Tuberculosis	-14	1	6	-10	-11	-15	-17	4	37	13	8	6
Neoplasm-Respiratory and intrathoracic organs	-353	-56	134	185	297	371	273	47	706	436	722	536
Acute rheumatic fever	-2	-14	-22	-22	-35	-31	-32	-25	31	-33	-43	-51
Chronic rheumatic heart disease	28	24	12	11	0	-16	-29	18	224	107	53	15
Hypertensive diseases	832	1214	1369	2019	2197	1377	1846	3265	6213	7211	7583	7347
Ischemic heart diseases	1320	2326	3214	3824	3123	2060	2365	2233	4069	4763	5642	6885
Pulmonary heart disease and diseases of the pulmonary circulation	-22	-5	4	-11	-1	-7	-2	39	122	81	79	98
Other forms of heart disease	293	662	753	1015	1213	988	823	2137	4964	4333	4404	4030
Cerebrovascular diseases	24	130	180	369	444	475	469	405	719	632	549	587
Diseases of arteries, arterioles and capillaries	85	52	144	158	229	223	164	142	653	585	416	508
Diseases of veins, lymphatic vessels and lymph nodes NEC	169	312	428	385	344	182	246	237	654	661	498	533
Other and unspecified disorders of the circulatory system	6	30	36	15	50	44	71	88	158	191	226	207
Acute upper respiratory infections	234	505	604	527	482	791	644	1029	1692	1623	1183	1089
Influenza and pneumonia	774	1172	2535	1701	2786	2182	1746	1446	4565	4870	1971	2000
Other acute lower respiratory infections	90	258	586	342	1116	735	1063	1698	3095	3201	1714	1530
Other diseases of upper respiratory tract	769	1361	918	693	1086	580	536	848	1351	1062	665	398
Chronic lower respiratory diseases	259	502	930	925	1422	1020	1641	1804	3610	3670	3217	3363
Lung diseases due to external agents	-68	-83	-86	-133	-132	-120	-120	-106	-62	-104	-77	-90
Other resp. diseases principally affecting interstitium	88	243	345	338	351	639	398	-39	452	427	338	224
Suppurative and necrotic conditions of lower RT	17	3	0	6	-2	3	2	-1	25	13	11	21
Other diseases of plura	9	-14	-68	-29	-7	11	9	150	652	578	479	413
Other diseases of the respiratory system	-72	45	-61	49	84	128	192	274	584	527	424	423

Table 20: Correlation Statistics.

Category of Disease	Neoplasm-Respiratory and intrathoracic organs	Hypertensive diseases	Other forms of heart disease	Cerebrovascular diseases	Other and unspecified disorders of the circulatory system	Chronic lower respiratory diseases	Other diseases of the respiratory system
Spearman Correlation Coefficient Rs	0.839	0.937	0.874	0.888	0.965	0.93	0.92
p-value for n-2 (n=sample size)	<0.1% (indicative of very strong and stastistically significant correlation)	<0.1% (indicative of very strong and stastistically significant correlation)	0.1% (indicative of very strong and stastistically significant correlation)	0.1% (indicative of very strong and stastistically significant correlation)	<0.1% (indicative of very strong and stastistically significant correlation)	<0.1% (indicative of very strong and stastistically significant correlation)	<0.1% (indicative of very strong and stastistically significant correlation)
Single linear regression equation	y = 2.1589x - 300.91	y = 17.787x - 1204	y = 11.309x - 881.27	y = 1.5677x - 2.8317	y = 0.5423x - 51.126	y = 8.8644x - 500.37	y = 1.5603x - 199.68
R-squared value (causal share attributed to x for y)	$R^2 = 0.7481$	$R^2 = 0.6756$	$R^2 = 0.6444$	$R^2 = 0.8712$	$R^2 = 0.7223$	$R^2 = 0.7719$	$R^2 = 0.7433$

4.2.4. NO_x Removal by Trees in Proximity to Emission Sources

An abundant body of literature has tested the interactions between atmospheric pollutants and trees. Nitrogen oxides for instance were proven to be absorbed by tree leaves' stomata as a main gateway for these gases' removal from the ambient air (Nasrullah, et al., 2000; Chaparro-Suarez, Meixner, and Kesselmeier, 2011; Zhang, et al., 2020) but also may be deposited on leave and other tree parts such as the apoplast, the stems and roots (Hu, Fernàndez and Ma, 2014), hence reducing their concentrations in the atmosphere. However, the deposition of pollutants' particles on tree parts is often temporary since changing weather conditions highly influence its durability on these retention sites. The latter makes the absorption through leaf stomata, the most impactful filtering mechanism for pollutants such as NO_x from the atmosphere (Nowak, et al., 2014).

Additionally, this service provided by trees is conditioned with their proximity to high NO_x concentration areas and thus to emission sources; this condition is linked to the high reactivity of NO_x and to the attenuation of their levels with distance, to background atmospheric concentrations (WHO, 2013), which renders this service provided by trees insignificant beyond a certain buffer from emission sources. NO_x concentrations are found to be significant within 200 m from busy roads when tested in upwind locations and up to 500 m downwind of expressways (WHO, 2013). The computation of NO_x removed by trees in this study will adopt a zone of influence up to 200 m buffer from roads since Lebanon's roads' infrastructure is not comparable to expressways, and upwind and downwind directions from roads vary between different months in a single year.

Although NO_x emissions refer to both NO_2 and NO gases, this calculation will solely account for the absorption of NO_2 gas and considers the one for NO less significant in comparison. This assumption is undertaken since numerous studies showed differences in the range of sorption by plants up to 70% for NO_2 compared to NO (Zhang, et al., 2020), and data on mass of NO absorbed by tree cover are scarce. Thus, the discussion on the quantity of NO_2 absorbed by trees in this study is assumed to be representative of a lower threshold of their total NO_x absorption. Considering that MoPH subsidized hospitalized diagnosis were correlated with NO_x emissions from passenger cars expressed in tons in section 4.2.3, and not with changes in NO_2 concentrations (as the latter were not available or accessible to this study) , the calculation of NO_2 removed by tree leaves should be expressed as a mass unit (i.e., grams or tons), to be able to compare these values with the ones for emissions, as shown in the following sections. Considering the latter requirement, as well as the impossibility to follow the common approach of calculating NO_2 absorbed by the leaves of the studied tree cover using NO_2 concentrations around busy roads and deposition velocity factors among others, this study adopts a value of 0.7 grams of NO_2 removed per square meter of tree canopy cover per year as a representative order of magnitude of NO_2 absorption by the existing tree canopy cover within 200 m buffer from busy roads in Lebanon. This value is transferred from a study by Nowak, et al. (2014) p.126. These authors calculated this value as representative of the average yearly value of NO_2 permanently removed from the atmosphere by the existent tree canopy cover in the urban areas of all the United States in 2010, using remote sensing and field data. This study recognizes that differences in tree species characteristics, NO_2 concentrations and weather conditions between the United States and Lebanon inherently creates a margin of error to the precision of this value to the Lebanese context. However, this value is deemed by this study to be representative of a potential magnitude of NO_2 absorption by the targeted canopy cover, and supports the discussed hypothesis throughout this chapter, without seeking a high level of precision that can only be met at a narrow site level and with intensive field data collection.

Only areas covered by trees within the previously discussed buffer zone from busy roads will be accounted for in the calculated results. Busy roads are defined in this study as belonging to the following categories: International roads; primary roads; secondary roads; and local roads inside Beirut Governorate, Tripoli, Jounieh, Zahleh, Saida, Sour, Nabatiye et Tahta and Habbouch urban agglomerations. Consideration for local roads in the cited cities was undertaken since these urban areas have high population densities (World Population Review, 2020), reflecting higher traffic probabilities and higher pollutants' concentrations within their boundaries. To calculate the area of the tree canopy cover (TCC_a) within 200 m from the pre-mentioned roads, tree stands surface areas within the identified buffer are extracted from the results of the 2019 forest cover mapping exercise (whether these areas constitute a part of a forest area or don't fulfill this definition) and multiplied by the fraction of vegetation cover f_c, as given in equation 2 below.

$TCC_a = f_c$ *Area of tree stands (2)

f_c is calculated using Equation 3 below, based on freely available 2019 Sentinel 2 satellite images for Lebanon covering the months of June and July from the Copernicus Programme. The later months are chosen to better reflect the peak of greenness period in Lebanon and maximum tree leaf areas.

f_c = (NDVI – NDVIs) / (NDVIv – NDVIs) (3) (Zhang, et al., 2019, p.6)

Where

NDVI: Normalized Difference Vegetation Index. NDVI = (NIR - R) / (NIR + R) (Zhang, et al., 2019, p.6). NIR = Near Infrared Band. R= Red Band.
NDVIs: Normalized Difference Vegetation Index corresponding to bare soil.
NDVIv: Normalized Difference Vegetation Index corresponding to forest areas.
Error! Reference source not found.
Thus, by applying equations 2 and 3, this study estimated the existing 2019 tree canopy cover area within 200 m buffer from busy roads to be 95,766,903 m^2. These areas can thus potentially absorb 67.03 tons of NO_2 (assuming removal of 0.7 grams of NO_2 per m^2 of canopy cover as discussed in this section).

4.2.5. Distribution of the cost of air pollution from NO_x emissions on Lebanese stakeholders

The regression equations previously presented in sub-section 4.2.3 and that highlight the association between NO_x emissions and hospital admissions for certain respiratory and circulatory diseases are used to calculate the change in MoPH subsidized hospitalized diagnosis from 2006 due to an additional 13.45 tons of NO_x emitted in 2019. This value is considered as a maximum threshold for NO_x emissions from new and used passenger cars sold in Lebanon in 2019. In the absence of data on the number of used passenger cars sold in 2019 as well as on their distribution by brand, this value is deduced by assuming a 38.4 % drop of NO_x emitted from new and used passenger cars sold in 2019 compared to the values previously calculated for 2018. This drop is set based on the calculation of NO_x emissions from 21,991 new passenger cars sold in 2019 (italpress, 2020) by applying the equations in **Figure 17** under subsection 4.2.1 and comparing the result to the emissions of new passenger cars sold in 2018. This reduction in percentage is thus considered to be applicable as well to the used passenger cars sold in Lebanon in 2019 as the reduction in car sales is reported to be linked to the worsening economic situation in Lebanon in 2019 (italpress, 2020). The calculated 13.45 tons are then added to the excess of NO_x emissions from 2006 calculated for the year 2018. This addition is meant to reflect the potential impact of an increase in NO_x emissions from circulation in 2019 on hospitalization needs, accounting for built-up pollution levels from preceding years, and assuming the absence of any air enhancement service provided by the existing tree cover within 200 m buffer from busy roads. **Table 21** presents the details of this calculation.

Thus, in the absence of any service provided by trees, an additional 13.45 tons of NO_x emitted from new and used passenger cars sold in 2019 is estimated to potentially increase the number of MoPH subsidized hospitalized diagnosis for a select set of circulatory and respiratory diseases by 11,215.88 admissions compared to a 2006 baseline value. This potential burden is undertaken by two stakeholders: The Ministry of Public Health and the hospitalized patients who constitute part of the disadvantaged segment of the Lebanese population. These potential costs include the hospitalization bill (drugs are not included as they are not covered by MoPH) and the loss of wages undertaken by the prementioned patients due to their stay in hospitals (days of inactivity following discharge from hospitals are not accounted for in this calculation).

The minimum monthly wage value in Lebanon is used to estimate the value of working days lost as the concerned population is considered to represent a segment of the population with modest economic capacities. Although the cost of hospitalization differs per case, treatment and length of stay, an average value for hospitalization in 2019 is used to calculate part of the costs associated to an additional 13.45 tons of NO_x emitted in 2019. This is due to the lack of specificity in the used dataset that refers to categories of diseases and not to a specific disease. This argument also applies for the length of stay in hospitals. **Table 22Error! Reference source not found.** provides the details of this calculation.

Table 21: Application of regression equations based on 13.45 additional tons of NOx emitted in 2019.

Category of Disease	Neoplasm-Respiratory and intrathoracic organs	Hypertensive diseases	Other forms of heart disease	Cerebrovascular diseases	Other and unspecified disorders of the circulatory system	Chronic lower respiratory diseases	Other diseases of the respiratory system
Single linear regression equation	y = 2.1589x - 300.91	y = 17.787x - 1204	y = 11.309x - 881.27	y = 1.5677x - 2.8317	y = 0.5423x - 51.126	y = 8.8644x - 500.37	y = 1.5603x - 199.68
R-squared value (causal share attributed to x for y)	$R^2 = 0.7481$	$R^2 = 0.6756$	$R^2 = 0.6444$	$R^2 = 0.8712$	$R^2 = 0.7223$	$R^2 = 0.7719$	$R^2 = 0.7433$
Incremental NOx emissions from 2006 accounting for 13.45 additional tons of emissions in 2019 (2018 incremental NOx value + 13.45 tons)	**436.66**						
Incremental MoPH subsidized hospitalized diagnosis from 2006 value for 13.45 additional tons of NOx emitted in 2019 (calculated by applying regression equation) (value rounded)	641.8	6,562.87	4,056.92	681.72	185.67	3,370.36	481.64
Incremental MoPH subsidized hospitalized diagnosis from 2006 value for 13.45 additional tons of NOx emitted in 2019 (corrected share using R-squared value)	480.13	4,433.87	2,614.28	593.91	134.11	2,601.58	358
Incremental MoPH subsidized hospitalized diagnosis from 2006 value for 13.45 additional tons of NOx emitted in 2019 (all diseases)	**11,215.88**						

Table 22: Calculation of the costs inflicted by 13.45 additional tons of NO_x emitted in 2019.

Parameter	Value	Calculation Method / Consulted Reference
Hospitalization cost in public and private hospitals undertaken by MoPH in 2018 (LBP)	465,000,000,000	Direct Value / MoPH, 2018 - Statistical Bulletin 2018, p.7 found via https://moph.gov.lb/en/Pages/8/327/statistical-bulletins
Hospitalization cost in public and private hospitals undertaken by MoPH in 2018 (2018 USD)	308,457,711.4	Calculated: Hospitalization cost covered by MoPH in LBP /1507.5 (Banque Du Liban official LBP-USD conversion Rate, Banque Du Liban, 2019)
Total number of MoPH subsidized hospitalized diagnosis in 2018	322,591	Direct Value / MoPH, 2018 - Statistical Bulletin 2018, p.35 found via https://moph.gov.lb/en/Pages/8/327/statistical-bulletins
Cost of 1 MoPH subsidized hospitalized diagnosis in 2018 (rounded - 2018USD)	956.19	Calculated (Hospitalization cost in 2018 USD / Total Number of hospitalized diagnoses in 2018)
Cost of 1 MoPH subsidized hospitalized diagnosis in 2019 (rounded - 2019 USD)	889.26	Calculated (Equal to Cost of 1 diagnosis in 2018 deflated using % change of consumer price index from year 2018 (7%) found at (IMF, 2019). LBP to USD conversion rate is similar for 2018 and 2019
Cost of 1 hospitalized diagnosis in 2019 undertaken by a patient as co-payment for MoPH covered cost (2019 USD)	889.26*0.15/0.85 = 156.93	Calculated based on the cost of 1 MoPH subsidized hospitalized diagnosis in 2019 assuming each admission refers to a unique patient (MoPH covers 85% of total cost of a hospital admission and the remaining 15% are covered by the patient (Ammar, 2003)
Average length of stay for MoPH subsidized hospital admission (days)	4.25	(Ammar, 2003, p.39 - value reported in 1998)

Parameter	Value	Calculation Method / Consulted Reference
H = Total potential incremental MoPH subsidized hospitalized diagnosis from 2006 for 13.45 additional tons of NO_x emitted in 2019 (all diseases)	11,215.88	
Cost of one day of work lost by a patient in 2019 due to hospital stay (2019 USD)	18.54	Calculated: Official minimum monthly wage 445$ (2019 USD) divided by 24 working days per month - Source for minimum wage (CAS/ILO,2020, p.16)
Cost of hospitalization (undertaken by MoPH) for H (2019 USD)	9,973,833.4488	Calculated: Cost of 1 MoPH subsidized hospitalized diagnosis in 2019 * H / Assumption: each hospital admission corresponds to a singular patient
Cost of hospitalization (undertaken by patients) for H (2019 USD)	1,760,108.0484	Calculated: Cost of 1 hospitalized diagnosis in 2019 undertaken by a patient as co-payment for MoPH covered cost (2019 USD) * H / Assumption: each hospital admission corresponds to a singular patient
Loss of wage (undertaken by patients) due to days of stay in hospital calculated for H (2019 USD)	883,755.2646	Calculated: Cost of 1 day of work lost by a patient due to hospitalization * Average length of stay for MoPH subsidized hospital admission (days) * H (Assumption: each hospital admission corresponds to a singular patient)

Parameter	Value	Calculation Method / Consulted Reference
Loss of wage (undertaken by patients) due to days of stay in hospital calculated for H and corrected for probability of patient being part of the labor force in 2019 (2019 USD – value rounded)	714,692.8825	Calculated: Loss of wage (undertaken by patient) due to days of stay in hospital calculated for H * percentage of working age population in 2019 from total 2019 population. Data Source / Working age population in 2019 (>=15 years): 3,677,100 (CAS/ILO,2020, p.6) -Total Lebanese resident population in 2019: 4,546,618 (MoPH, 2019 - Statistical Bulletin 2019, p.13 found via https://moph.gov.lb/en/Pages/8/327/statistical-bulletins). Assumption: Distribution of age groups for people seeking MoPH coverage is like the distribution of age groups in the population
Total Cost (undertaken by MoPH and by patients) due to H (2019 USD – value rounded)	**12,448,634.38**	

4.2.6. Value of Air Quality Enhancement Service Provided by Trees

The value of air quality enhancement service provided by trees at proximity to busy roads, inside and outside the main urban areas, is estimated in this study from a potential avoided cost associated with an amount of NO_x emitted from land transport vehicles and that can be potentially removed from the atmosphere through these trees' absorption mechanism. This service gains in likelihood with built-up concentrations of NO_x in the atmosphere due to the yearly increase in vehicle fleet in circulation in Lebanon. It is important to reiterate that this study assumes that the concentrations of NO_2 over busy roads and in cities with high population densities are already around 40 µg/m^3 and that additional NO_x emissions are adding to the long-term risk of exposure to even higher levels of NO_2 near emission sources (see section 4.2.3), thus the need and relevance of this air quality enhancement service. Yet, this study doesn't identify a value for the incremental change in NO_2 concentration levels above which a high correlation with incidences of respiratory and circulatory diseases is detected. Also, it uses NO_x as proxy to other pollutants from the transportation sector that can collectively be associated with the detected correlation with the studied hospital admissions of circulatory and respiratory diseases. Based on the above, the probability of a potential service provided by the existing studied tree cover increases towards the highest amounts of emissions recorded. This potential service can be expressed as a potential avoided cost on several stakeholders. The incremental value from a 2006 baseline of NO_x emitted by cars sold in 2019 is calculated at 436.66 tons (see section 4.2.5) and can be potentially associated with 11,215.88 hospital admissions (see **Table 21**). The existing targeted tree canopy cover can potentially remove 67.03 tons of NO_2 by the end of 2019, thus presumably decreasing the incremental 2019 NO_x emissions values in the atmosphere starting year 2020[6] to 369.63 tons. The latter can be associated with 9159.43 hospital admissions by applying the equations in **Table 21**. Thus, trees through their absorption mechanism can potentially contribute to the avoidance of 2056.45 hospital admissions starting year 2020, if all the purchased cars up to 2019 continue to be in circulation and the frequency of trips remains high. By applying the same calculation parameters as presented in **Table 22**, the estimated potential avoided costs, and thus the potential value of the air quality enhancement service associated with pollution from vehicle emissions is 2,282,477 $ (value rounded). Based on the distribution of stakeholders and costs presented in **Table 22**, the Ministry of Public Health (and thus the national economy) can potentially benefit from an avoided burden amounting for 80.12% of this value (1,828,720 $) in a year, while a vulnerable group of the Lebanese population can potentially benefit from an avoided burden of 453,757$ per year (19.88% of value), through the conservation of this service of the existing tree canopy cover.

Finally, it is to be noted that the calculated value of air quality enhancement service assumes a potential collective service provided by all trees located within 200 m from busy roads[7] that would capture part of the NO_x emissions released by vehicles in circulation all year long and impact the health burden on all stakeholders. This value, being built on the assumption of a collective impact of NO_x uptake by trees, cannot thus be expressed in USD per unit area of tree canopy cover and distributed geographically by district, as is the case with the forest ecosystem services presented in the first 3 chapters of this study.

4.3. Importance of the Air Quality Enhancement Service

The valuation of air quality enhancement service provided by trees and presented above showcases the potential role of a strategically located tree cover (near busy roads and in areas of high population densities) to reduce the economic burden on the national economy and on vulnerable households, by possibly reducing the health bill associated with air pollution from transportation. The values calculated above constitute a lower threshold for this service since they only concern 33.8% of the Lebanese population in 2019, and do not account for the health bill of patients suffering from the studied circulatory and respiratory diseases and who are covered by other health coverage schemes. Hence, this implicates the existence of additional categories of beneficiaries from this air quality enhancement service such as a wider range of patients, as well as private insurance companies. Although the calculated value of this service is only meant to be indicative of a potential average yearly benefit from conserving the existing tree cover, it can be argued that this value will conserve its significance, despite the devaluation of the local currency and the current and mid-term foreseen economic and financial situations in Lebanon. In fact, the number of Lebanese people that will most probably fall under the category of “disadvantaged segment of

[6] Trees are assumed to need a certain period to filter NO_x from the atmosphere, which results in people being exposed to high levels of NO_x emissions before the latter being reduced from the atmosphere. The full service provided by a certain tree cover is thus assumed to be best reflected in the year following the emissions.

[7] Tree stands might include orchard trees.

the Lebanese population" as defined in this study (without health coverage and with high disposition to respiratory and circulatory diseases) will highly likely increase in 2020 and beyond under the current and forecasted national economic hardships and COVID-19 pandemic, due to 2 main reasons: The unemployment rate is forecasted to increase in Lebanon in 2020 and beyond, with estimations reaching 40% of the workforce in Lebanon in 2020 (FAO, 2020) supporting the assumption that more people will need to rely on the MoPH support for their health coverage, having lost their legibility or their ability to have or purchase other forms of health coverages; and the long-term adverse impact of COVID-19 on health, increasing damages in the heart and the lungs (Brunekreef, et al., 2021) and making more people predisposed to the effects of air pollution. Additionally, although the calculated value for the air quality enhancement service assumes the 2019 vehicle emission trends as minimum emission trends from transportation, and decreasing traffic instances might be observed due to the worsening economic situation and COVID-19 movement restrictions, this service provided by trees will conserve its relevance in the future in the absence of reliable public transportation means, and with any future improvements that might occur in the economic sectors.

4.4. Conclusion

This chapter aimed at computing part of the potential economic value of the air quality enhancement service provided by the existing 2019 tree canopy cover within a 200 m influence zone from busy roads in and outside the main cities in Lebanon, specifically perceived from its filtering potential of NO_x emissions from the transportation sector in Lebanon. It argued that the indicated tree canopy cover could possibly remove 66.03 tons of NO_2 emissions, and thus potentially avoid 2056.45 projected hospital admissions associated with a selected set of circulatory and respiratory diseases. It hence estimated a yearly minimum potential avoided economic burden on the national economy and on a vulnerable segment of the Lebanese population starting 2020 to be 2,282,477 $. It thus made the case for the added value of this nature-based solution to protect people's quality of life, especially with the increasing stress on people's livelihoods due to the current economic crisis in Lebanon.

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III. Annexes

Annex 1

Forest Tourism Survey

This survey was developed under the USAID-funded "Livelihood in Forestry" project implemented by the Lebanon Reforestation Initiative NGO. The purpose of this survey is to calculate the value generated within forest nature reserves and protected areas as well as in the villages surrounding them. It is part of an ongoing study to value forest ecosystem services in Lebanon and highlight their importance to human well-being. Ultimately the results will be used to support forest conservation and reforestation efforts. The survey is 5 minutes long and inquires about the respondents' most recent trip to a forest nature reserve/protected area between 2016 and 2019.

Trip Description

The following section inquires about the respondents MOST RECENT trip to a forest nature reserve/protected area between 2016 and 2019. The information given should describe only one trip.

1. Select the MOST RECENT forest nature reserve/ protected area that you visited between 2016 and 2019

a) Cedars of God Forest (Bcharre)
b) Horsh Ehden Nature Reserve
c) Bentael Nature Reserve
d) Tannourine Cedar Forest Nature Reserve
e) Jaj Cedars Nature Reserve
f) Shouf Cedars Nature Reserve
g) Yammouneh Nature Reserve
h) Jabal Moussa Biosphere Reserve
i) Shnaneer Nature reserve
j) Houjeir Valley Nature reserve
k) Karem Shobat Nature reserve
l) Nature reserves of Ramiyah, Kafra, BeitLeef and Dibil

2. In what year was your MOST RECENT visit to the forest nature reserve/protected area?

a) 2016
b) 2017
c) 2018
d) 2019

3. Including yourself, how many people were in your group during this visit to the forest nature reserve/protected area?

4. What type of group were you with during this visit to the forest nature reserve/protected area?

a. Alone
b. Friends
c. Family
d. Family and friends

e. Hiking group
f. Organized visit (e.g., educational)

5. Was the forest nature reserve/ protected area the primary destination of your visit?
a. Yes
b. No

6. Please indicate all of the forms of transportation you used to reach the forest nature reserve/protected area from your home
a) Owned or rented car
b) Tour bus or tour van
c) Walk/hike

7. On this trip to the forest nature reserve/ protected area, which one of the following entrance fees did you pay?
a) Regular Fee
b) Student Fee
c) Group Fee
d) Local Fee (Fee for residents of the area)
e) Did not pay a fee

8. On this trip, in which of the following activities did you participate inside the forest nature reserve/ protected area?
   a) Viewing wildlife, natural features, etc.
   b) Visiting a cultural or historic site
   c) Educational tour
   d) Walking/hiking
   e) Snowshoeing
   f) None

9. Did you go to any other locations within the surrounding area during this trip?
a) Restaurant
b) Souvenir Shop
c) Pubs/Bars
d) Supermarkets/stores
e) None

10. On this trip, did you stay overnight within the surrounding area, away from your permanent residence?
a) Yes
b) No

11. If YES, please list the number of nights you stayed in the surrounding area of the forest nature reserve/ protected area, on this trip.

Trip Expenditures

In the following section please estimate (as closely as possible) how much money you spent both inside the forest nature reserve/protected area and the surrounding area ON THIS TRIP. Please choose zero if you did not spend any money in a particular category.

1. Reserve Entrance fee

2. Restaurants or bars within the surrounding area ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

3. Grocery store supermarket expenses within the surrounding area ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

4. Hotels or accommodation in the surrounding area ($)
   a) 10 -20$
   b) 20-50$
   c) 50-100$

5. Camping fees/ equipment for camping in the surrounding area ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

6. Rental of recreation equipment (e.g., Snowshoes, bicycles, ATV, etc.) in the surrounding area ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

7. Guides and tour fees for reserve activities ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

8. Souvenirs, clothing, supplies, other retail within the surrounding area ($)
   a) 5-10$
   b) 10 -20$
   c) 20-50$
   d) 50-100$

9. Other (Please specify activity with cost)

Respondent Profile

1. Nationality
   a) Lebanese
   b) Other

2. Town of residence

3. Age

4. How often do you visit forest Nature Reserves / protected areas per year? Please state the number of times per year.

Annex 2

Forest Tourism in Nature Reserves

السياحة المرتبطة بوجود الغابات تحت اطار المحميات الطبيعية

The following survey collects data on revenues generated by nature reserves from tourism associated with the existence of forests.

هذه الدراسة الاستقصائية تجمع معلومات عن الايرادات التي تحققها المحميات الطبيعية بسبب السياحة المرتبطة بوجود الغابات

Please fill in the questions below where data is available. يرجى الاجابة على الأسئلة التالية عند توافر البيانات

Name of the Nature reserve: اسم المحمية الطبيعية				
Contact person: الشخص المرجعي				
Email: البريد الالكتروني				
Phone number: رقم الهاتف				
Question 1: How many persons visit the nature reserve per year				
السؤال رقم 1: كم عدد الأشخاص الذين يزورون المحمية الطبيعية سنويًا؟				
	2016	**2017**	**2018**	**2019**
N. of visitors عدد الزوار				
Question 2: Distribute the percentage from total number of visitors by age group/ nationality				
السؤال رقم 2: وزّع النسبة المئوية لمجموع الزوار بحسب الفئة العمرية / الجنسية				
Age group - الفئة العمرية	**Percentage - النسبة المئوية**		**Nationality - الجنسية**	**Percentage - النسبة المئوية**
e.g., 18-25 (Young adult)			e.g Lebanese	
25-35				
35-45				
45 and above				
Question 3: Does your Nature Reserve charge an entrance fee?				
السؤال رقم 3: هل تفرض المحمية الطبيعة رسوم دخول؟				
Answer: الجواب	yes - نعم	no - كلّا		

Question 4: How much is the entrance fee? Divide by category of visitors if applicable. السؤال رقم 4: ما هي تكلفة رسم الدخول؟ ميّز بحسب الفئة في حال غياب تكلفة موحّدة	
Visitor category / فئة الزائر	**Entrance fee رسم الدخول**
E.g., Individual fee, group fee, ecotour operator, hiking company, ecotourism company	
أمثلة مقترحة: رسم دخول للفرد أو للمجموعة مع أو بدون مشغّل سياحي، أو لشركة سياحة بيئية	

Question 5: Does the reserve provide any paid services? If yes, please list them below with the requested details. السؤال رقم 5: هل تقدّم المحميّة أيّة خدمات مدفوعة؟ في حال توفّرها, يرجى ذكرها أدناه مع التفاصيل المتعلّقة بها					
Service - الخدمة	**Price - السعر**	**Sales 2016** **الايرادات لسنة 2016**	**Sales 2017** **الايرادات لسنة2017**	**Sales 2018** **الايرادات لسنة2018**	**Sales 2019** **الايرادات لسنة2019**
Ex: Snowshoes rental, tourist guide, educational tours, Bungalow rental, products sales أمثلة: تأجير أحذية الثلج دليل سياحي، ، جولات تعليمية ، تأجير الأكواخ ، بيع المنتجات					

Question 6: Does the reserve host any events/workshops during the year? If yes, please fill in the below with the requested information. السؤال رقم 6: هل تستضيف المحمية أي أحداث اجتماعية أو ورش عمل خلال العام؟ إذا كانت الإجابة نعم ، فيرجى ملء ما يلي بالمعلومات المطلوبة		
Type of Event - نوع الحدث	Number per year - العدد في السنة	Average revenue - متوسّط الايرادات

Question 7: List a few ecotour operators that conduct activities in the reserve
السؤال رقم 7: اذكر بعض منظّمي السياحة البيئية الذين يقومون تقوم بأنشطة في المحمية
1_
2_
3_
4_
5_

Question 8: In your professional opinion, what percentage of local restaurant visitors come due to the existence of the nature reserve?
السؤال 8: بحسب تقديرك المهني ، كم نسبة زوار المطاعم المحلية الذين يأتون بسبب وجود المحمية الطبيعية؟
Answer:

Question 9: Please list below any other revenues generated by the reserve that are not listed above. (Revenues generated due to the existence of the forest in this nature reserve)
السؤال رقم 9 : يرجى ذكر أدناه أيّة ايرادات أخرى للمحمية الطبيعية المرتبطة بوجود الغابة في نطاق هذه المحمية والتي لم تدرج أعلاه.
ex: donations, funding from international donors, etc.- أمثلة: تقدمات مالية، تمويل من جهات خارجية

Question 10: Please list forest tourism related services that the nature reserve provides free of charge
السؤال رقم 10: يرجى ذكر أدناه بعض الخدمات المتعلقة بالسياحة في الغابات التي تقدمها المحمية مجانا"
Ex: Awareness sessions - مثل: حلقات توعية