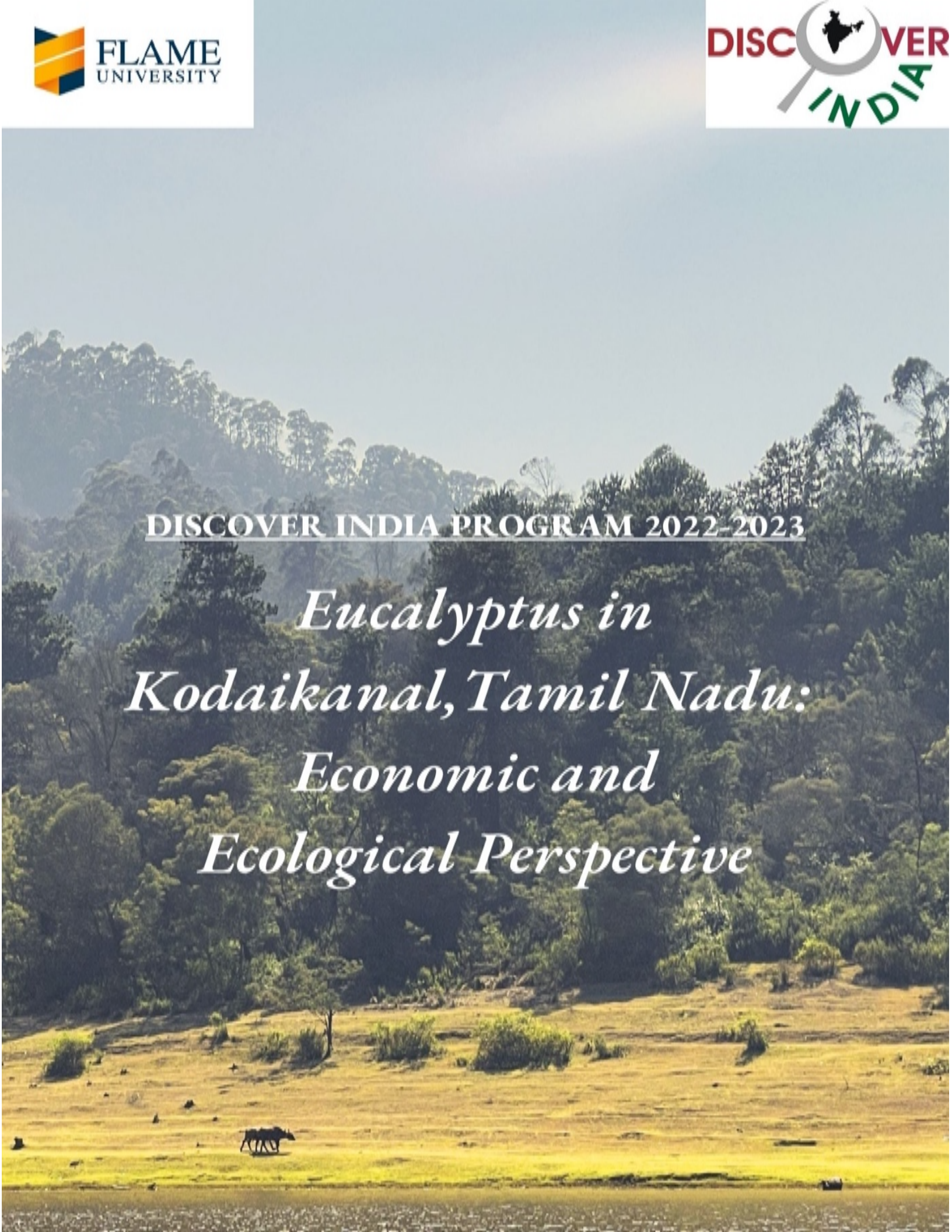


FLAME UNIVERSITY

DISCOVER INDIA

DISCOVER INDIA PROGRAM 2022-2023

Eucalyptus in Kodaikanal, Tamil Nadu: Economic and Ecological Perspective

Eucalyptus in Kodaikanal, Tamil Nadu: Economic and Ecological Perspective

DISCOVER INDIA PROGRAMME 2022-23

Certificate

This is to certify that the work incorporated in this DIP report titled *"Eucalyptus: Economic and Ecological Perspective"* submitted by the undersigned Research Team was carried out under my mentorship. Such material as has been obtained from other sources has been duly acknowledged.

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Abstract

This research report analyses the Economic and the Ecological impact of Eucalyptus in Kodaikanal, Tamil Nadu. The research was conducted using both primary and secondary sources of data. Our primary sources included Eucalyptus oil distillery owners, Palini Hill Conservation Council members, environmentalists, activists and locals. It also included field visits to analyse eucalyptus interaction with the town of Kodaikanal. This was done so as to support our secondary literature and to gain further insights from reviewing existing literature based on what primary information was collected. To gather qualitative information, the interviewees were asked questions related to the impact of eucalyptus trees, both economically and ecologically, and also asked for their opinion on whether or not eucalyptus trees have been good for Kodaikanal. Questionnaires were handed out to two stakeholders: consumers and producers of eucalyptus oil and honey industry to be able to analyse and understand how economically beneficial has eucalyptus been. Data analysis is mainly exploratory and qualitative and is presented using different visualisations for better understanding of the topic. Our secondary sources consisted of reviewing existing literature, gathering data from government sources, newspapers, and research papers from various renowned universities. The literature review analyses how and why were Eucalyptus trees planted, spread and outcompeted with other ecosystems of Kodaikanal. It also tries to shed light into understanding how and why products derived from eucalyptus trees benefit the local economy and aims to reach a conclusion on whether it has been successful in doing so or not.

Keywords: Eucalyptus, Shola forests, grasslands, eucalyptus oil, eucalyptus honey, forest fires, Kodaikanal

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Chapter 1

INTRODUCTION



1.1 Background information on Eucalyptus Trees:

"A small leak can sink a great ship." This quote by the renowned scientist Benjamin Franklin may sound simple, but when the impact such small mistakes have had on native ecologies of large regions is viewed, the burden of destruction it carries, hidden in its meaning, becomes evident. There are many examples of species which have shown a similar behaviour and have led to other species' destruction. For e.g, the impact of *Batrachochytrium dendrobatidis* (a fungus), on the local amphibians in places all around the globe was so extreme that it even led to the extinction of the species in certain parts of the world (Pappas, 2019 ; *Invasive alien species - convention on biological diversity)*. Another fungus, *Cryphonectria Parasitica,* nearly wiped out all the Chestnut trees in the United States and Canada. Similarly, when you look at the plant species, one of the major tree species which has had an impact globally, due to its invasive nature, are Eucalyptus trees (Petruzzelo & Rafferty, 2017).

Eucalypts are widely available in the tropical regions and are primarily shrubs and trees belonging to the Myrtle family (*Eucalyptus*). The myrtle family is a dicotyledonous plant and they are said to have originated 50-60 million years ago ("Myrtle Family (Family Myrtaceae)"). Concurring with this, pollen records provide evidence that Eucalyptus was present in Australia 45 million years ago. All the species belonging to the family are woody, contain essential oils, have flowers and their leaves are evergreen in nature ("Myrtle Family (Family Myrtaceae)") which can be of two types, broad-leaved and narrow-leaved. Broad-leaves are found in the regions where there are hot and dry summers, along with mild and wet winters whereas narrow-leaves are found in regions similar to where Eucalyptus and pines are found (The Editors of Encyclopaedia Britannica, 2022).

Out of the over 800 eucalyptus species identified, the leaf glands of many contain a volatile oil, known as eucalyptus oil, which has several medical benefits attached to it (Thornhill, 2019 ; *Eucalyptus*). It is used to cure issues relating to cough, cold and congestion. It is also used in creams and ointments to relieve muscle and joint pain (Nordqvist, 2018). Other than this, eucalyptus wood has many benefits attached to it like providing wood pulp and fuelwood to name a few (*Eucalyptus*).

Research published in Australian Systematic Botany provides evidence that the vast diversity of the species identified evolved only 2 million years ago. Most of them are only native to Australia, yet some of them are also considered to be native to Indonesia, Timor and New Guinea as well (Thornhill, 2019).

Researchers believe that Eucalyptus did not spread around Australian land till the time the continent was covered in rainforests, which was until about 20 million years ago (Thornhill, 2019). Since the time drier environmental conditions kicked in, they have adapted to the country's nutrient-deficient soil, arid, and dry climatic conditions by growing smaller leaves with a waxy coating and low nutritional content which scientists term as 'sclerophyll' (Bennett, 2010). Sclerophyll is a type of vegetation which is said to have hard, leathery and evergreen leaves whose main aim is to prevent loss of moisture.

Further adaptive characteristics that allow Eucalyptus to grow in the toughest of terrains include (Teketay, 2000):

a. Preventing water loss by closing stomata of the leaves during periods of high water deficit.
b. Surviving drier seasons by becoming deciduous
c. Adapting to soils with low nitrogen and phosphorus content
d. Becoming fire and insect-resistant through lignotubers (swollen root crowns) and thick barks respectively.

Being a native plant species, Eucalyptus has had a great impact on the ecology of Australia– especially on the Koala Bears. Eucalyptus leaves are the main source of a koala's diet, and its digestive system has uniquely adapted to break down the harsh leaves and assuage not only their hunger (eating nearly 500-800 grams per day), but also their hydration needs (Mella, 2018). Indigenous Australians use the leaves and its oil, its sap as adhesive resin, and bark and wood for making tools, vessels, and weapons. The variance in wood colour, shape, hardness, weight, strength and durability makes eucalypt useful for many applications in Australia like large-scale construction, general building, furniture-making and wood-turning, construction and flooring, paper pulp, fuelwood, and for aromatherapy and perfumery (*Eucalypt Forest*).

Outside Australia however, Eucalyptus acts as an invasive species. A collective total of 6,493,000 hectares of land is under Eucalyptus plantations in countries like Brazil, India, China, Portugal, South Africa, Spain, Ethiopia, Morocco, Chile, and Thailand (Teketay, 2000).

In Ethiopia, Eucalyptus trees were planted on the orders of Emperor Menelik II in 1895, once he figured that his people did not have sufficient fuelwood and timber for construction. He thereby called upon Mondon-Vidaillet, a French Railway Engineer and Philologist who ordered seeds of the Eucalyptus species from Australia (Teketay, 2000). Today, the use of Eucalyptus in Ethiopia ranges from being a source of timber and fuelwood, shelterbelts around farms, shady groves in and around villages, and as ornamentals. However, Eucalyptus, being the invasive species it is, caused its fair share of problems in Ethiopia. Water depletion, affecting the forest's macroclimate, soil erosion, depletion of soil nutrients, and outgrowing the native animals' shelter were some of the problems Eucalyptus brought with it (Teketay, 2000).

In Portugal too, Eucalyptus plants were introduced by the British and French botanists in the late 18th century for similar reasons as in Ethiopia. In fact, by the 19th century, there was almost no native woodland left in Portugal, with an additional 35000 trees being planted in 1866 to prevent erosion, drain swamplands, and prevent malaria (McGuire, 2013). However, as was the case in Ethiopia, Eucalyptus forests in Portugal were unnervingly quiet. The Eucalyptus forests were inhospitable to the native fauna; it wasn't edible for insects, hence disturbing the local birds' food chains (McGuire, 2013).

Similar patterns were observed even in South Africa. Eucalyptus trees were brought in by the British colonists as a back-up for the rapidly reducing native forest species. Here too, the growth of plantations was purely for a capitalistic, market-driven economy (Bennett, 2010). Eucalyptus trees were grown for timber, draining marshlands and for medicinal purposes. However, their ecological impacts remained the same as had been the case in Ethiopia and Portugal. The invasive Eucalyptus species outgrew the local forests and grasslands, and became inhabitable to the local fauna and insects. In fact, some researchers blamed an increase in aridness of the landscape to Eucalyptus (Bennett, 2010). Being a haven for new pests and diseases, like the Australian Snout Beetle (the beetle plagued plantations in the country from the 1930s to 1950s), also did not help improve Eucalyptus's acceptance by the South African farmers and foresters (Bennett, 2010).

Without a doubt, the trend continues in India as well. Eucalyptus was primarily grown in India by the British to provide medication for themselves, fuel, and timber for sleepers on railway tracks (Bennett, 2010). Andhra Pradesh, Punjab, Karnataka, Telangana, Haryana, and Tamil Nadu are some prominent states where Eucalyptus trees are found today. After the planting at Nandi

Hills, Karnataka, the following significant introduction of Eucalyptus was in Tamil Nadu's Nilgiri hills in 1843, and later 1856, where regular plantations were raised to meet the demands for firewood (Nazir, 2022). The Eucalyptus trees were introduced to the Palani Hills in the year 1843 by Major JM Partridge for not only timber and fuelwood, but also to drain marshes and swamplands to reduce insects (Mukherjee, 2021). State forestry boomed and grew in the mid-late nineteenth century to provide fuel and timber for the increasing state population and armies, and the railways (Bennett, 2010). Since then, eucalyptus has grown in number as well as the land they occupy. Eucalyptus trees have had their fair share of problems and benefits associated with itself for Kodaikanal which is further explored in this report.

1.2 Overview

1.2.1 General Overview on Kodaikanal

Kodaikanal, also known as the Princess of Hill Stations, is located amidst the slopes of the Palani Hills in the Dindigul district in the state of Tamil Nadu. It was established in 1845, by American Christian missionaries and British bureaucrats, to escape from the high temperatures and diseases of the plains(Gupa, 2007). The locals in Kodaikanal say that the meaning of the word Kodaikanal is, “A place at the end of the valli’s forest which is a gift in the summers”. Even though Kodaikanal was established only in 1845, according to sources, there is archaeological evidence that proves the presence of humans in Kodaikanal before it was established, during the pre-christ era as well. Based on the type and design of the artefacts, pots and other constructions, it is reported that the earliest residents of the city of Kodaikanal were the Paliyans and the Puliyan tribe (Gupa, 2007). Dahmen says Paliyans were considered to be a nomadic tribe who mainly roamed through the jungle clad gorges, also known as Sholas (1908). Post that entered the Mannandiars who migrated to the hills to look for new agricultural lands. Following Mannandiars, even Arundhatiyars joined these early migrants to provide labour for the settlements. It was around the same time that Aasaris started to shift to the place and worked as blacksmiths, carpenters and masons serving the Mannandiars. After that, several other groups shifted to the hills as well and traded various different items like cloth, oil and salt in exchange for millet and garlic. The earliest modern day settlers of the city were the 14th century migrants from the foothills of Palini who escaped to the city so as to run from Tipu Sultan’s invasions (Gupa, 2007). Today, the city has a population of 36,501 with the scheduled castes being roughly around 19.86% and scheduled tribes

being 0.28% of the overall population. The number of households is roughly around 9442 with the literacy rate of the town being 79.78% (Choudhry and Choudhry).

1.2.2 Geographical Overview on Kodaikanal

The town sits on a plateau above the southern escarpment of the upper Palini Hills at a height of 2133 metres. The town itself falls within 1600-2000 metres elevation. It is surrounded by villages like Vattakanal, Poombarai, Poondi, Mannavanur, Pallangi etc. The highest part of the range is in the south-west, called Vandaravu Peak (elevation of 2533 metres). Meadows and grasslands cover the hillsides and the shola forests beautify the valleys of the area. The town is surrounded by a star-shaped lake which was created by damming three streams. The range is rich in the diversity of flora and fauna it offers. Grasslands of the area have almost twice the floristic richness when compared to the forests. Some of the species that can be found are: Orchids, asters and sedge plants. Species that can be found in native forests are very distinctive. They support the growth of herbs, shrubs, mosses, ferns to name a few. Some predominant species found are Magnolia, Indian Mahogany, and Jamun. When looking at the fauna in the ecosystem, one can find over 200 varieties of birds (most of which are endemic to the Western Ghats), Indian Gaur, Malabar Giant Squirrels etc. However, due to plantations of invasive species like Eucalyptus, Wattle and Pine, and other human developmental activities that have increased in the town, the whole ecosystem of the place is in jeopardy (Choudhry and Choudhry).

1.2.3 Economic Overview on Kodaikanal

The economy of Kodaikanal mainly depends upon the tourism industry. The change in the number of tourists that visited the place went up from 2 million in 1999 to 5.3 million in 2015 (Choudhry and Choudhry). The town's infrastructure continuously changes, develops and prepares before the yearly tourist season. It relies so heavily on tourism that people spend their entire year with the revenue they earn during the peak tourism season. To complement the peak tourist season, the city also hosts the Summer Festival of Kodaikanal yearly for 10 days in the month of May. Additionally, the second source of revenue for the city is agriculture and horticulture. From observation, there exists several smaller industries in the area as well like Eucalyptus oil manufacturing and retail industry, honey industry, handmade chocolates and artefacts industries from southern states (Choudhry and Choudhry).

The economic hub of the city lies on the road around the lake, on the Poet Thyagaraja Road and Anna Salai. You can find both food shops and bakeries, along with small shops which sell everything; from fruits and vegetables to clothing and bedsheets (Choudhry and Choudhry).

1.3 Rationale and Scope

The invasive species of Eucalyptus has played an important role in influencing the lives of the people as well as the state of the ecosystem in the town of Kodaikanal. Though there have been studies conducted on the ecological harms caused by eucalyptus on the local fauna and flora, the economic benefits derived by the local economy as a result of the products derived from eucalyptus is still unexplored. This report tries to gather information on all the possible impacts of Eucalyptus in Kodaikanal and tries to draw a conclusion on what has been the overall effect of Eucalyptus in Kodaikanal. This is of importance so that better clarity and understanding can be provided to the people since the views and beliefs of the people are quite dispersed today.

The report mainly focuses on two lenses: the ecological lens and the economic lens. As a part of the ecological lens, it looks at the interaction of eucalyptus with the various crops, the native forests and the grasslands around it. A comparison of what was gathered from literature review and the primary research was conducted to help derive the conclusion. For the economic lenses, the report primarily focuses on three products derived from eucalyptus trees: eucalyptus oil, eucalyptus honey and firewood. Since there hasn't been a lot of studies conducted on this aspect, the analysis mainly comprises the primary research that has been conducted. It tries to answer the question on whether or not having eucalyptus trees benefited the local economy of Kodaikanal. Other than that, the phenomenon of the eucalyptus' role during natural disasters has been studied from both lenses.

The study was conducted over a period of six months including 9 days of on-field research. The interviews and questionnaires that were taken during the on-field research involved people with expertise in the given field of study. The concepts that were examined were effects of allelopathy, reasons for the eucalyptus trees outgrowing native species, the consumer preferences and demand of the products derived from eucalyptus trees and the producers costs and take on the production of those products.

In conclusion, the report tries to answer if planting eucalyptus trees has been good for the town or not after looking at all the variables of the study.

1.4 Research Overview

Research Statement

The report aims to provide a holistic perspective of Eucalyptus trees in Kodaikanal through ecological lenses such as allelopathy, Shola forests, grassland ecosystem, and economic lenses such as Eucalyptus oil and honey industry

1.4.1 Research Questions

The research report tries to answer the following questions:-

1. To what extent has the Kodaikanal economy benefited from the Eucalyptus Oil and the Eucalyptus Honey industry?
2. What is the overall nature of the allelopathic impact that eucalyptus is having on other plant species in Kodaikanal?
3. What has the overall impact of Eucalyptus been on the Sholas forests?
4. What has the overall impact of Eucalyptus been on the grassland ecosystem?
5. How much has Eucalyptus trees contributed and impacted the city in cases of natural disasters like forest fires and the Cyclone Gaja?

1.4.2 Research Aims

The aims and objectives of this research report is as follows:

- To be able to conduct extensive literature review studying the impact of eucalyptus trees on the ecosystems present in Kodaikanal and to be able to understand how they have been successful in impacting them the way they have.
- To be able to analyse all the primary research collected during the field work so that a parallel can be drawn with what was studied and what actually is the case.
- To comprehend and connect the secondary literature with the primary research collected so that a conclusion can be drawn
- To provide an unbiased perspective on whether the plantation of this invasive species has been good for Kodaikanal after collating and analysing the data collected through different sources and coming up with the appropriate answers for the research questions.

1.5 Methodology

1.5.1 Methodology for Literature Review

The research aims to study the ecological and economical effects that the Eucalyptus trees have had on the town of Kodaikanal. To proceed with this research, understanding the history of Eucalyptus in Kodaikanal, and the effects it has had so far becomes important. The literature review will not only help in gaining that insight, but will also enable us to understand what we can expect going on-field.

The literature review that will be done, will be based on research articles sourced from scholarly websites like JStor, Google Scholar, ResearchGate etc. While the papers sourced are highly descriptive and provide information on the history of Eucalyptus in Kodaikanal and its science behind its effects on ecology ; newspaper articles from newspaper websites like The Times Of India, Hindustan Times, and The Kodai Chronicle, will help us achieve a more updated, present-day understanding of our research topic in Kodaikanal.

The literature review produced will not only help set the stage for the on-field research findings, but will also act as evidence and proof to back the findings made during the field visit.

1.5.2 Methodology for Primary Data

Collection of primary data will be done majorly on-field. However, before going for the field visit, the group was able to get in touch with some of the points of contact via google meet, and telephonic conversation to collect initial information. The data collected through these conversations helped in further shaping the research.

During the time the group would spend on-field, numerous field visits have been planned. They would include visiting places where Eucalyptus trees can be seen interacting with the Native shola forests and grasslands. Visits to local small-scale oil extraction sites have also been planned, where interviews of the distillery owners would be conducted to collect information about the economics of oil production in the town, and the process of extraction. To gain a better understanding of Eucalyptus Oil's presence on the economy of Kodaikanal, a consumer and shopkeeper interview is also necessary. Hence, surveys have been prepared for the same, through which data will be collected for analysis. The surveys were first typed out, then converted into a Google Form to obtain a dataset in an excel format for better infographics visualisation. We assume atleast 400 small-scale shops to sell Eucalyptus Oil in Kodaikanal, and plan to target at least 40 for data collection through surveys.

Along with this, interviews with experts like Mr. Karthikeyan (Rotary Club President), Dr. Rajamanikam (a member of the Kodaikanal International School's Centre for Environment and Humanity), and interactions with children and faculty of the Sholai school (who experience and put out forest fires) have been scheduled. Lastly, a focus group discussion with the President (Mr. Mark Antrobus) and other prominent members of the Palni Hills Conservation Council (PHCC) are also planned.

1.5.3 Methodology for Data Analysis

Data collected will be analysed in two ways:

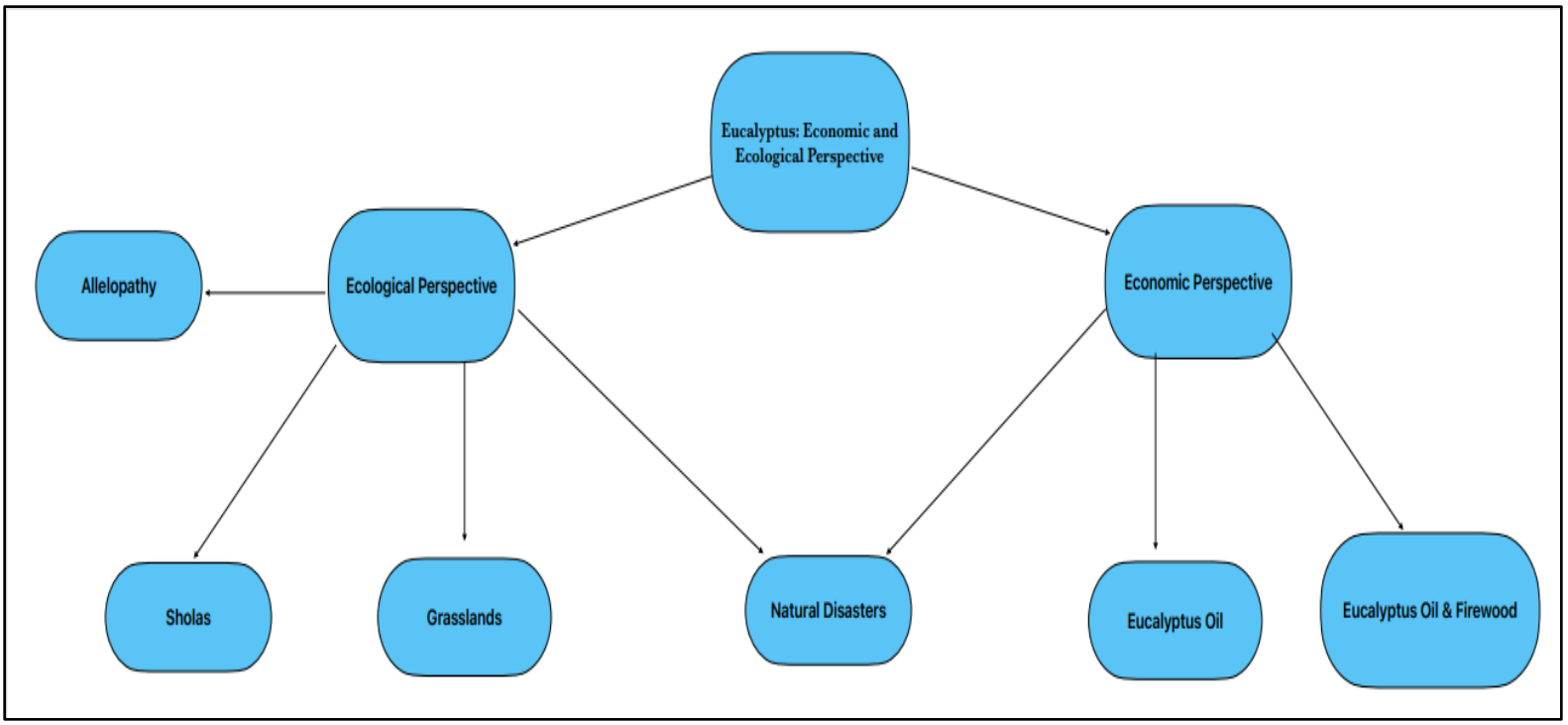
The first would be the use of literature review to back our findings on-field, and provide explanations for the same. This kind of analysis would be descriptive.

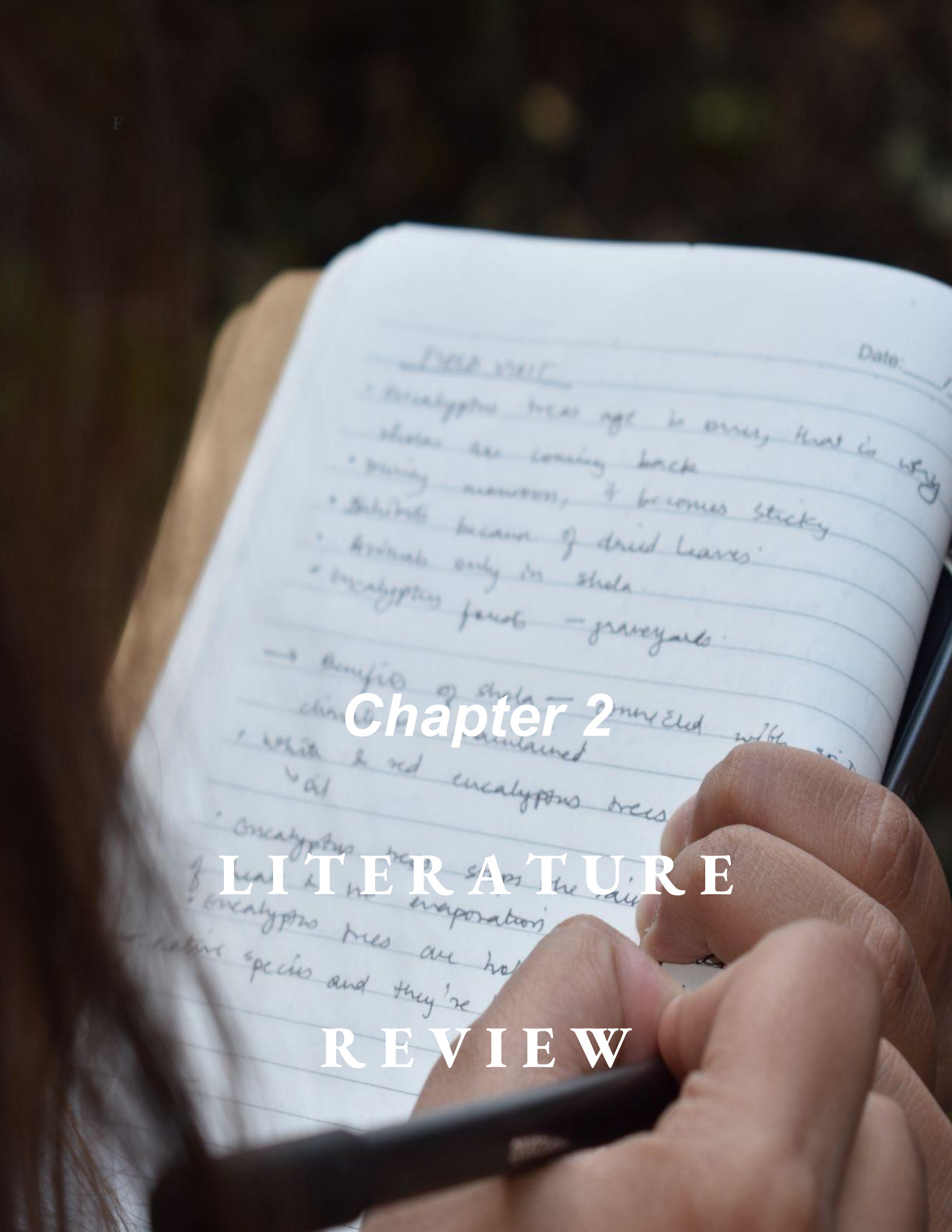
The second would be through the use of infographics. For the economic analysis of Eucalyptus Oil's impact in Kodaikanal, data collected through surveys would be of the utmost importance. Direct analysis would be done that would be based on the responses collected. However, a deeper and more intricate analysis will also be done, in which analysing the surveys would be done through certain fixed variables, and how they correlate with other influencing variables. Based on the relation between these, an attempt will be made to present a deeper understanding of the economic impact of eucalyptus oil in Kodaikanal.

1.6 Chapterization

The report is divided into six chapters. The first chapter introduces the research with the background study of the Eucalyptus trees and Kodaikanal. It enfolds the Research Overview which includes the research statement, aims and objectives, and the Research Methodology. The second chapter consists of a comprehensive study of previous research that has been conducted on this topic, ie, the Literature Review. The third and fourth chapters embody the understanding of the impacts of Eucalyptus trees through ecological (Allelopathic chemicals, Shola forests, Grasslands, Forest Fires) and economic (Eucalyptus Oil, and Honey & Firewood) aspects based on the primary research and backing up with secondary research respectively. The following fifth chapter consists of natural disasters such as Cyclone Gaja, and Forest Fires and eucalyptus' role in those aspects. This chapter will look at the role played, and the trees' impact from both perspectives. The final chapter consists of the conclusion of the research.

Figure 1.6 (a) Flowchart of the report





Chapter 2

LITERATURE REVIEW

This chapter provides initial findings on all aspects we aim to cover on-field. It provides information sourced through many scholarly articles and newspaper findings, and helps set the stage for the forthcoming findings. The chapter has been divided into 2 broad sections, with subsections in each. Each section refers to an aspect of the research.

2.1 Ecological Perspective

2.1.1 Allelopathy

In 300 BCE a Greek philosopher named Theophrastus discovered an interesting interaction related to the chickpea plant. He noticed that chick pea plants have a certain ability to "exhaust the ground." Furthermore, he pointed out that the same plants also have the capability to destroy weeds in their vicinity (Rice, 1984). Similarly in 1 CE Plinius Secundus mentioned that a variety of plants such as barley, fenugreek and bitter vetch damage cornland, he also demonstrated understanding of certain chemicals which caused damage when interacting with other species of plants or themselves. Although the word "chemical" was not used by him, it was substituted by mention of "juices" and "scent" (Rice, 1984). While these observations and findings may seem like primitive knowledge, they provide important insights and first steps towards understanding this phenomenon today.

Through modern science the understanding of many phenomena including this one was further developed and can now be explained in depth with more clarity. The word allelopathy was coined by dr. Hans Molish in 1937, the word derives its roots from greek vocabulary where *allelo* stands for "mutual" and *pathos* for "suffering" (Aubertin, 2018). Molish also introduced the notion of chemicals that are released by plants through various methods which proceed to affect other organisms in adverse ways.

Allelopathy is a biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival, and reproduction of other organisms from the same community. These allelochemicals can have beneficial (probioses) or detrimental (antibiosis) effects on the target organisms and the community. Allelochemicals are secondary metabolites which are not required for metabolism (i.e., growth, development, and reproduction) of the allelopathic organism. (Zihmdal, 2018) Various species of Eucalyptus including Eucalyptus Globulus are known to have high allelopathic impact. This is further supported by researcher R J

Willis who in his journal, “The Commonwealth Forestry Review", discusses the allelopathic impacts of various eucalyptus species. (1991)

Eucalyptus tree litter plays a crucial role in structuring plant populations and regulating crop quality. (Abdelmigid & Morsi, 2017) This is because allelopathic effects stem from the biomass litter (leaves) of the eucalyptus plants, which when damp release chemicals into the nearby environment inhibiting and stunting nearby planting growth (Willis, 1991). This phenomenon has been documented in multiple research studies. One research conducted by H. M. Abelmigid, & M. M. Morsi showed that allelopathic interactions of *Eucalyptus globulus* allelochemicals include variable genetic effects on soybean plants which may be responsible for retardation of growth of understory plants and consequently reducing the plant yield. (Abdelmigid & Morsi, 2017) Another research conducted by N Lisanework & A Michelsin, showed that E. Globulus (*Eucalyptus globulus*) was the second highest rated species with allelopathic potential amongst other plant species like *C. lusitanica*, *E. globulus*, *E. saligna* and *E. camaldulensis* (Lisanework & Michelsen, 1993).

In one situation, the allelopathic effect harms the ecology by impeding the growth of young native plants, but on the other hand, provides impetus to the honey-making industry. Allelopathic compounds like terpenoids attract bees (Nayek, 2018). Insects use olfactory cues not only to recognize potential mates, relatives, nestmates, or enemies but also to find suitable nesting sites or resources for food and/or nest construction. Olfactory cues involved in finding and recovering resources for the supply of food or nesting substrate have been studied in honeybees (Leonhardt et al., 2010). In fact, there are published studies that show that the honey-making industry depends on eucalyptus in countries like Ethiopia and Rwanda (Daba, 2016). Whether or not the same effects can be seen in Kodaikanal remains a point of research and exploration.

2.1.2 Shola Forests

The Sholas are the evergreen forests of Kodaikanal. Interspersed with the grasslands, the Kodaikanal landscape was once a natural wonder due to the juxtaposition of two very diverse plant species. However, natural vegetation in the vicinity of Kodaikanal has been com-pletely disturbed by man with plantations of *Eucalyptus, Pinus, Acacia,* etc (Gupta, 1959).

When the British settlers arrived in Kodaikanal, they brought with them the invasive species of the Eucalyptus, Acacia, Pine etc. The establishment of these exotic forest plantations

led to the felling of native forest 'Sholas' to a certain extent (Naudiyal et. al., 2012). This replacement of the native sholas with invasive species like Eucalyptus brought their own share of ecological problems.

Once established in a plantation, fast-growing exotic trees impose greater competition for water, nutrients, and light than native plants. Some species, like the eucalyptus, can impede the germination, establishment, and development of other plants, especially native ones, by emitting allelopathic compounds (Feyera et. al., 2002). As a result, environmental changes beneath and around the plantation may take place that are detrimental to the normal functioning of the habitat. Massive plantation of exotic trees reduced the soil, as well as above surface moisture, which is not conducive for the sholas (Gupta, 1989). Furthermore, the sholas have been exploited for fuel and wood so much that they have practically vanished.

However, all hope has not been lost for the Shola forests. The Madras High Court Bench decided to give top priority to restoration of Shola forests in Kodaikanal, the Nilgiris, Palani and the entire Western Ghats in the State (*Top Priority for Restoration of Shola Forests*). The interim order stated that the authorities concerned should take steps to annihilate exotic species such as wattle and eucalyptus that had invaded marshes, Shola forests and grasslands on the Western Ghats and formulate a comprehensive scheme for restoration of Shola forests (*Top Priority for Restoration of Shola Forests*). And so, in the last few years, the Forest Department has taken measures to stop the invasive species from spreading by planting native floral species. The removal of eucalyptus and wattle is being carried out in the Reserve Forests of the Nilgiris and Kodaikanal (Sundararaju, 2018).

New discoveries in the field of Shola regeneration have also produced some interesting results. Senbeta Feyera et al., in their research mention how along with providing economic resources like timber and oil, exotic species have potential ecological advantages also. Some possible advantages mentioned include improving microclimatic conditions, protecting degraded lands against soil erosion, and stabilising soil development, thereby enhancing soil nutrient status and increasing soil organic matter through enhancement of litter and humus production and supporting water catchment values. In addition such plantations may foster the regeneration of native species under their canopy and provide a habitat for various wildlife (2002). Whether or not this holds true for the invasive Eucalyptus species in Kodaikanal has been explored ahead in this report.

In fact, in a research done by Nandini Kumar and her two peers on the prospect of Eucalyptus aiding in the regeneration of Shola species, they found conclusive evidence that Eucalyptus can foster the regeneration of native tree species. Eucalyptus plantations can therefore, they state, be used for the regeneration of native Shola forests while the silviculture tools for this are available (Naudiyal et. al., 2012). V Sundararaju, President of the Society for Conservation of Nature, Trichy, Tamil Nadu and consultant with the Society for Social Forest Research & Development, Tamil Nadu, writes, "Although the eradication of these alien species may not be possible in a short span of time, if the measures are taken persistently, it is likely that the landscape may turn into its original vegetation in the long run. Intensive planting of the indigenous floral species should also be conducted after removing the alien species. A dedicated and scientific approach is the need of the hour" (2018).

2.1.3 Grasslands

Grasslands are considered to be the most widespread form of vegetation (Smith, 2022). These grow in the regions where there is less rainfall. The amount of rainfall does not support the growth of a forest, but it is not so scanty as to make the land as arid as a desert. Grasslands are present in conditions that encourage the growth of this plant cover but not that of taller plants, such as trees and bushes (Smith, 2022). They are home to several species of plants, birds & amphibians. Not just that, they are also said to play an important role in the carbon cycle due to slower decomposition rates of the organic matter. Other than that, they also provide water for the downstream communities (Arasumani et al, 2018). Even though grasslands have so many benefits, the British termed them as "barren" and reshaped the Palani Hills by planting exotic woody trees like black wattle (Acacia mearnsii), eucalyptus and pine. These were planted as there was a need for timber and pulpwood (Pendharkar, 2018) at the time. When the demand started to fall, the plantations stopped. However, in a study conducted by Robin, he found out that in Palini Hills over 60% of the grasslands have disappeared (2014). Even after the plantations stopped, the invasive species kept outcompeting the grasslands and these plantations spread way beyond the original space they were originally planted in (Lockwood, 2018).

The studies also compare the impact of plantations on Shola forests when compared to the Grasslands. The conclusion they reached was that Grasslands have suffered more than the Shola

forests due to invasive species. One of the reasons stated is that Shola's were still given some protection as they were known to conserve water but because the benefits of the grasslands were unnoticed, they weren't looked after (Pendharkar, 2018). Unlike in the case of Shola forests, whether or not grasslands can be restored back is something that is currently unknown. What is known is that the grasslands have depleted dramatically since the plantations of the Eucalyptus and other invasive species in Kodaikanal.

2.2 Economic Perspective

2.2.1 Eucalyptus Oil

The leaves of most species of eucalyptus, when steam-distilled, yield an essential oil which is known in the trade as eucalyptus oil (Coppen & Hone, 1996). Essential oils often associated with aromatherapy is a type of naturally obtained oil-resembling liquid that is extracted from various plants through the processes of distillation. Most essential oils retain a colourless complexion and remain in liquid form at room temperature. Eucalyptus Oil is no different and is known to also have a colourless appearance, though in some instances during the initial processes of distillation, it is known to retain a yellowish hue.

Like other essential oils they are mixtures of organic compounds - mainly terpenes - the individual components of which, and their proportions, determine the chemical and olfactory characteristics of the oil and, therefore, its value. The composition of the oil is dependent, mainly, on genetic rather than environmental factors (Coppen & Hone, 1996). For Eucalyptus oil then, the specific species through which eucalyptus oil is being derived is essentially the most important factor to consider while making decisions regarding its uses and determining its overall quality. Within a species, there may still be significant quality differences according to the provenance of the seed, and even between individual trees within a provenance (Coppen & Hone, 1996). There are around 300 species of Eucalyptus that have the capability of containing this essential oil but only 20 are exploited for commercial buying and selling purposes with only 6 from those 20 accounting for majority of the world production for eucalyptus oil.

A 1991 estimate suggest that the worldwide production for eucalyptus oil stood around 2480 - 3130 tonnes at the time of publication (Coppen & Hone, 1996). This suggests that the eucalyptus oil is one of the more popular essential oils produced and has a fairly large market

carved out for itself. This point is further supported by looking at the various types of eucalyptus oils that one can find in the market. The oils of these exploited species are classified in the trade into three broad types according to their composition and main end-use: medicinal (cineole-rich), perfumery and industrial. Of these, the most important in terms of volume of production and trade is the medicinal type (Coppen & Hone, 1996).

The medicinal properties of eucalyptus oil were known to the aborigines of Australia thousands of years ago, but were first exploited commercially by Bosisto. He began production in Australia in 1852, extolling the oil's virtues for the treatment of a wide range of ailments (Coppen & Hone, 1996). In modern times, this medicinal properties of eucalyptus oil has further been validated and verified by multiple research. Research has shown that eucalyptus contains a volatile photochemical known as Isopernoids, or terpenes, which has multiple medicinal properties such as antiviral and antibacterial efficiency. (Parul et al., 2021) According to various researches this antiviral efficiency can also be used to prevent SARS-CoV-2. Techniques such as in vitro assay and molecular docking depict the efficacy of eucalyptus oil against viral activity of SARS-CoV-2 (Asif et al., 2020). For such reasons, Eucalyptus oil is found as one of the main ingredients in the production of sprays, lozenges, cough sweets, ointments and other oils. In the home, eucalyptus oil is used in liquid form as an inhalant or chest rub to ease breathing difficulties, as a mouthwash in water to refresh or ease the throat, and as a skin rub to provide relief from aches and pains (Coppen & Hone, 1996).

Besides being used from a medicinal perspective, eucalyptus oil is also used in an industrial capacity. The term 'industrial' oil is commonly used to denote usage of the oil as a raw material for isolation of individual chemical constituents. The isolates may then be used in their own right for some applications, or further processed into marketable derivatives (Coppen & Hone, 1996). One of the main utilizations of eucalyptus oil as an industrial oil is derived from its containing piperitone and phellandrene. However, only a certain type of eucalyptus variant yields these chemicals and is in contrast to the cineole variant of the same species, which produces a medicinal-type oil (Coppen & Hone, 1996). Phellandrene is usually used as a cheap fragrance source, usually in the lower-cost soaps, perfumes and disinfectants, whereas piperitone is used in the production of Methanol, a popular flavour ingredient.

2.2.2 Eucalyptus Honey

Another economic product that is derived from eucalyptus is eucalyptus honey. Floral honey can be multi-floral and monofloral. In the first case, honey comes from various plant species, while in the second case, honey is made from the nectar of a single species (Bobis & Moise, 2020). Eucalyptus honey has a dark colour and a distinctive flavour. Its flavour and aroma can be attributed to certain important chemical compounds like hydroxy ketones, sulphur compounds, diketones, norisoprenoids, etc (Flores et al, 2014). Eucalyptus honey is an important unifloral honey. For Eucalyptus honey to be characterised as Unifloral, the concentration of Eucalyptus pollen should be at least 70% (Terrab et al, 2003). About 800 Eucalyptus species are utilised by bees to produce Eucalyptus honey.

The process of production of Eucalyptus honey is intricate and involves various processes. The first step involves bees transferring the pollen to the blossom of the Eucalyptus tree. Gathering the nectar from the blossom as well as from the Eucalyptus tree bark encompasses another important stage of honey production. Honey bees carry an enzyme in their mouths known as the invertase that gets mixed with the nectar collected from the blossom when they return to their hives. The mixture of the invertase or the bee enzyme with the nectar converts nectar into honey. It is commercialised worldwide and much desired by consumers due to the medicinal properties attributed to it because of the plant from which it is produced (Bees Wiki 2023).

The major medicinal benefits of Eucalyptus honey are that it performs anti-oxidant, anti-microbial activities and also acts as a preventative measure against cancer. Eucalyptus honey shows high antibacterial activities against K. pneumonia bacteria, which are responsible for causing pneumonia, bloodstream infections, and several other diseases (ElBorai et al., 2018). As Eucalyptus honey contains sodium, potassium, iron, zinc, copper, manganese, and magnesium, it can aid children with compromised and weak immune systems (Gautam, 2022). The antioxidant properties of Eucalyptus honey have been remarked on by several authors. It is the ability of Eucalyptus honey to reduce oxidative damage within our food systems and health. These oxidative properties are brought about by certain important compounds including phenolic acids, flavonoids, and amino acids among others. These compounds are injected into Eucalyptus honey during the process of honey production. It occurs when bees absorb the pollen and plant nectar from the flower and carry it back to their hives (Bobis & Moise, 2020).

Eucalyptus honey production varies depending on the species, but it generally gives high honey yields. For instance, in a conducive environment, a single Eucalyptus plant from the Erythoris species can bear around 2000 flowers, yielding more than 8 litres of nectar containing 970 grams of sugar. Eucalyptus trees are generally regarded as an excellent source of nectar production, and in a favourable environment can lead to massive yields of 200 kg per hectare, and in some situations, as high as 600 kg per hectare (Floris et al, 2020). In general, eucalyptus honey has been classified as being rich in pollen grains from the eucalyptus tree as well as having physicochemical characteristics that, in a way, have made it stand out from honey from other plant species (Bobis & Moise, 2020).

It is because of the above-mentioned reasons that the gathering and selling of Eucalyptus honey is a lucrative venture. In fact, this occupation is practised by several communities in India. One such example is the honey-gathering practices in Tamil Nadu. The Paliyans that live in the Palini hills where Kodaikanal is situated have been gathering honey for generations. Over centuries, they have developed sophisticated awareness about the habitat based on observation and knowledge of their ancestors. However, access to forests is an issue that continues to trouble these communities. Although the Forests Rights Act passed in 2006 has mandated that native communities be allowed to access and use the forest produce for their livelihood, the implementation of the act is an issue that remains to be solved. This is especially the case for Tamil Nadu, which has been one of the worst-performing states in terms of the execution of the act (Mani, 2022).

2.3 Forest Fires

Forest fires are generally categorised as an incident wherein a large and destructive fire breaks out in a forest or an area of woodland. According to the reports by the Forest Survey of India, 54.4% of the forests in India are exposed to more frequent fires and 7.49% of the forests catch fire less frequently (Webline Infosoft Pvt. Ltd., Dehradun). North and East India regions are the most prone to catching forest fires. The causes of the forest fires in India are mainly human activities. One of the other causes could also be the presence of Eucalyptus Globulus trees (also called Tasmanian Blue Gum trees) in the area.

The eucalyptus trees, mainly the Blue Gum species, are considered to be dangerous in a fire-prone area because they can shoot up sparks if they catch fire (Grant, 2022). According to Grant, The trees contain their aromatic oil in all parts of their body which makes them highly

flammable. The bark of the trees is deciduous in nature (Boyd et al., 2006). This constant shedding of bark and dried leaves ends up getting accumulated under the trees. When the temperature rises, the eucalyptus oil present in the trees vaporises in the heat. Grant goes on to say that, “The oil leaves a smoggy miasma hanging over the eucalyptus groves”. The gas released during the process is extremely flammable which causes a fire to break out also because the detritus (organic matter produced by the decomposition of organisms) beneath the trees acts as a catalyst in this process. The detritus acts as a catalyst because they are resistant to fungal breakdown due to the presence of the oil which makes them volatile and fire prone in nature (Grant, 2022).

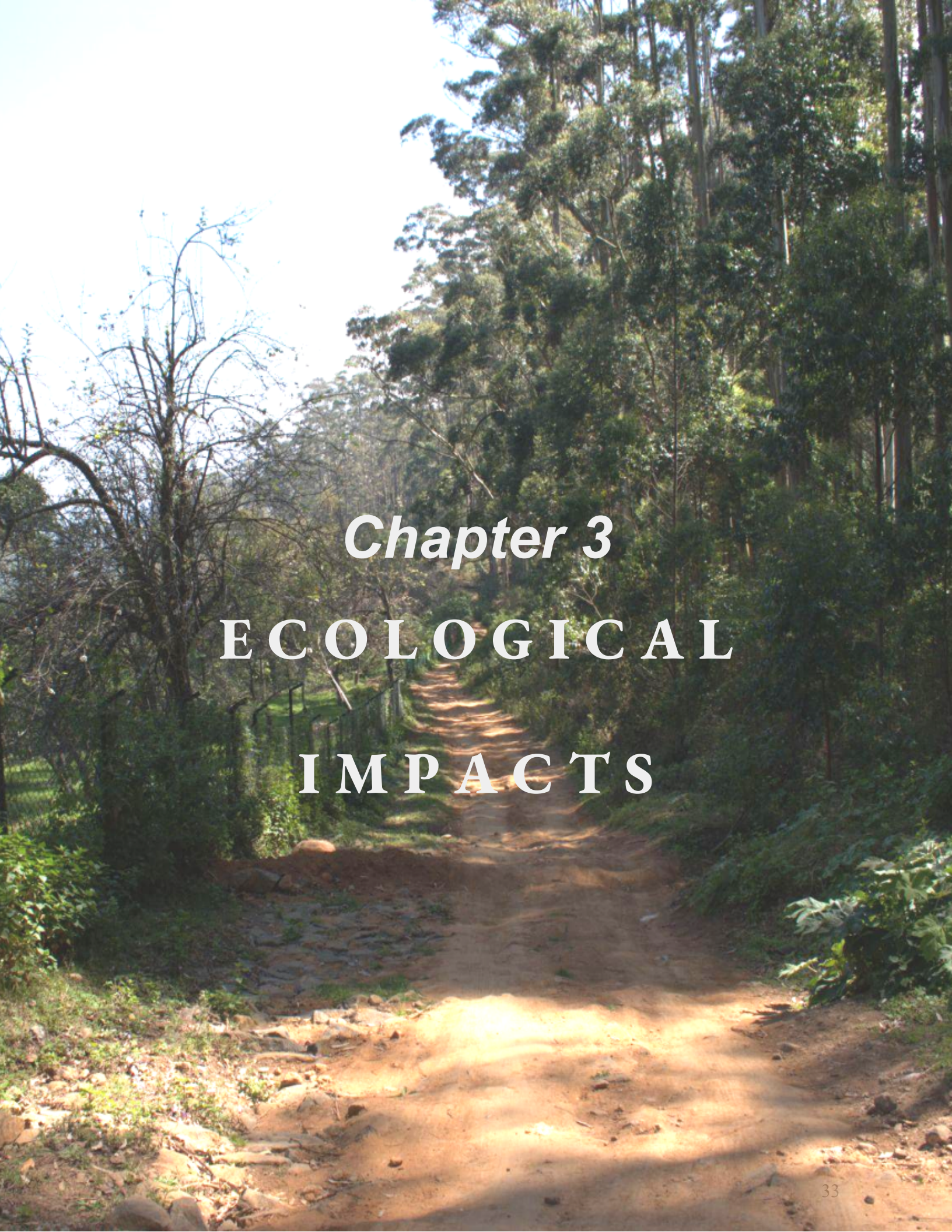
Another study conducted by the National Park Service (U.S department of the Interior) also concludes that the detritus that is collected beneath the trees is what makes the trees a fire hazard (Boyd et al, 2006). The study states that the barks catch fire easily and the loose strips that are present carry the fire up to the canopy which then spreads the fire. Despite the trees containing volatile oil and bark, the leaves are categorised as intermediate in fire hazard when they are green and highly resistant when they are juvenile, i.e. smaller than adult leaves with a pointed tip. The main cause of the fire pointed out by the study is the accumulation of the litter. The litter is highly flammable. Once it catches fire, it is carried by the long branches and the fire ends up getting spread very quickly in eucalyptus groves. When there is enough dead material in the canopy, the fire becomes capable of moving easily to the treetops as well, spreading the fire even more. The spreading of the forest fires due to the presence of dead material along with the volatile oil causes a lot of destruction and harm to the environment as well as the ecosystem (Boyd et al, 2006).

An interesting observation to point out is that even though eucalyptus trees burn when they cause fires, they are still able to regrow in the region (Grant). They have adapted to fire and evolved to become fire-resistant (Boyd et al, 2006). This is because they have dormant shoots which tend to germinate when the temperatures are high (2019). According to Grant, when there is no litter left to burn and the fire moves along the forest, the plant starts to retain its trunk which then grows new limbs. The trunk regenerates the plant unlike other plants which have to re-grow from the roots (Grant, 2022). Another point that Boyd’s study points out is that the eucalyptus seeds are highly resistant to fire and heat. So, when the fire reaches the crown, the seeds are protected for a short period of time. This period is enough to protect the seeds as the fire keeps moving on once the litter is burned off. Thus, by reseeding, the trees are also able to take advantage of the new and fresh uncovered soil that is available after the fire (Boyd et al., 2006). Eucalyptus trees cause these

forest fires and benefit from it in the end while hampering the ecosystem which cannot recover from the fire as easily.

These forest fires are mainly caused during the summer months as this is when the temperatures are high enough to cause a fire. A similar case was observed in Odisha. In an article published by Down To Earth, the secretary of Odisha Environmental Society mentions that Eucalyptus plants were planted in place of other native species in Similipal Tiger Reserve and this was the reason the fire spread easily in March of 2021. The secretary stated that the trees are fire prone and the leaf litter beneath them leads to spreading of the fire throughout the forest. The fire was very intense as it lasted for over 15 days according to the article (Senapati, 2021). Whether or not Eucalyptus trees play a role in causing or spreading forest fires in Kodaikanal remains unexplored.

Thus, it can be seen that the overall recorded impact of Eucalyptus trees on the environment has been degrading. From allelochemicals inhibiting plant growth, to the out competition of natural vegetation, Eucalyptus trees have been aggressively invasive. However, oil derived from Eucalyptus holds an important place in the minds of the users due to excellent medicinal and aromatic properties. As is the case with any industry, the Eucalyptus Oil industry will also provide employment to the local populace. From here, on-field research has been conducted in each of the aspects, to try to understand the scale of damage, and the modern-day impact of the Eucalyptus trees in Kodaikanal ; along with gaining an insight to the impact that Eucalyptus Oil has had on the economy of Kodaikanal.



Chapter 3

ECOLOGICAL IMPACTS

From this chapter onwards, till chapter 5, findings of on-field research have been presented. This particular chapter focuses only on the findings done for the ecological aspects, ie, Allelopathy, Sholas, and Grasslands.

3.1 Allelopathy

It has already been established how many plant species are capable of secreting allelochemicals which have adverse impacts on other plants, and that list includes Eucalyptus. Numerous studies confirm that certain species of Eucalyptus trees secrete allelopathic chemicals and negatively affect other plants (Zhang & Fu, 2009 ; Bayle, 2019; Moral et al., 1970). Eucalyptus is a tree which grows and reproduces quickly, and while it is not much of a threat as an endemic species in its native areas, it poses a significant threat as an invasive species. This threat is augmented by the allelopathic effect of some of its variants which may cause eucalyptus to out compete native species especially if the native species are smaller in size such as shrubs, grasses, small trees etc. Since eucalyptus trees are not native to India, their impacts as invasive species drive native species out of resources.

In Kodaikanal, *Eucalyptus globulus* consists of almost 22 thousand hectares of land (Pancholi, 2022). Unlike the traits that are found commonly in plant species which are endemic to Kodaikanal, Eucalyptus is a fierce competitor when consuming resources as mentioned before. This trait is further amplified when its allelopathic effect suppresses the growth of other plants. This causes other species to struggle in order to procure fundamental resources while eucalyptus dominates and essentially eliminates nearby small competitors. More specific traits such as height advantage and wide leaf cover synergise well with allelopathy to cut off sunlight as a resource for small plants while also stunting the plants' growth.

Although strategies which implement allelopathic chemicals as advantageous assets have been discovered, Eucalyptus trees have significant deleterious effects on the native species which has been studied extensively (Zhang & Fu, 2009). On the other hand certain possible opportunities do present themselves when concerned with allelopathic chemicals, for example there is evidence that indicates certain allelopathic chemicals such as terpenoids attract bees (Nayek, 2018). In the context of Kodaikanal this aspect had not been explored. Additionally based on the previously mentioned literature and information, it can be understood that Allelopathy has caused significant

damage to the native species of Kodaikanal, yet it remains to be uncovered what actions can and have been taken against this rapid deterioration of native habitats of Kodaikanal.

To possibly discover the answers to these questions or lack thereof, we interviewed various respondents. These individuals were veterans in the research of Eucalyptus and their impacts on the ecology. Their insights were very valuable to us as we learned which problems they face due to allelopathy and which measures they are willing to take in order to mitigate damage.

From our interview with Mr. Karthikeyan– a third generation farmer– it could be understood that Eucalyptus trees shed their leaves and seeds yearlong, regardless of the season.. Within his experience, no other biodiversity can be witnessed nearby a eucalyptus tree. Furthermore he goes as far as to say that eucalyptus forests are "graveyards" referring to the lack of species diversity due to the allelopathic effects on the many species usually found in Kodaikanal. His comments about leaves falling irrespective of season could also be supported by the fact that Eucalyptus trees are classified as "evergreen". This term in botany relates to the tree retaining its green foliage through more than one season indicating rapid leaf production.

This indication is a problem for ecology in Kodaikanal as studies have proven that leaves of eucalyptus trees contain the allelopathic compounds hence effectively becoming an allelopathic vector (Willis, 1991). Mr. Karthikeyan further developed this point by adding that rains cause the allelopathic chemicals to leach into the soil causing more suppression of plant growth. These findings are also consistent in an experiment conducted by Saxena and Singh in 1978. The experiment involved soaking 400 grams of eucalyptus leaves in 2 litres of water and extracting the leachate (solution formed after soaking leaves) to conduct plant growth experiments (Willis, 1991). In order to counter such effects on his cropland, Mr. Karthikeyan highlighted two points through which he combats allelopathy. First one was to simply avoid all eucalyptus trees altogether when choosing where to plant crops to avoid any damage ; the next involved killing the tree by shaving off the base of its bark which consists of the xylem effectively cutting off the tree's nutrient supply–a method called "ring barking."



Mr. Karthikeyan's farm (foreground). Eucalyptus Trees can be seen in the background behind the cottage.

Utilising the knowledge that Mr. Karthikeyan passed on to us we were able to draw tangents during our PHCC focus group discussion. Mr. Mark Antrobus– who was leading the discussion– provided us with glimpses of new and interesting information which was quite consistent with our secondary research. He mentions that the reason Eucalyptus trees are so dominant over native species in Kodaikanal is due to its evolutionary advantage. To elaborate, he told us that Eucalyptus does not spread this fiercely in countries where it originates from due to hundreds of years of coevolution. Species that grow nearby eucalyptus (in their native lands) have gone through this process and as a result developed a resistance towards the allelopathic chemicals (Moral et al., 1970) . On the other hand, species of Kodaikanal which have no prior exposure to inhibitors from eucalyptus lay defenceless and get out competed.

On more social lines of this topic, Dr. Rajamanikam talked about how there are two communities in Kodaikanal where one side is the scientific and the other are the common residents. He says that there is a rift between ideologies as each community has their stance upon how to deal with eucalyptus trees. This rift primarily exists due to the gap in knowledge about allelopathy within residents. These people are okay with not getting rid of eucalyptus trees as they do not understand the unseen damage it does to the nearby plants, soil, and the microbes within it. In stark contrast the scientific community wants to get rid of eucalyptus trees but through slow and calculated elimination. Here we start to see a contrast between the opinions of Mr. Karthikeyan, as a farmer directly impacted by eucalyptus's allelopathic impact, and Dr. Rajamanikam, as a nature activist. Mr. Karthikeyan believes that through natural progression eucalyptus will be removed and taken over by the Shola forests while Dr. Rajamanikam supports the systematic removal of Eucalyptus through human intervention.

The debate over which approach to take towards combating allelopathic effects is a complex one, especially when factors such as economic dependency of residents are taken into account, yet so far we have been successful in establishing that the allelopathic effects of eucalyptus on the ecology is indefinitely harmful and uncontained in Kodaikanal.

3.2 Shola Forests

Shola forests are present in the South Indian region of India. The name *Shola*, is derived from the Tamil word *Sholai* which means a "tropical rainforest" (Sundararaju, 2020). Since they are found in the upper regions of the Western Ghats like Nilgiris, Palani Hills, and Kalakadu etc, they are referred to as "tropical montane forests", and depending on the elevation the forest is at, they are either classified as "lower montane cloud forest" or "upper montane cloud forest". The term "cloud" is present as sholas are commonly considered to have constant cloud cover, and the word "montane" emphasises that the ecosystem is a part of mountain regions (Sasmitha et al., 2021).

A fascinating fact about these forests is that they coexist with grasslands in the area naturally. This existence of grasslands along with sholas is categorised as the *shola-grassland ecosystem mosaic* (Sasmitha et al., 2021). As explained by Mr. Mark in an interview, the ecosystem consists of vast lands covering grasslands with shola forests present in fragments in the valley and folds of the mountains. There are two theories that explain how sholas and grasslands are able to coexist: the frost hypothesis and the fire hypothesis (Thomas & Palmer, 2007). The frost

hypothesis states that ground frosts on the grasslands prevents tropical species from growing, however, a few that are able to grow are considered to be temperate, frost-adapted species as can be seen in the shola-grassland ecosystem as well (Meher-homji, 1965). The fire hypothesis on the other hand states that the grasslands are a result of pastoral and agricultural activities done by early human settlers (Bor, 1938). Even though there's no real proof on how this unique ecosystem came into existence, one thing studies conclude for sure is that the grasslands and shola forests were coexisting before human habitation and that the vegetation was highly dependent upon monsoonal changes (Chandran, 1997).



Dense shola forests of the Tiger Sholai

Contrary to the belief that limited availability of shola forests for the shola forest species would restrict a-diversity, the variety of species and the vegetation found in the ecosystem is rather

vast and diverse (Bunyan et al., 2012). To talk about only Sholas, the fragments contain species which are both tropical and temperate. As suggested by the frost hypothesis, the genera found on the borders of the grasslands are temperate in nature. To name a few, you can see *Rubus, Eurya, Mahoia* & *Berberis* which are Himalayan in origin. As for species within the shola fragments, they are considered to be Indomalyan or Indian in origin and a few examples being: *Myrtaceae*, *Oleaceae* & *Fabaceae* (Bunyan et al., 2012). A study on one shola fragment shows that the trees on the edge of the forest were more influenced by soil moisture and nitrogen. Shola forests are also said to present prolific epiphytic growth which means that they comprise a lot of plants which grow on the surface of other plants. When we look at the fauna in the ecosystem, the study by Sasmitha et al. states that, "The shola-grassland ecosystem mosaics are home to many threatened faunal species due to their unique climate, evergreen nature and high altitude" (2021). Some of the species found are: *Gaur*, *Dhole* & *Nilgiri Langur*. Flora and fauna found in this area is different from the species you find in the lowland forests however, sholas of different regions show little to no similarity in the species composition. Therefore, having a clear distinction between a normal forest and a shola forest becomes necessary.

To be able to distinguish a shola forest from any other forest, there are certain physiognomic characteristics of the trees that are looked at. Shola forests consist of evergreen tree species which are also dwarf in nature i.e. they are green, small, profusely branched trees (Bunyan et al., 2012). They are said to have leaves which are small, leathery in size and texture. When the leaves are young, they are red in colour and upon maturity, they turn into different colours (2021). The study by Bunyan et al. defines Sholas (ecologically) as any forest on an elevation higher than 1700m with the given distinct properties (2012). If the elevation is below 1700m, it is recommended that the distinction should be subjected to the forests surrounding the grassland regions.

Other than being a home for so many different species, Shola forests have more value attached to them. Along with the grasslands, they act as a water-reservoir. The grasslands store the rainwater and then let it flow through the Sholas as streams throughout the year (Sasmitha et al., 2021). According to Bhale, even during peak summer, Shola forests would have a stream coming down from it which ultimately joins rivers such as Bahavni that supports a lot of economic activities in the nearby areas. In our focus group discussion, we also found out that Shola forests reduce the water run-offs extensively. This means that they store water and do not let soil erosion

take place. They are good at preventing floods caused due to run-offs and maintaining the soil moisture. Mr. Karthikeyan also shared that Shola forests help in maintaining the climate in the region which was also experienced first-hand by us; the climate in the Shola forests was way cooler than the climate near the eucalyptus tree forests. Although Shola trees are not of great importance from a commercial perspective (the trees are slow growing with little or no timber value), because of their immense contribution in water conservation & its contribution in supporting all the locals throughout the year, and having such a great biodiversity, they are an important ecosystem for our country (Sundararaju, 2020).

However, the Sholas have gradually started to shrink mainly due to getting replaced by the invasive species which were planted by the Britishers before independence. According to studies, the Sholas were spread around 8600 hectares during 1849 whereas, in 1992, it was only 4225 hectares (Sundararaju, 2020). The loss in Shola forests was around 50% which is extremely significant. When asked the same question to Mr. Karthikeyan, he said that only around 17% of Shola forests are now left in Kodaikanal region. In his opinion, eucalyptus trees have never supported the people of Kodaikanal. He also mentions that eucalyptus trees stop the rains because of all the heat they generate and at the same time soak up a lot of water for themselves, therefore, the water available to the other plant species reduces drastically. This is one of the reasons why the Sholas in Kodaikanal have depleted. Dr. Rajamanikam states that Sholas trees are not very flexible when it comes to temperature, water level and the microbes in the soil; a small change would lead to a reduction in the forest. As we know that eucalyptus trees shed a lot, he also explained to us that when the leaves fall on the soil, they contaminate the soil and make it acidic in nature which is not suitable for Shola trees to grow. And because there is lack of water, the microbes in the soil get affected which in turn affects the growth of Sholas. However, the discussion in the focus group interview brought different insights. According to the members of Palini Hills Conservation Council, eucalyptus trees have not competed with Shola forests because they weren't planted in the areas near the Shola forests. The interesting point over here is that post independence is when the eucalyptus plantation started to grow so as to be able to meet increased demand for firewood and paperwood. An article written by Ramesh states that the invasive species weren't planted as a replacement for the native shola trees but instead were planted across the open grasslands (2018). The article also states that even Shola trees were planted in the grasslands so as to meet with the increased demand but they couldn't be sustained which led to furthermore

plantations of eucalyptus trees (Ramesh, 2018). Things became worse for Shola trees when the rumour about grasslands having infertile soil led to the plantations being shifted to patches cleared by felling sholas. When this happened, the soil and water issues led to shola depletion as explained by Dr. Rajamanikam and Mr. Karthikeyan. The research article by Sasmitha et al. also suggests that grasslands and sholas were slowly cleared so that invasive species like eucalyptus can be planted in the area to fulfil the demand for wood. This was initially done by the Britishers but was also followed by the Indian Forest Department post independence to benefit from the growing economy (2021). Along with the plantations causing the depletion of forests, the developmental activities like tea and coffee plantations, increased scope for tourism etc added on to the gradual loss of the ecosystem.

The depletion of Shola forests due to the plantation of eucalyptus trees has caused several other problems in Kodaikanal as well. The main problem that arose was that fauna of the shola forests lost their habitat. There are many news articles published talking about the discomfort caused to the people of Kodaikanal due to wild gaur (bison) roaming around on the roads of the city in order to look for food. Even Mr. Mark in his interview commented that planting any invasive species hurts the animals that are a part of that ecosystem the most. Additionally, as eucalyptus forests are considered to be a monoculture or '*graveyards*,' they don't support not only animals but also other plant species as has been explained in the previous chapters. In Mark's opinion, another issue that is concerning is the problem of run-offs. Since there are no shola forests to hold the water that pours, the water just flows by causing further problems like floods and soil erosion in and around the city. The problems Mr. Karthikeyan talks about revolve around water and temperature. He states that 14 districts rely on the water provided by this ecosystem which is currently in jeopardy due to depletion of the forests and because of a grown eucalyptus tree sucking 1250 litres of water on a regular basis. On top of that, he quotes that the change in temperature is 4 degree celsius higher than usual.

Once the government realised how important this ecosystem actually was and how eucalyptus was badly affecting the area, they put a ban on both planting and cutting of eucalyptus trees and asked the authorities responsible to create a plan for restoration of the lost Shola forests. Following this interim, the forest department also started to actively work on getting the native ecosystem back in the state (*Top Priority for Restoration of Shola Forests*). They've been taking measures to stop eucalyptus from spreading and at the same time, planting the native species back.

When we spoke to our contacts before going on field, one revelatory fact that was told to us was that now the Shola forests are growing back under the eucalyptus trees that are present in Kodaikanal. Even though there have been studies which hypothesised that eucalyptus trees can provide a habitat for shola regeneration, this was surprising primarily because all the other secondary research suggested that eucalyptus is a monoculture and it doesn't support any other life. In our interview with Mr. Karthikeyan, when we asked him about why he thinks sholas are growing back under eucalyptus trees, he is of the opinion that the *age of eucalyptus trees* is over and because they've matured now, their interaction with other species is not problematic anymore. This is why they are not inhibiting the growth of shola trees anymore. On the other hand, Dr. Rajamanikam strongly believes that sholas can not grow back. He says that not all shola species are strong enough to compete with the eucalyptus trees and therefore, in order to make the regeneration possible, we should know which species out of the 87 varieties found in the region can be planted so as to stand a chance against eucalyptus trees. However, in opposition to what Dr. Rajamanikam said, in our field visits to study eucalyptus and shola interactions with Mr. Karthikeyan and Mr. Murugesh, we saw that shola regeneration under eucalyptus trees was actually taking place. Both the forests were coexisting in the same vicinity with shola trees also growing under the eucalyptus trees. To better understand this phenomenon, when we asked the same question to the members of the Palini Hills Conservation Council, Mr. Mark explains that the sholas are able to regrow because the climatic and other environmental conditions provided in a eucalyptus forest are now suitable for the shola forests to grow. For example, the eucalyptus trees create a canopy which restricts the amount of sunlight that penetrates. This lack of sunlight is in turn better for the growth of shola trees as they are very sensitive to the light. Upon further research on this topic, an article by Mrs. Pippa Mukherjee explains this relationship more scientifically. She writes that in the first seven years of a eucalyptus tree's life is when they slurp the water the most. By the next 7-10 years, they mature and then, "they reach a stage of living within its means", and therefore do not affect the growth of other species; instead, protect and shelter them to grow under them (2021). This was initially seen happening in Perumalmalai, one of the places we had the opportunity to visit as well. Although, one thing that needs to be taken care of is to control the herbivore impact.



Shola Regeneration under the Eucalyptus (only trunks visible) canopy, Tiger Sholai

To be able to do this, a clear understanding of the shola species is required (Srimathi et al., 2012). The conclusion derived at in the study by Selwyn and Ganesan also remains constant: "If eucalyptus plantations are left undisturbed for a period of time, it can recover the native species, and accelerate the natural succession processes at faster rate by providing complex habitat that increases the seed movement from the surrounding forests by attracting more dispersal agents," (2009). It is important to note that the shola regeneration is only true when we talk about eucalyptus trees; other invasive species like *wattle* and *pine* haven't supported the regeneration (Mukherjee, 2021), they might in the future when they've *"reached their age"* in Mr. Karthikeyan's terminology but it cannot be seen happening today.

In retrospect, Shola forests have always been an integral part of the Western Ghats. They have existed in harmony with grasslands (referred to as Shola grasslands) from even before

humans settled in the area and have not only taken care of the ecosystem they give rise to but also humans. They've provided humans with water throughout the year (so much that they roughly supported around 30 rivers), maintained a good climate for the people living nearby and also provided fuelwood at the time demand wasn't that high. Post british invasion is when the things started to get worse for these forests. Human intervention and plantation of invasive species like Eucalyptus became problematic for the ecosystem. The interesting point is that even though eucalyptus trees primarily weren't planted in shola forests, shola forests ended up suffering. The Britishers didn't plant the invasive species in place of shola forests because they considered it to be a useful ecosystem so they targeted *waste grasslands* instead. Another demotivating factor was that it would have taken more time to cut forests when compared to planting the same on the grasslands. Eucalyptus didn't end up competing with sholas as much as it competed with other species in the area but an overall impact was still visible as there were water shortages and depletion of soil quality by them which suffered the growth of shola trees. The depletion of the forests weren't only because of eucalyptus but there were other contributing factors as well like tourism, changes in land uses etc. What made it worse was when post independence, Indians didn't realise the problems associated with eucalyptus and other invasive species and kept on planting them more and more as a means of earning money. This is when the eucalyptus forests actually started spreading (around 1960s) as explained by the members of the Palini Hills Conservation Council. The important thing to take note of is that even after the High court passed an order to stop human intervention when it comes to planting and cutting eucalyptus trees, the eucalyptus trees still outgrew and competed with other plant species in Kodaikanal. This was because eucalyptus trees shed a lot of seeds and it is very easy for the seeds to germinate under the sun which is unlike how shola seeds behave. As explained by Dr. Rajamanikam, shola trees can't germinate very easily as they need very specific conditions under which they can grow. Due to this, shola forests depleted dramatically in the area. However, as many newspaper articles state, not all hope is lost for the shola forests. As can be seen in places like Perumalmalai in Kodaikanal, shola trees are now growing back under eucalyptus trees. There are many theories on how this is happening; some state that it is happening because the eucalyptus era is over backing up with the claim that once eucalyptus trees mature, they stop interfering with their surroundings and become self-reliant. Others state that the conditions provided in the eucalyptus forests is very suitable for sholas to grow and since allelopathy doesn't affect (according to what Mr. Mark Antrobus says)

sholas, they're able to grow right under eucalyptus tree cover. Scientific studies tell us that, eucalyptus if left undisturbed can help in restoration of the shola trees but the a clear understanding of which seeds to plant, under which conditions should they be planted and when to plant them etc is needed to be able to restore the shola forests successfully which is what even Dr. Rajamanikam told in his interview. Whether or not we will get the complete ecosystem back is also something we can't be sure of yet. One important point to observe is that even though the sholas are growing back, they're doing so in the place where grasslands used to be in the past. If, in future, shola trees end up outcompeting the invasive species, there would be shola forests in place of shola grasslands. Whether or not we will get grasslands back is a mystery which will only unfold in the future. However, one thing that is understood from the interactions of eucalyptus and sholas is that, if nature is left untouched, it will make things right by itself; it adjusts and corrects everything if humans let them be as is agreed upon by all our primary contacts as well.

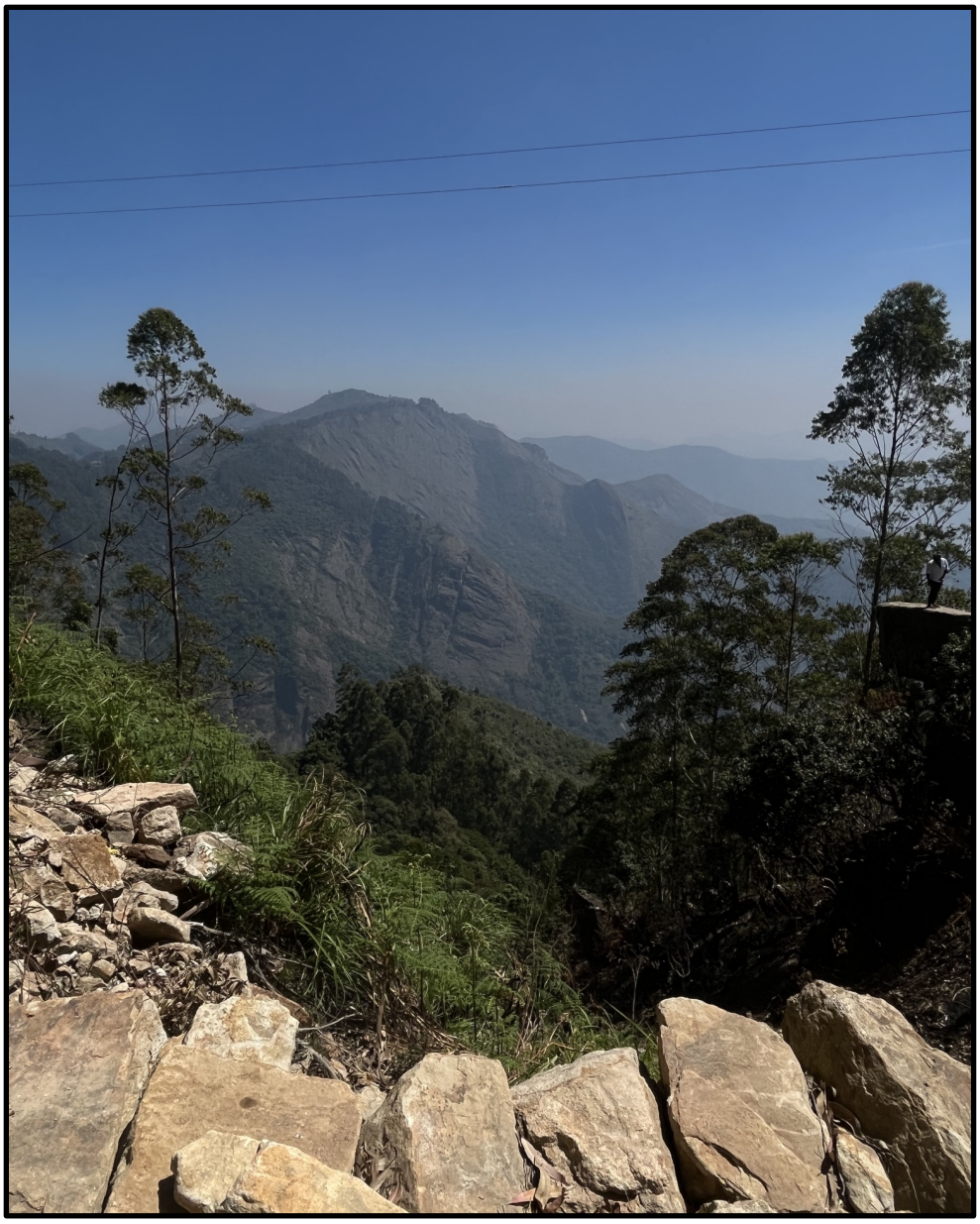
3.3 Grasslands

Grasslands are one of the most extensively distributed terrestrial biomes on the planet. In a broad sense, the term "grassland" refers to all herbaceous vegetation types, including the Eurasian steppes, North American prairies, South American pampas, and African veld and savannas, as well as some woody shrub-based deserts and tundra and various artificial grasslands and grazing land around the world. There are mainly two types of grasslands, the Savannas and the Temperate Grasslands (Zhao et al., 2020). The tropical grasslands or the Savannas generally have scattered individual trees. Savannas are very sensitive to the climate and it is one of the most important factors. Savannas generally grow in the regions with an annual rainfall 20- 50 inches with the rainfall being distributed in the period of six- eight months. This is then followed by a period of droughts where there is a possibility of fires taking place. Climate savannas are savannas formed as a result of climate conditions. Edaphic savannas are savannas that are caused by soil conditions and are not totally maintained by fire. They can occur on steep slopes or ridges with shallow soil, or in valleys with clay soils that become saturated in wet weather. People clearing forest areas for farming creates a third sort of savanna, called a derived savanna. Farmers cut down a section of forest, burn the dead trees, then sow crops in the ashes for as long as the soil is fertile. The other type of grasslands are the Temperate Grasslands. Temperate grasslands are distinguished by grasses as the dominant vegetation. There are no trees or huge bushes. Temperatures in temperate

grasslands vary significantly from summer to winter, and rainfall is less than in savannas. (*The Grassland Biome*).

This mosaic ecosystem of grasslands and sholas is only found in the high altitude highlands of Kerala, Tamil Nadu, and Karnataka and is endemic to the southern Western Ghats. This is a one-of-a-kind system in which extensive grassland is interlaced with forest. The forest is made up of dwarf evergreen native trees, while the hill slopes are covered with natural grass species. The vegetation is two-layered and has a closed canopy. The Western Ghats grassland ecosystem is distinct from Himalayan cold desert, Aravalli, Vindhya, Eastern Ghats, and Deccan plateau grasslands in terms of height, distribution, species composition, and species association. At Palani Hills, 66% of native grasslands and 31% of native woods have been destroyed during the previous 40 years, and local authorities must make quick conservation measures to conserve the ecological composition of this region. Palani Hills grasslands provide ecological niches for *Anaphalis spp., Impatiens spp., Strobilanthes spp*., and grass species, all of which are indigenous to the Western Ghats Biodiversity Hotspot. These high altitude Shola grasslands provide a one-of-a-kind home for endangered birds Sharpe's Anthus nilghiriensis (*Nilgiri pipit*) (Arigela et al., 2019).

The climate on Earth was extremely varied, with multiple cycles of cold and heat. Carbon deposits from wetlands in shola forests suggest that the environment was dry 16,000-20,000 years ago, resulting in a plethora of flora dominated by grasslands. As a result, the environment began to become wetter, and the woods were considered to have recolonised the vegetation approximately 11,000 years ago. About 6,000 years ago, the monsoon began to diminish, and grasses are considered to have resurged, resulting in the current grassland-forest matrix. While climate did shape these grasslands over geological time, studies indicate that elevation and topography may also play a role in the persistence of the grasslands. Topological elements such as valleys and climatic parameters such as precipitation during dry months and yearly temperature are expected to impact the occurrence and extent of shola forest mosaics over the length of the Western Ghats. Thermal profiles are likely to be unfavourable for numerous species



Grasslands as seen on the slopes of the hills, interspersed with the tall Eucalyptus trees.

due to elevation and bioclimate. Frost, for example, inhibits plant spread and colonisation on certain mountaintops with the grasslands (S, 2022).

These ecosystems have a great potential for water retention, absorbing rain and retaining it inside their soil. As implied by Dr. Rajamanikam, Mr. Karthikeyan and the officials of the Palini Hills Conservation Council, the grasslands of Kodaikanal are referred to and compared to a “water sponge” because of its water retention capacity. Dr. Rajamanikam also pointed out in the interview

that the grasslands helped the origination of around 30 rivers in the Palini region. These rivers slowly died down because of the decrease in the grasslands which supported and acted as a source of water to those rivers. In an interview with Mr. Karthikeyan, he mentioned that the roots of the grasslands absorb the mist and water from the atmosphere and store it in their roots. This phenomenon in Tamil is called '*Chadambal*', which when translated means: a place where you get a lot of water. The roots of the grasslands act as a carrier of rainwater. The water flows down to the streams, around which the Sholas are found. Mr. Karthikeyan also mentioned the fact that there are around 16 dams in the Palani region which depend on Kodaikanal for water. Over the years, the streambed and decomposing litter of the forest store the water and slowly release it to form tiny streams, which unite to make larger streams and finally rivers. As a result, it serves as the region's water reservoir for the Nilgiri Biosphere Reserve. This shola-grassland is the source of several rivers in Tamil Nadu and Kerala (Sarvajayakesavalu et al., 2021).

When the British found the Nilgiri mountain range, which is part of the Western Ghats, in 1826, they concluded that the unusual mosaic of grasslands and forests divided by clear borders suggested that the natives had modified a previously hilly terrain by razing forests. The settlers then began planting trees in the hills without understanding the different types of plants, ecosystems, or soils. The reasons behind the exercise included beautification, but the primary motive was commercialisation. Yet the demand for timber wasn't satisfied, and it was believed that additional trees were needed. As a result, more Eucalyptus trees along with other invasive species were introduced. With the theory gaining ground that the grasslands had bad soil, the trees were planted in patches cleared by felling sholas. The planting of Eucalyptus trees disturbed the entire water table. These trees require a lot of water and have very thick roots which suck the groundwater. Mr. Mark in his interview mentioned that the problem was that the roots of Eucalyptus trees started spreading rigorously around the grasslands causing water run-offs, causing the native species to suffer (Ramesh, 2018). The Britishers assumed the grasslands to be wastelands as they did not directly contribute to economic growth. It was because of this they cut down the grasslands and started planting Eucalyptus trees for the paper, timber and firewood.

According to all our respondents, the rampant increase in the cultivation of potatoes also played a role in the loss of grasslands. During the 1960's, the government leased the grasslands to the farmers to grow potatoes. This was the golden time for the people of Kodaikanal. Later, after a period of three years, when the lease got over, the government ordered the farmers to grow

eucalyptus trees in that land and move to other lands to cultivate even more potatoes. Due to this, there was an increase in the eucalyptus plantation and, at the same time, there was a dramatic decrease in the grasslands. In our discussion with PHCC, they mention that, another explanation that was given to plant more Eucalyptus trees by the authorities was to reduce the moisture content around the Berijam Lake in Kodaikanal. This could be concluded to be one of the reasons for the depleting grasslands.

The grassland ecosystem is one of the Western Ghats' most diversified yet endangered landscapes. These ecosystems are extremely vulnerable to climate change, and climate change has a stronger impact on this forest-grassland. Several natural and artificial influences are degrading these distinct habitats. Land use changes have fragmented the Nilgiri grassland since the mid-nineteenth century. The British company and royal administrations significantly modified land management in the Nilgiri Hills, and beginning in 1837, tea and eucalyptus plantations were developed and expanded. During World War II, the colonial authority pushed wattle, eucalyptus, and pine plantations at the expense of highly diversified and resource-rich grasslands. Gradually, grasslands were removed to make way for plantation areas and timber. Planting mostly of exotic timber trees Black wattle and eucalyptus have been a source of concern in certain areas. Since grasslands are easily cleared, the British and later the Indian Forest Department created tea estates, coffee farms, and lumber plantations to meet the different needs of the rising economy. This resulted in the destruction of a large amount of the grasslands. Numerous development projects have been carried out in the region, and these projects have resulted in the steady degradation of the ecology. A documentation study conducted in the region revealed that factors responsible for the declining grassland ecosystem include extensive land conversion, such as conversion into agricultural plots, commercial plantations, development activities, exotic tree plantation, and burning practices, such as annual fires (Arasumani et al., 2018). Dr. Rajamanikam also mentioned the fact that the rapid urbanisation and the growth in the real estate industry is one of the main causes for the depletion of grasslands.



Interaction of Grasslands and Eucalyptus Trees, Poondi, Kodaikanal

Several types of invasion are affecting the grasslands region. This has resulted in the loss of endemic species of birds and animals by affecting their food reserves, the gradual disappearance of wild edible fruits and other plant species, and the native forest is reducing at a faster rate, which also results in man-animal conflicts, ultimately affecting the region's biodiversity. A documentation research conducted in the region found that the area is experiencing soil-related concerns such as loss of soil fertility, loss of soil beneficial microbial activity, subsoil compaction, frequent soil erosion, and soil unsuitability to grow lucrative crops. According to the study, indiscriminate use of fertilisers and pesticides, soil transportation, repeated application of chemical inputs above recommended levels, use of heavy farm machinery, cultivation of exotics, loss of local natural vegetation, faulty land resettlement, loss of natural windbreaks, mono-cropping, and loss of healthy soil biological process have all contributed significantly to the region's natural soil ecosystem (Arasumani et al., 2018).

The shola grasslands are tropical montane forests separated by rolling grasslands in the high altitudes of the Western Ghats. The grassland ecosystem has suffered significant habitat loss, owing mostly to exotic tree plantings, widespread commercial plantations, substantial monoculture, and cow grazing. Plant and animal species are likely to become extinct as a result of

habitat loss in the ecosystem. Moreover, climate change is projected to alter the balance between forest and grassland. Responding to these difficulties requires identifying the knowledge gap and using current levels of knowledge. There is an urgent need to map the degree of grassland loss, exotic plantation spread, and invasive species distribution in each forest division (Arasumani et al., 2018).

Nature has a way of getting back, and it is predicted by our respondents that there might be an increase in the grasslands, as people are becoming more aware of the many benefits the grasslands have given. There are chances that Kodaikanal might see an increase in the grasslands even though it is not yet seen. It is possible that once the shola forests outgrow the eucalyptus trees, nature would be able to get the shola grasslands back as well.

Thus, it can be observed that certain aspects of the ecological impacts of Eucalyptus in Kodaikanal have changed over time significantly. While allelopathic effects of Eucalyptus are still prevalent today, with farmers still facing issues, changes can be seen in the impact the trees have had on the local sholas and grasslands.

While sholas have started showing signs of regeneration, and can be seen in pockets under the Eucalyptus' canopies, unfortunately, no positive sign for the regeneration of the grasslands is seen yet. Grasslands form the underlying foundation for the ecosystem to thrive in Kodaikanal, acting as a water bank and providing water not only to the town of Kodaikanal, but also to the shola forests. The impact that grassland depletion has had was also visible since we could spot wild *gaurs* feeding on the grass in the town itself.

This doesn't completely rid the eucalyptus trees of blame though. As mentioned earlier, Eucalyptus trees shed their seeds along with their leaves yearlong. This implies that, even if human activities (similar to those of the British) do not ensure the growth of the eucalyptus trees, natural processes will. This can probably cause newer trees to spring up and have more allelopathic, and water guzzling impacts, thereby, restarting the cycle all over again.



Chapter 4

ECONOMIC IMPACTS

This chapter focuses on the economic impacts of Eucalyptus, primarily through oil. Some information regarding our findings on Eucalyptus Honey, and the use of Eucalyptus trees as firewood in the homes' of villagers has also been discussed.

4.1 Primary Product - Eucalyptus Oil

4.1.1 Eucalyptus Oil Industry in Kodaikanal

Eucalyptus Oil has an important role in the lives of its users (a point discussed ahead in this chapter), and its extraction supports the lives of many. In this section, we will be taking a closer look at the kind of extraction processes used for Eucalyptus Oil in the world and in Kodaikanal, the costs involved in the extraction, and its viability as an industry in Kodaikanal.

Mr. Murugesh, a local working with the PHCC, states that out of the 3 major Eucalyptus species planted in Kodaikanal, it is the *Eucalyptus Globulus* or the 'Blue Gum' that is used for commercial oil. The other two species– E. Citriodora and E. Grandis– are used in the perfumery and timber industry respectively. However, as in the case with all other industries, profitability of manufacturing Eucalyptus Oil in Kodaikanal depends very much on the scale and method of production, since at a cottage industry or small-scale, the oil manufacturing is not a money making business, a point experienced by Mrs. Jenyz Satori– a cottage-industry based oil extractor.

It is quite logical to assume so, since with larger production capacities, economies of scale come into play, making production on a larger scale feasible. The numbers as far as the economic cost is concerned are discussed ahead, but before proceeding there, it is important to understand the nature of the set-up for obtaining Eucalyptus oil.

According to Dr. Satori, there are three primary ways of obtaining Eucalyptus Oil:

I. <u>Carbon Dioxide Distillation</u>

This kind of distillation uses highly pressurised and heated Carbon Dioxide. CO_2 in this state (beyond 31° C and 7.38 MPa temperature and pressure respectively) is said to be in its 'supercritical' state (Okamoto et. al., 2016). The process uses the liquid state of supercritical CO_2 as the solvent. In this stage, carbon dioxide liquifies and is pumped into a chamber containing the plant matter. Here, due to its properties as a supercritical gas, oil dissolves into the liquid carbon dioxide, which it carries with it into a depressurising chamber. In this chamber, the supercritical carbon dioxide is brought back to its original

pressure where it evaporates back into its gaseous state, while what is left is the resulting oil (2017).

Despite Carbon Dioxide distillation being one of the world's most famous– and easiest– processes for eucalyptus oil extraction, producing the best yield of the oil, Dr. Satori and Mr. Suresh cannot set it up in their distilleries. The reason being, to set up a small unit of this distillation technique costs nearly Rs. 20-30 lakh, making it too expensive to be used in a cottage-industry/small-scale level. Furthermore, usability and operability of the equipment is also tough (Immaroh et. al., 2021).

II. Steam distillation

Oil is contained in eucalyptus leaves within glands below the surface of the leaf, which may be seen as tiny transparent 'windows' of light if the leaf is held up to a bright source of light. In order to recover the oil the leaves are subjected to a process of steam distillation (Coppen & Hone, 1996).

Steam distillation is a process that allows compounds to be distilled at a temperature below their boiling points. Eucalyptus oils contain substances with high boiling points (150-200°C), but steam or boiling water can volatilize them at close to 100°C. The resulting mixture of vapours can be condensed into a liquid with distinct layers of oil and water. Eucalyptus oil forms the top layer since it is lighter than water, and it has negligible solubility in water at ambient temperature (Coppen & Hone, 1996).

III. Hydrodistillation

Hydrodistillation is a traditional extraction method used for eucalyptus oil. In this method, the eucalyptus oil is evaporated by heating a mixture of water and eucalyptus leaves. The vapour is then liquefied in a condenser, and flows into a separate room in which there will be separated into oil and water. This method is quite simple, it can be used in either a small or big scale, can avoid chemical content loss due to the long extraction process, and saves energy (Immaroh et. al, 2021).

According to Dr. Satori , Hydrodistillation and Steam distillation are the two extraction methods through which eucalyptus oil meant for medicinal purposes is extracted. In Kodaikanal, small-scale industries like Mani Natural Essential Oil (run by Mr. Suresh), and cottage industries like the one run by Dr. Satori (a Nature Analyst based out of Kodaikanal), uses the latter two as their form of eucalyptus extraction. The only difference between the two is the source of steam. In

case of hydrodistillation, the steam is obtained from water, whereas in case of steam distillation, an external boiler provides the steam (Coppen & Hone, 1996).

Steam distillation has its fair share of benefits over hydrodistillation: it is relatively rapid and capable of greater control by the operator, the process can be re-initiated quickly without delays, and oil quality produced by this method is much better than that of the oil produced by hydrodistillation (Coppen & Hone, 1996). In fact, Dr. Jenyz is not only able to gather the volatile and non-volatile components of the oil, but is also able to produce the highest quality, purest-form of eucalyptus oil through a steam distillation set-up in her home.

Steam Distillation set-up in Dr. Jenyz Satori's house

Dr. Satori mentions that the purest form of eucalyptus oil is non-sticky, white in colour,



and evaporates soon after application. However, pure eucalyptus oil has the potential to burn your skin if applied undiluted. It needs to be diluted with carrier oils like coconut oil, almond oil, or sesame oil before application.

The widely and readily available eucalyptus leaves in Kodaikanal, along with the high medicinal value of eucalyptus oil makes it a shining business opportunity. Its smell, and use case as an anti-bacterial, anti-viral, and anti-inflammatory substance enables it to be used not only on the body, but also for cleaning floors and other surfaces.

Mr. Suresh's distillery, the Mani Natural Essential Oil, is one of the famous small-scale distilleries of Kodaikanal. This family business, run throughout generations, is into the oil extraction business of not only Eucalyptus, but also other essential oil sources like lemongrass, geranium, citronella, citradora, and clove. For Eucalyptus oil, they use hydrodistillation as the process of extraction.

The process of hydrodistillation starts with boiling around 100 L of water in a boiler with wood as fuel source. The steam produced is allowed to enter a vessel (the '*still'*), containing around 300 kilograms of eucalyptus leaves, from below. The leaf vessel is then covered and sealed with clay (to prevent leakage), with the entire set-up representing a tandoor. From here, the steam rises and carries the oil with it into a cooling chamber which condenses the steam into water. It is then collected in a jar, where oil being less dense floats on top of the water. This entire process takes nearly 5 hours and produces only 3 litres of oil.

Eucalyptus leaves also serve as an excellent source of biofuel. This can be seen in another set-up of the distillery, where the leftover mulch of leaves from the steam distillation is allowed to dry. Since these leaves have no oil content left, they are reused as a fuel source. They are used in another distillery set-up to boil the water and oil-containing leaves mixture. Although this process takes around an hour more than the aforementioned hydrodistillation process, it still produces the same amount of oil for the same amount of leaves, and is a much more economic option for the distillery, since costs and expenditure on wood and fuel is saved.



Hydrodistillation Set-up in Mr. Suresh's Distillery

This method however, did cause smoke. There was a cloud of smoke across the distillery due to this method, and by the time we left it, all of us were smelling like eucalyptus. When asked by Mr. Suresh about the pollution causes, he agreed it happened but the smoke produced through this process lies under an acceptable range of pollution for that area. Another interesting medicinal impact of eucalyptus was seen through its effect on the discharged water.

The water that gets collected at the end of this process is eventually let out to nature. This water is able to retain the medicinal properties and essence of eucalyptus, which it carries with it downstream. In fact, this water is used by some in face packs and for bathing properties. When tested in the lab, the water was shown to kill bacteria in the polluted water coming from upstream, thereby purifying it.

Now that light has been thrown upon the processes of Eucalyptus Oil extraction, and the way it is used for smaller scales of production in Kodaikanal, it is imperative to look at the economic cost and feasibility of economic oil production in the region.

One of the biggest expenses faced by small scale producers is that of the set-up cost. Just for setting up a steam distillation plant in his distillery cost Mr. Suresh nearly Rs. 10.5 lakhs (Rs. 10 lakhs for the set-up with wood as fuel source, and Rs. 50,000 for the set-up with used eucalyptus leaves as fuel-source). The distillation plant has many components to it, including the boiler, the still, and the condenser. Provision also needs to be made for water, since it acts as the coolant in the condenser (Coppen & Hone, 1996).

The cost would not have been an issue if the yield makes up for the oil produced. For Dr. Jenyz's cottage industry, 3-4 kilograms of leaves produces just 40 mL of oil. The time it takes for such a small amount of oil to be produced is nearly 3-4 hours. The selling price of this 40 mL of oil can at the most be Rs. 1000, since it is in the purest form. When additives like kerosene/petroleum are added to the oil the selling price decreases further.

Mr. Suresh's clients include big companies like Amrutanjan and Vicks. He sells them oil on a contract basis, with volumes ranging from 100 L to 200 L. Although the retail value is Rs.2500 per litre, when sold in bulk, the price drops to Rs. 1500 per litre. This is the selling cost after 5-6 hours of extraction time, along with labour charges faced for obtaining the eucalyptus leaves (discussed ahead). In one extraction cycle, 300-400 kilograms of leaves give just 30-40 L of oil. Across the six units that Mr. Suresh has, his net profit is just Rs. 1,00,000 a month.

Another issue lies in the gathering of leaves for extraction. Eucalyptus trees tower to a height of nearly 150-180 ft, and collecting fresh leaves becomes problematic (Bean & Russo). Thus, only dried/dehydrated leaves are used for oil production. Fresh leaves, if found at all, need to be dried in the sun in order to be used. The catch lies in the time it takes for the eucalyptus tree to refurbish its leaves. Dr. Satori states that it takes nearly 6 months for the leaves to regrow, and in cases where all the leaves of a specific tree are used, the manufacturer would have to wait for at least a year.



Used Eucalyptus leaves being burnt to provide fuel for the hydrodistillation process. The container on the slab above the fire contains the leaves from which oil is extracted.

Thus, the implicit cost of eucalyptus oil production is greater than the returns the owner gets. On a smaller scale, equipment cost, volume sold, selling price of the quantity sold, and the sheer amount of time taken for extraction far outweigh the profits manufacturers reap. This is why manufacturers like Dr. Jenyz Satori and Mr. K. R. Suresh remains in the industry for either their passion, or because the industry has been run in the family for generations.

Pulling the plug on their businesses can thus seem a feasible option for these small-scale distilleries, especially Mani Natural Essential Oils. But years of running this business has created a layer of dependency. Not from an economic perspective, but from a livelihood standpoint. Not only for people working in the distilleries, but also for those selling them.

Mani Natural Essential Oil provides a source of income to nearly 50 people, out of which 6 find employment in the distillery. The workers are tasked with everything ranging from leaf collection to oil extraction. While collection and selling of dry leaves is done primarily by women below the poverty line, it is the men who are primarily tasked with climbing the tree (to a safe height) and collecting the dry/semi-dry leaves.

However, there is a considerably large gap in the income received by women and men for their efforts, even if men do the same work. Mr. Suresh states that women collecting and selling leaves earn Rs. 15 per kilogram of leaves they sell. Men, on the other hand, receive payment on a per day basis. For a man climbing the tree and collecting leaves, he gets paid Rs. 1500 per day, whereas a man helping the women collect leaves earns Rs. 800 per day.



Pile of dry leaves collected and sold to Mani Oil Distillery by the womenfolk employed

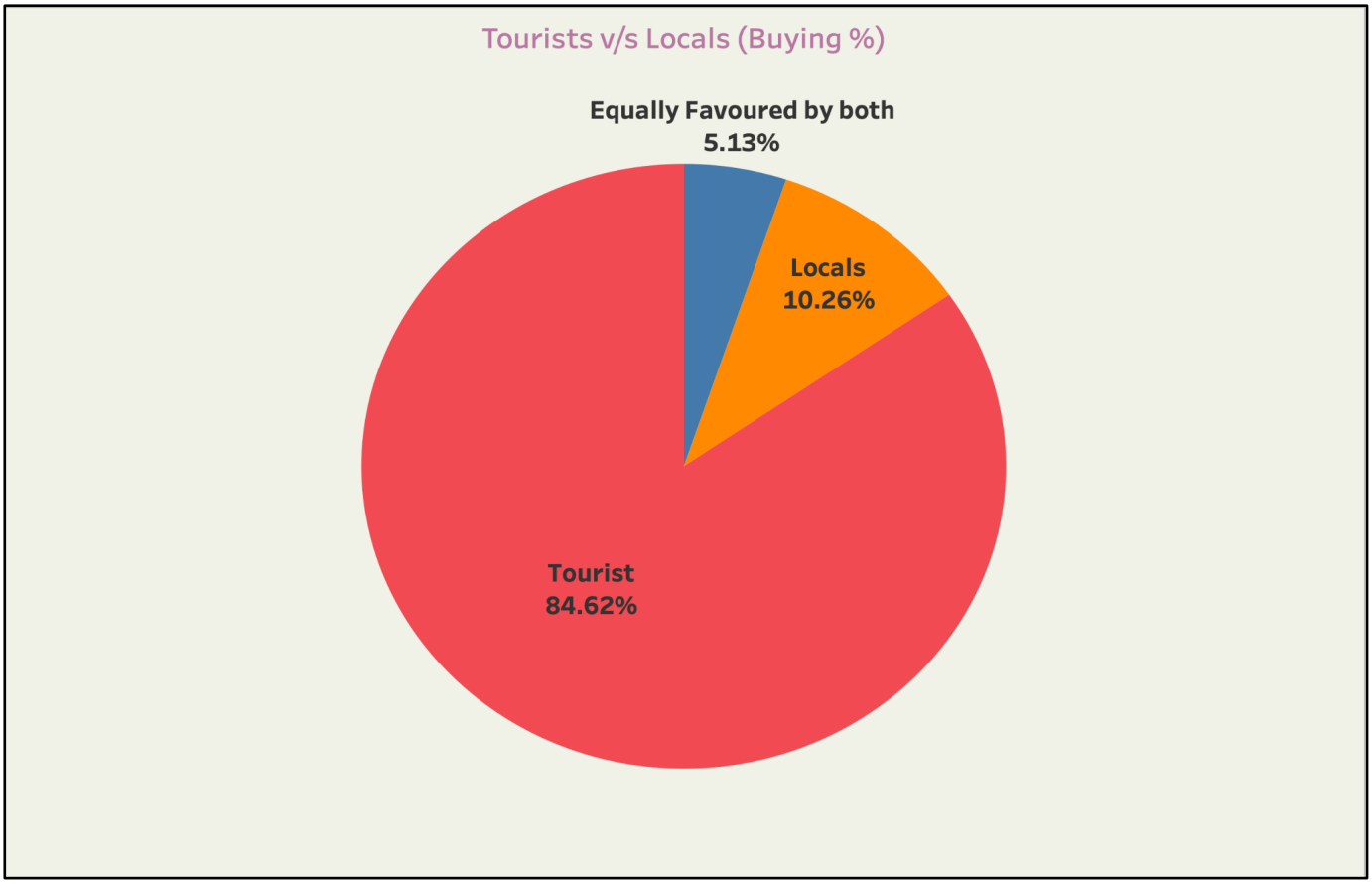
To sum up, Eucalyptus unknowingly has integrated itself deep into the Kodaikanal economy. It is a source of business and livelihood for many in the region, from distilleries to the sellers. However, due to profitability, many shop owners have started importing the oil from South Africa, and China (including Mr. Suresh himself). The matter is delicate. A decision to ban and remove eucalyptus completely from Kodaikanal can prove disastrous, and lead to more imports from South Africa and China, whereas economic costs of oil extraction can prevent newer distilleries from being set-up.



A shop in Kodaikanal displaying the various products it sells. Eucalyptus Oil (in yellow bottles) can be prominently seen in the picture.

4.1.2 Results of the Survey examining Producer's perspective on Eucalyptus Oil

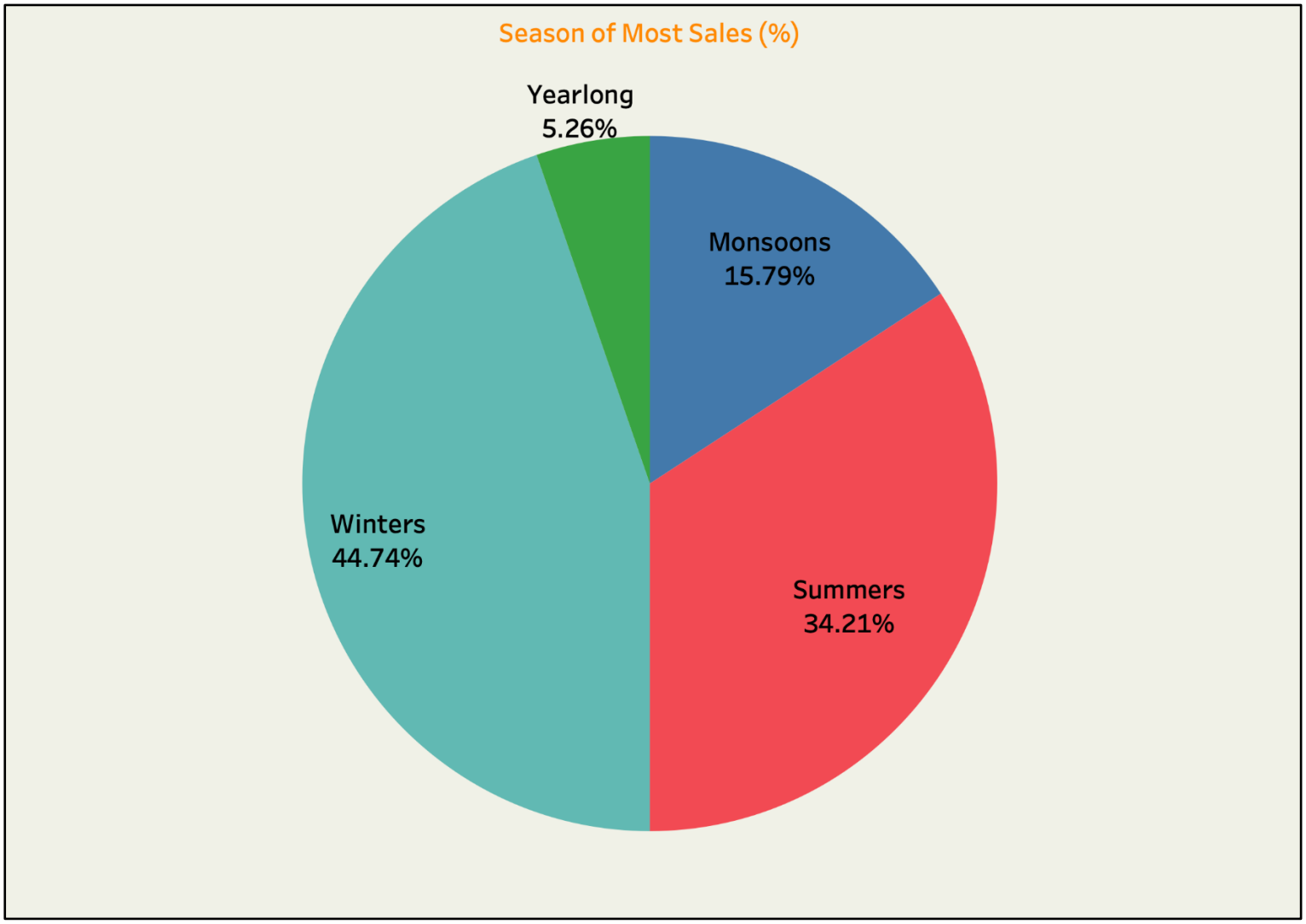
4.1.2 (a) Producer's Perception on who is their Primary Consumers



Source: Author's Own Creation

As it can be clearly seen in the graph, according to the producer's, the major portion of their customer base comprises tourists (84.62%) compared to locals (10.26%). There were some producers who considered an even distribution of customers and locals in their customer base (5.13%).

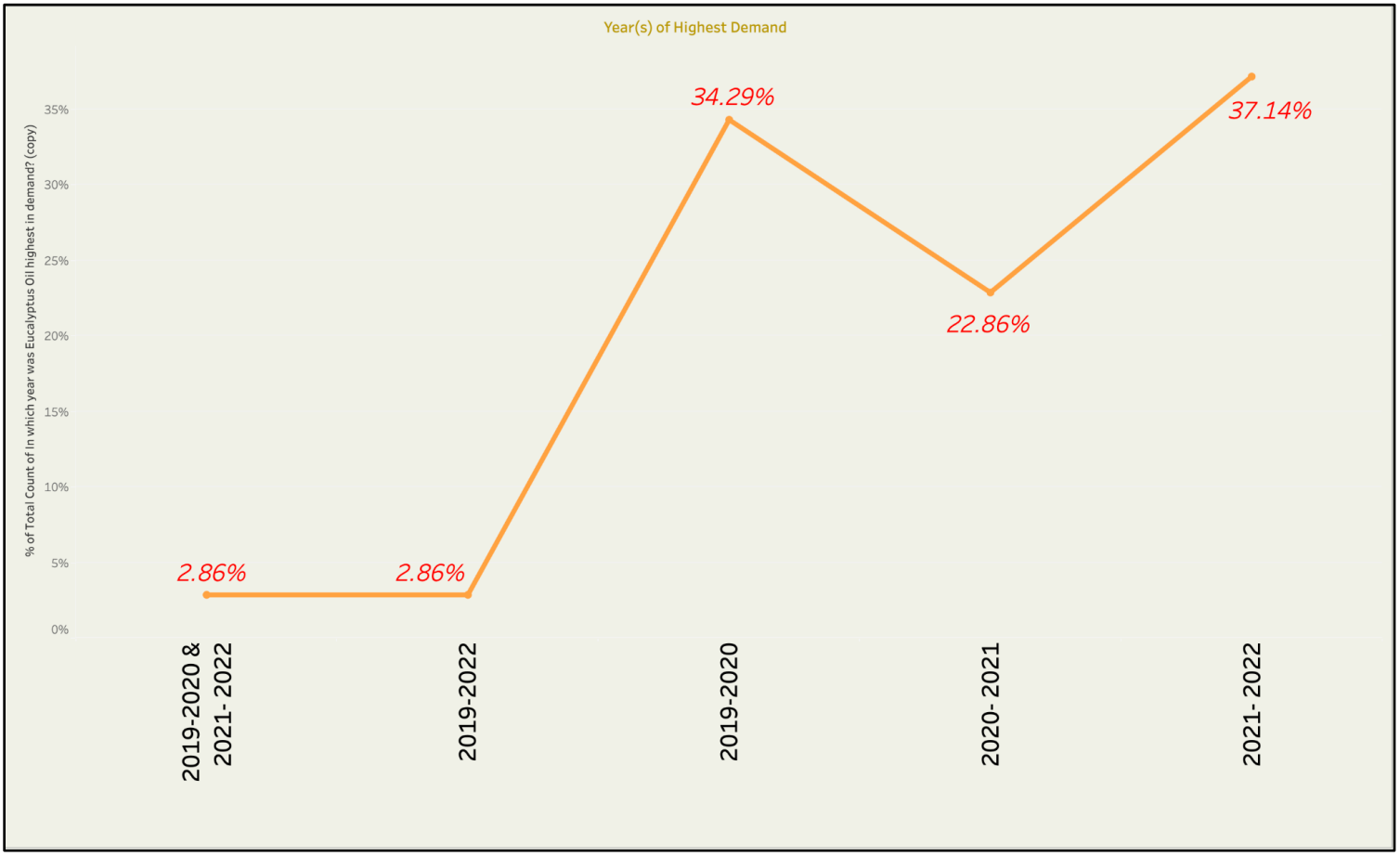
4.1.2 (b) Producer's Take on which is the season with highest sales



Source: Author's Own Creation

As it can be clearly seen from the graph, the majority of the producers responded to winters being the seasons where sales were highest (44.74%) followed by summers (34.21%) and monsoon (15.79%). There were some producers that felt that there was no one single month where the sales were the highest and sales were the same level year long (5.26%).

4.1.2 (c) Producer's Take on their Best Years

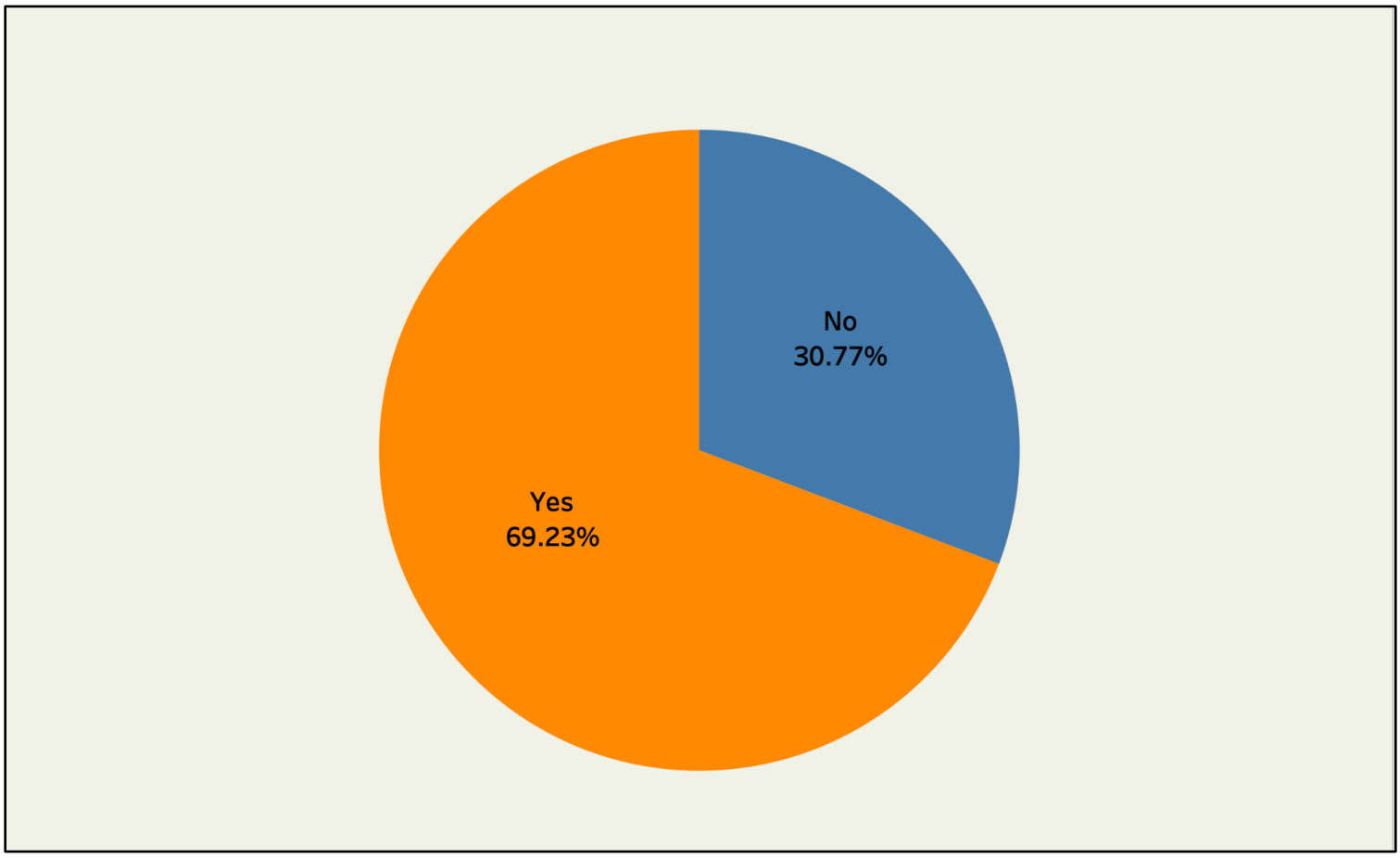


Source: Author's Own Creation

According to the graph, it can be seen that the best year for the producer's was 2021 - 2022 (37.14%) followed by 2019 - 2020 (34.29%) and 2020 - 2021 (22.86%) There were some respondents that they had two good years with approximately similar sales
such as 2019 - 2020 and 2021-2022 (2.86%). Furthermore there were some respondents who felt that all three years were equally good for them (2.86%)

4.1.2 (d) Producer's Take on Costs during COVID:

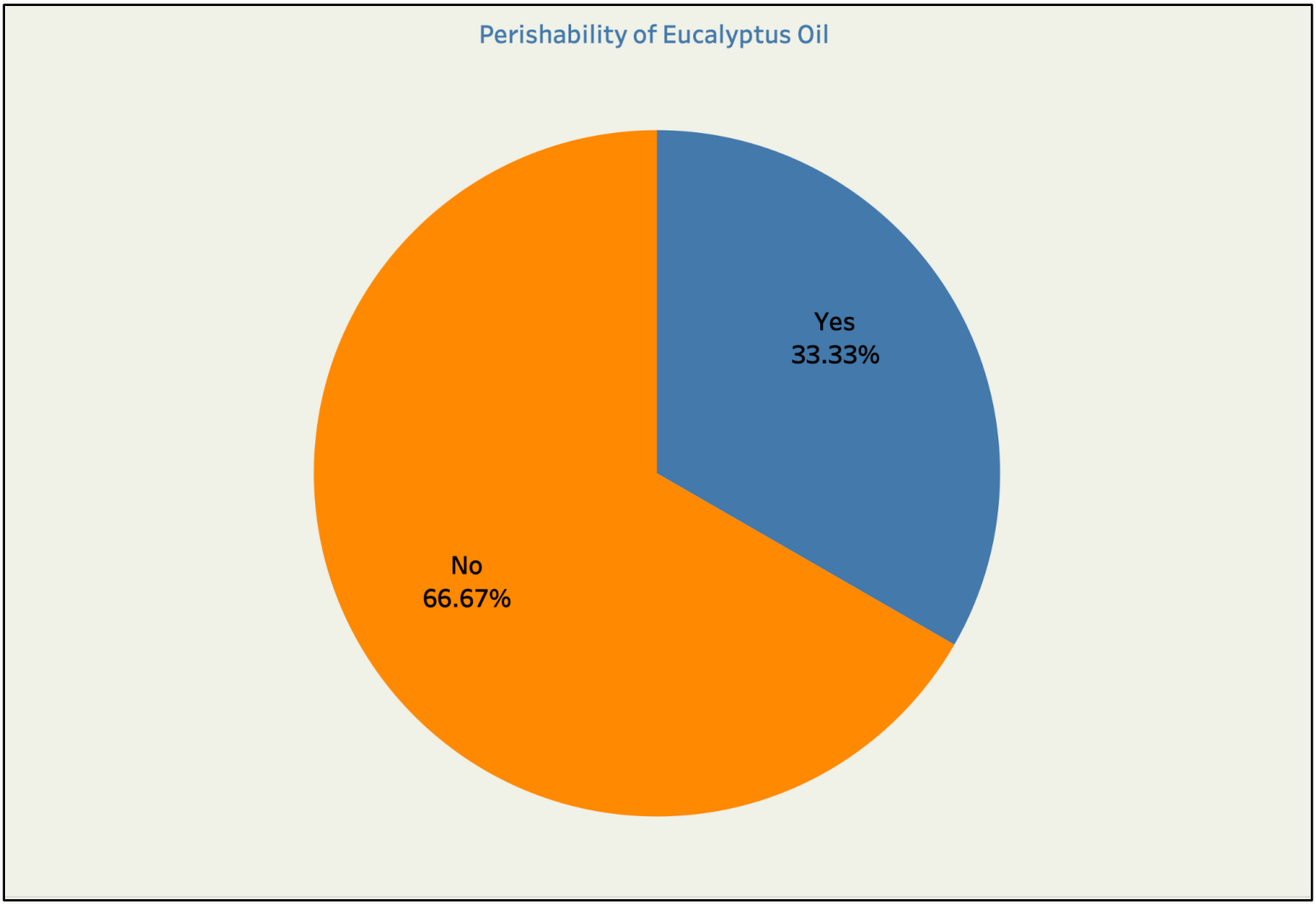
Did Cost of Raw Materials increase during COVID-19?



Source: Author's Own Creation

Majority of the respondents agreed to there being an increase in costs during COVID for costs associated with the sale of eucalyptus oil. (69.23%)

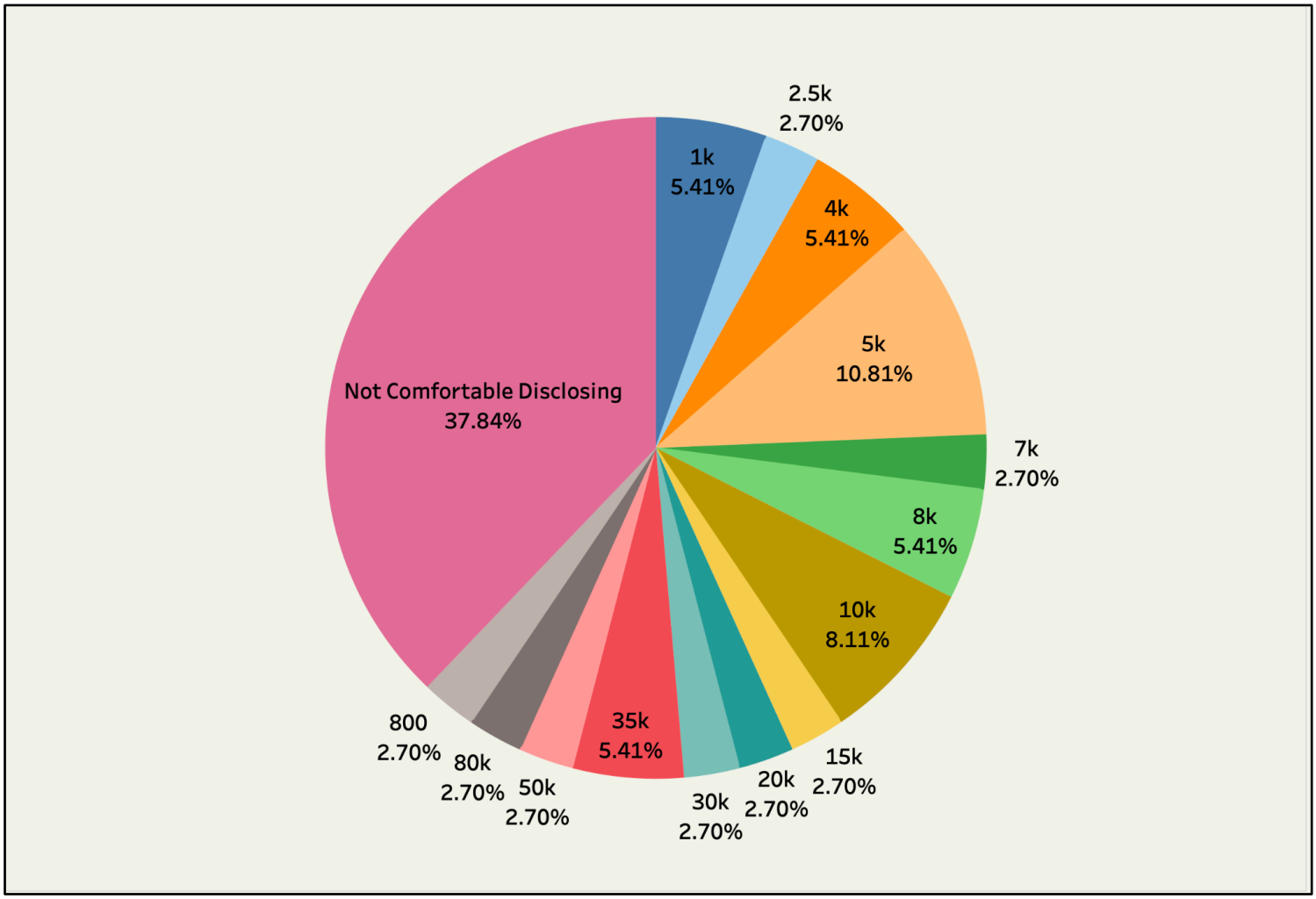
4.1.2 (e) Producer's Take on the perishability of Eucalyptus Oil



Source: Author's Own Creation

Majority of the producers considered eucalyptus oil to to be of not very perishable (66.67%)

4.1.2 (f) Producer's Take on the sales they make per month attributed to Eucalyptus Oil



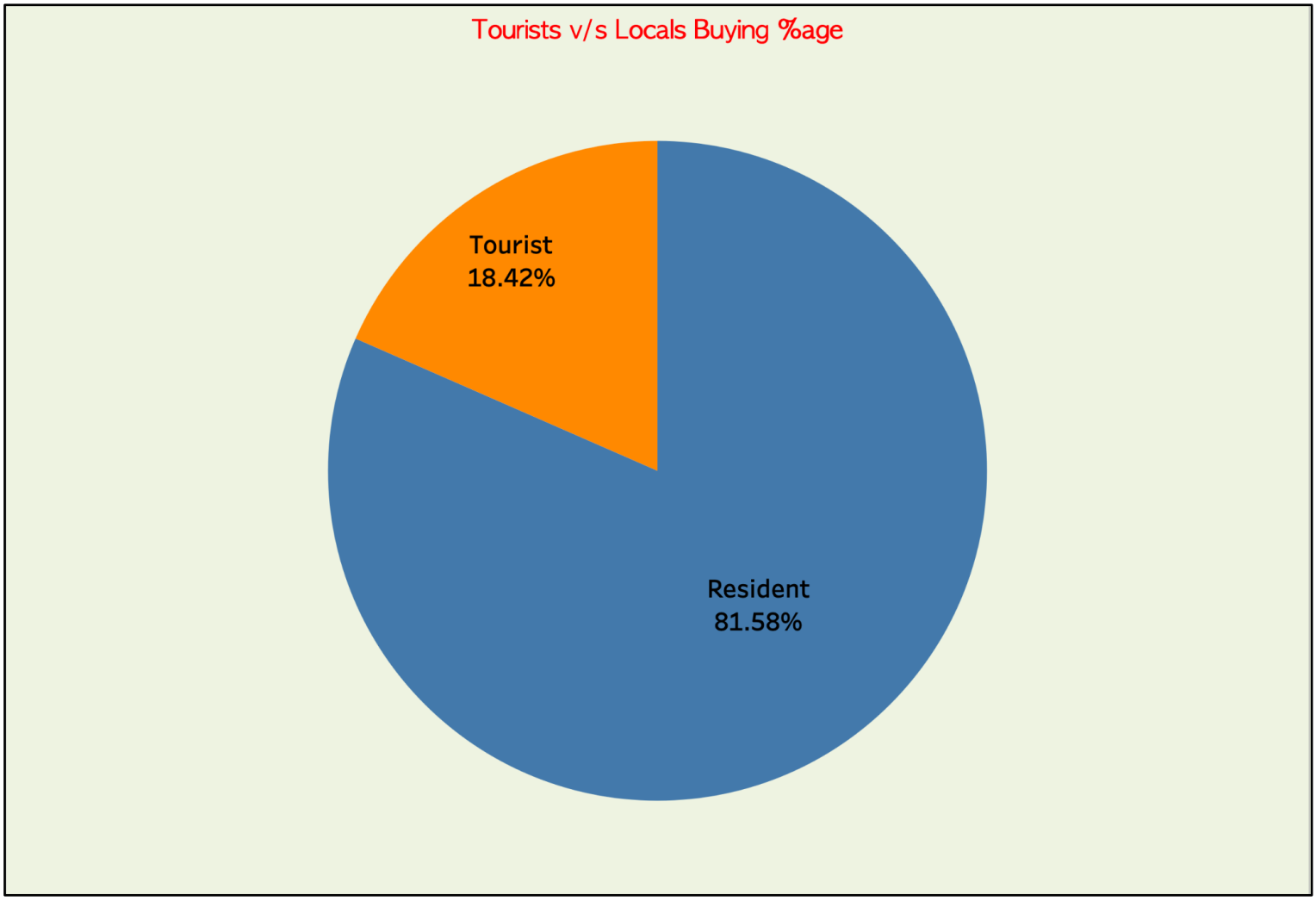
Monthly Earnings from Sales of Eucalyptus Oil

Source: Author's Own Creation

As can be seen in the graph, the majority of the producers were uncomfortable to share information. regarding their sales figures (37.84%). The remaining gave varying answers with the most popular answer being 5K.

4.1.3 Results of the Survey examining Consumer's perspective on Eucalyptus Oil

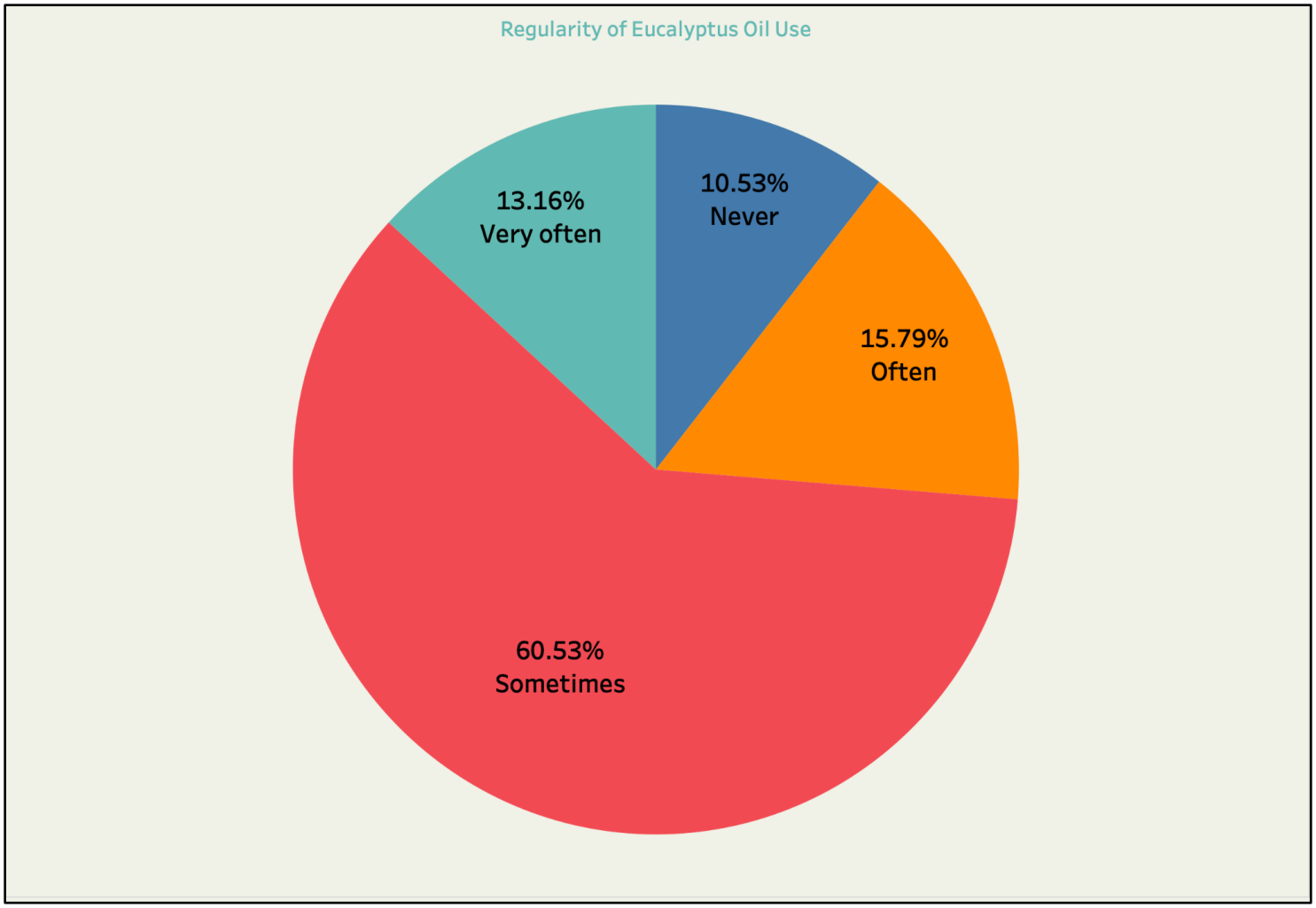
4.1.3 (a) Distribution between Tourists and Residents



Source: Author's Own Creation

Out of the total number of respondents that we were able to get to fill up our surveys, a majority of them were residents (81.58%) when compared to tourists (18.42%). This particular result signifies that the majority of the consumers of eucalyptus oil are primarily residents.

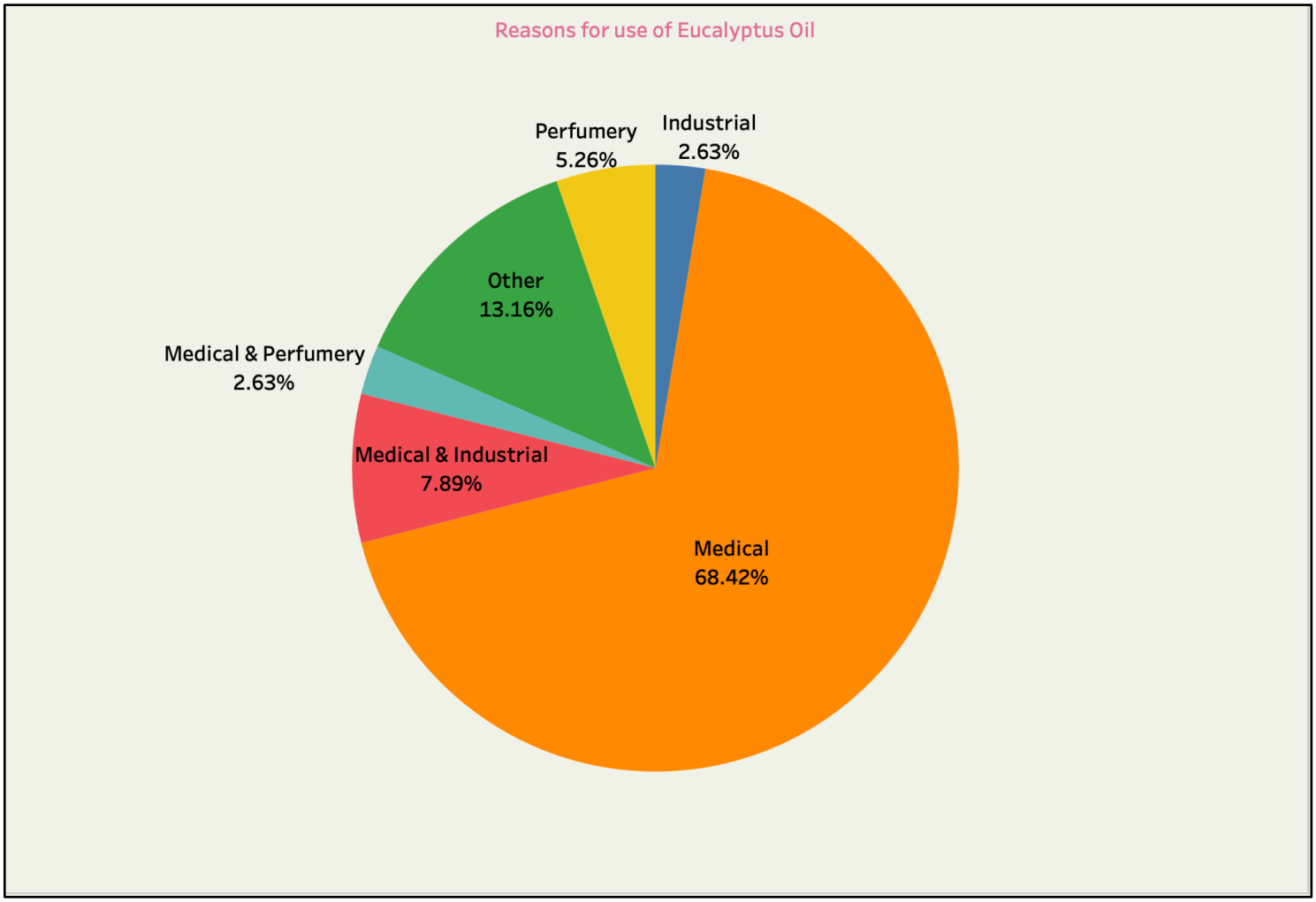
4.1.3 (b) How often do the respondents use Eucalyptus Oil



Source: Author's Own Creation

The results signify that the majority of the respondents utilise eucalyptus oil on an infrequent basis as 60.5% of the people surveyed responded to using eucalyptus oil sometimes. 29% of the respondents surveyed responded to using eucalyptus oil on a frequent basis with 15.8% from the 29% responding to using the product often with the remaining 13.2% responding to using the product very often. 10.5% of the respondents responded to never using the product themselves.

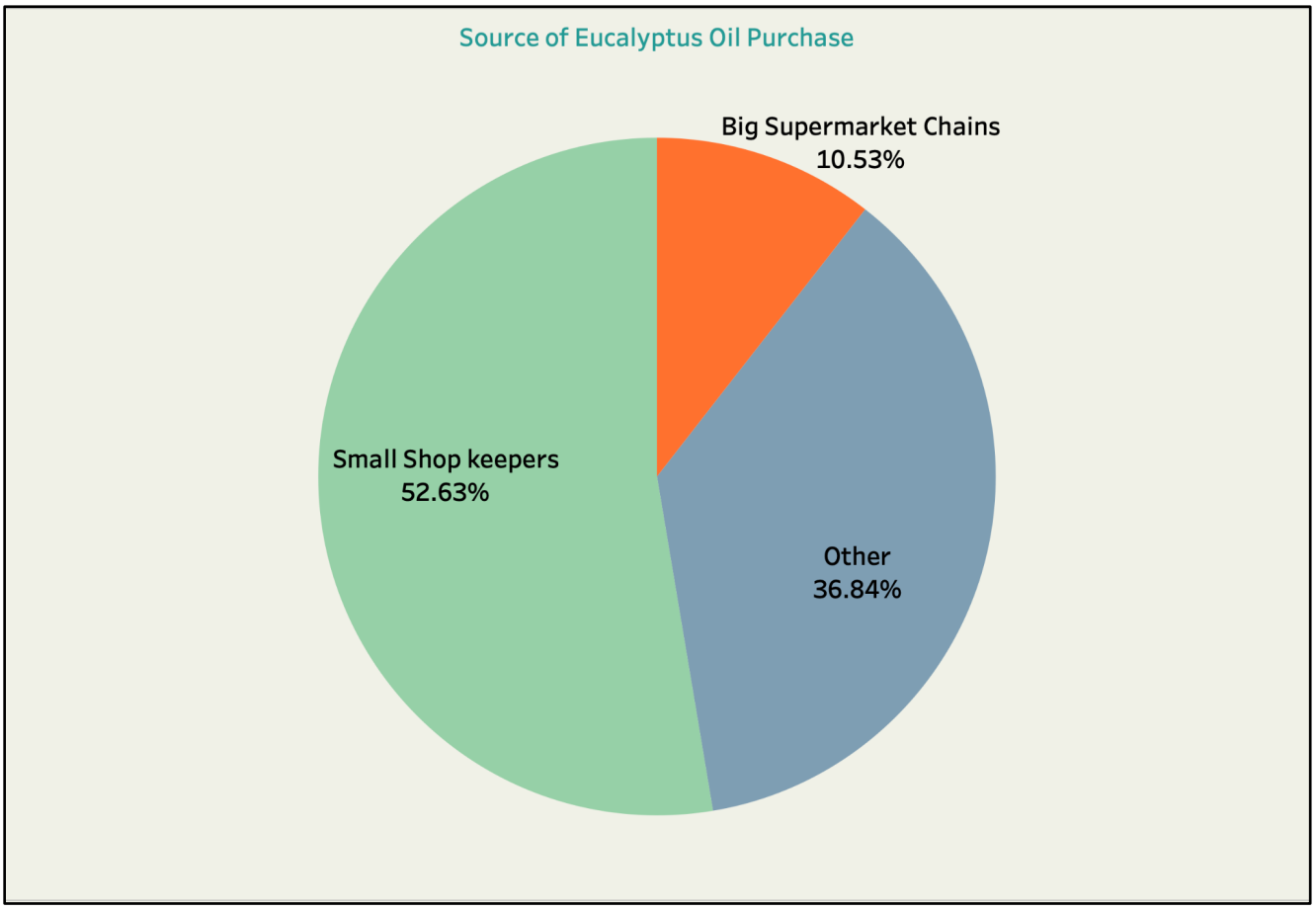
4.1.3 (c) Utility derived from Eucalyptus Oil



Source: Author's Own Creation

The results here signify that the main reason behind the usage of eucalyptus oil is medical reason (78.94%) followed by industrial reason (2.63%) and Perfumery Reason (5.26%). Four respondents (13.16%) responded to using the product for other reasons with 2 out of these 4 respondents (5.6%) further stating that they used the products for massage and for personal care for senior citizens respectively

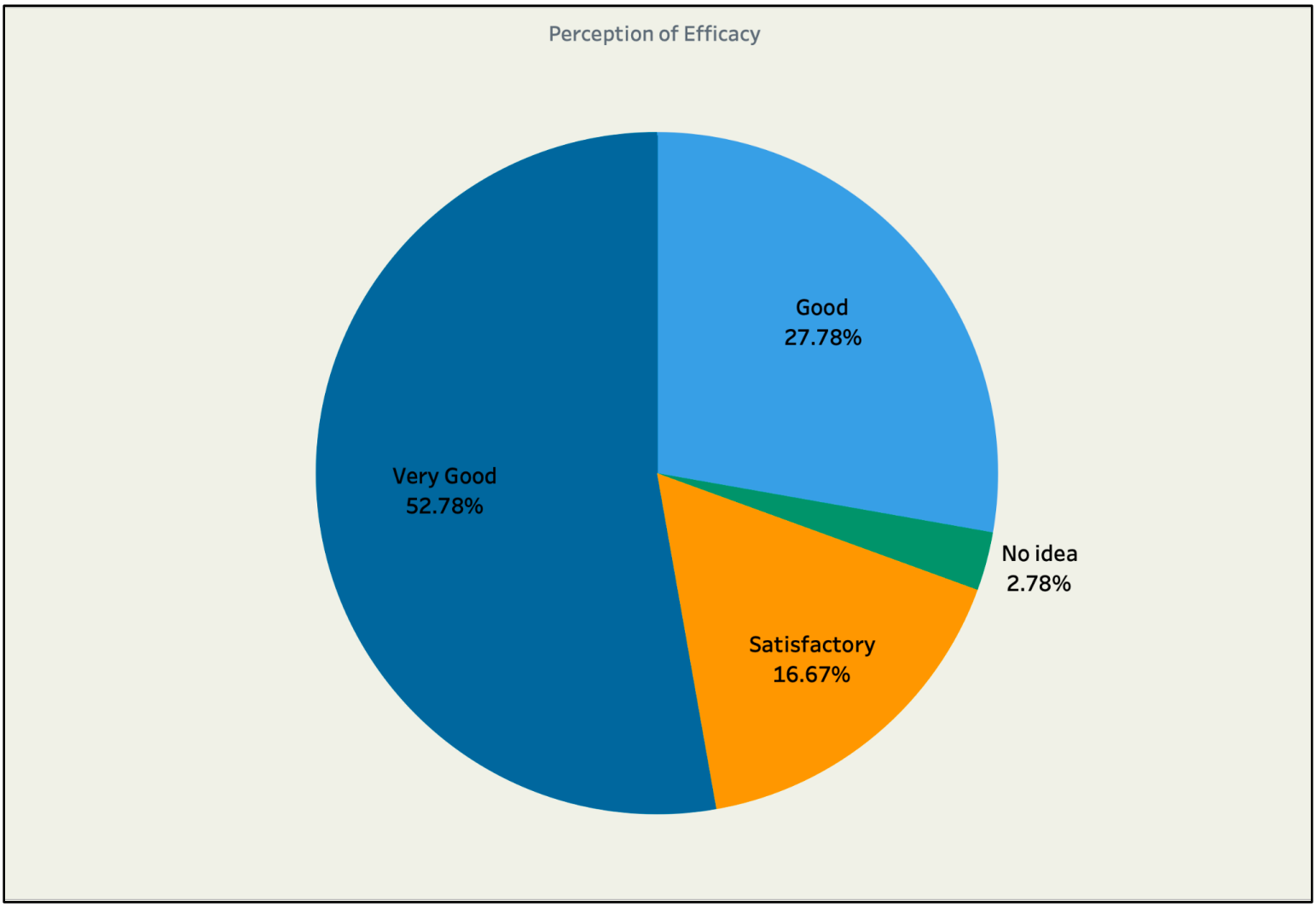
4.1.3 (d) Point of Purchase for Eucalyptus Oil



Source: Author's Own Creation

According to the result, the respondents primarily purchased eucalyptus oil from small shopkeepers (52.63%). Interestingly, the next most popular response was other (36.84%) with 3 out of the 11 respondents who selected that option further specifying various reasons such as obtaining it from their own manufacturing plant and having contacts within the extraction industry, having a trusted seller respectively.

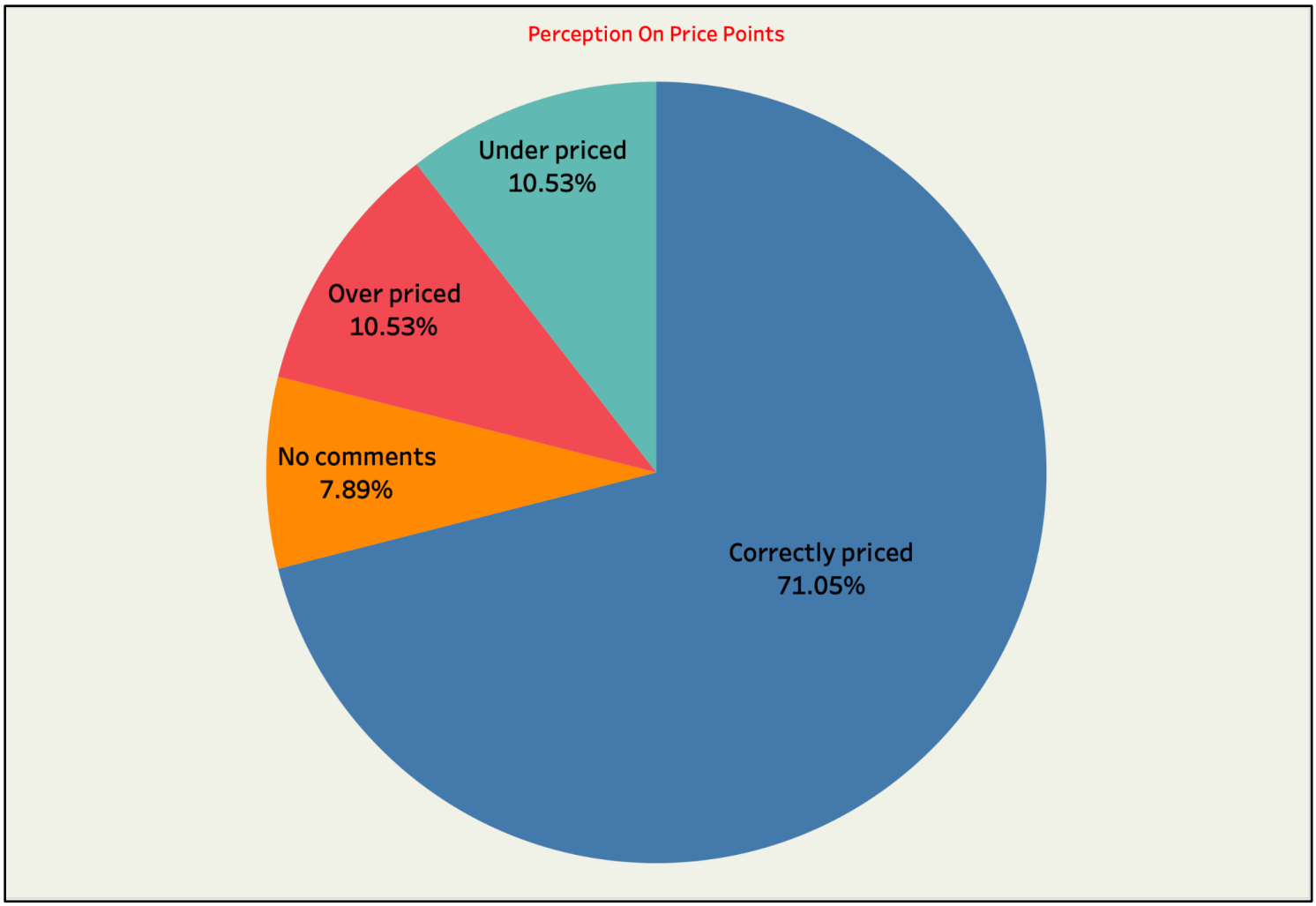
4.1.3 (e) Perception on the efficacy of Eucalyptus Oil



Source: Author's Own Creation

According to the result for this particular question, the majority of the respondents (52.78%) found the efficacy of the eucalyptus oil to be very good. The other responses in descending order include good (27.78%), satisfactory (16.67%), no idea (2.78%)

4.1.3 (f) Perception regarding affordability of Eucalyptus Oil

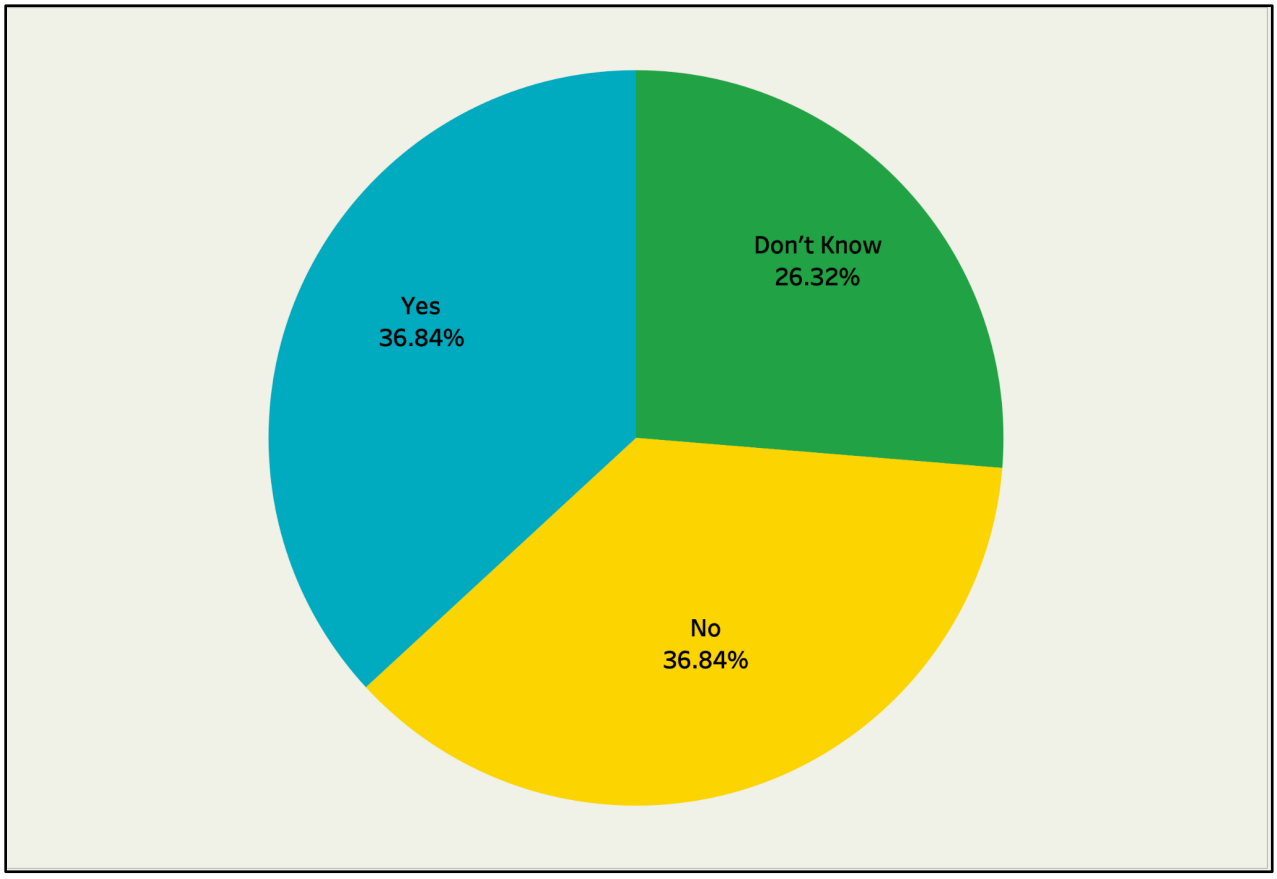


Source: Author's Own Creation

According to the result for this particular question, majority of the respondents perceived eucalyptus oil to be correctly priced (71.05%) whereas equal number of respondents found it to be under priced and over priced respectively (11.4% for both)

4.1.3 (g) Perception regarding substitutes to Eucalyptus Oil

Consumers Perception on Availability of Substitutes for Eucalyptus Oil

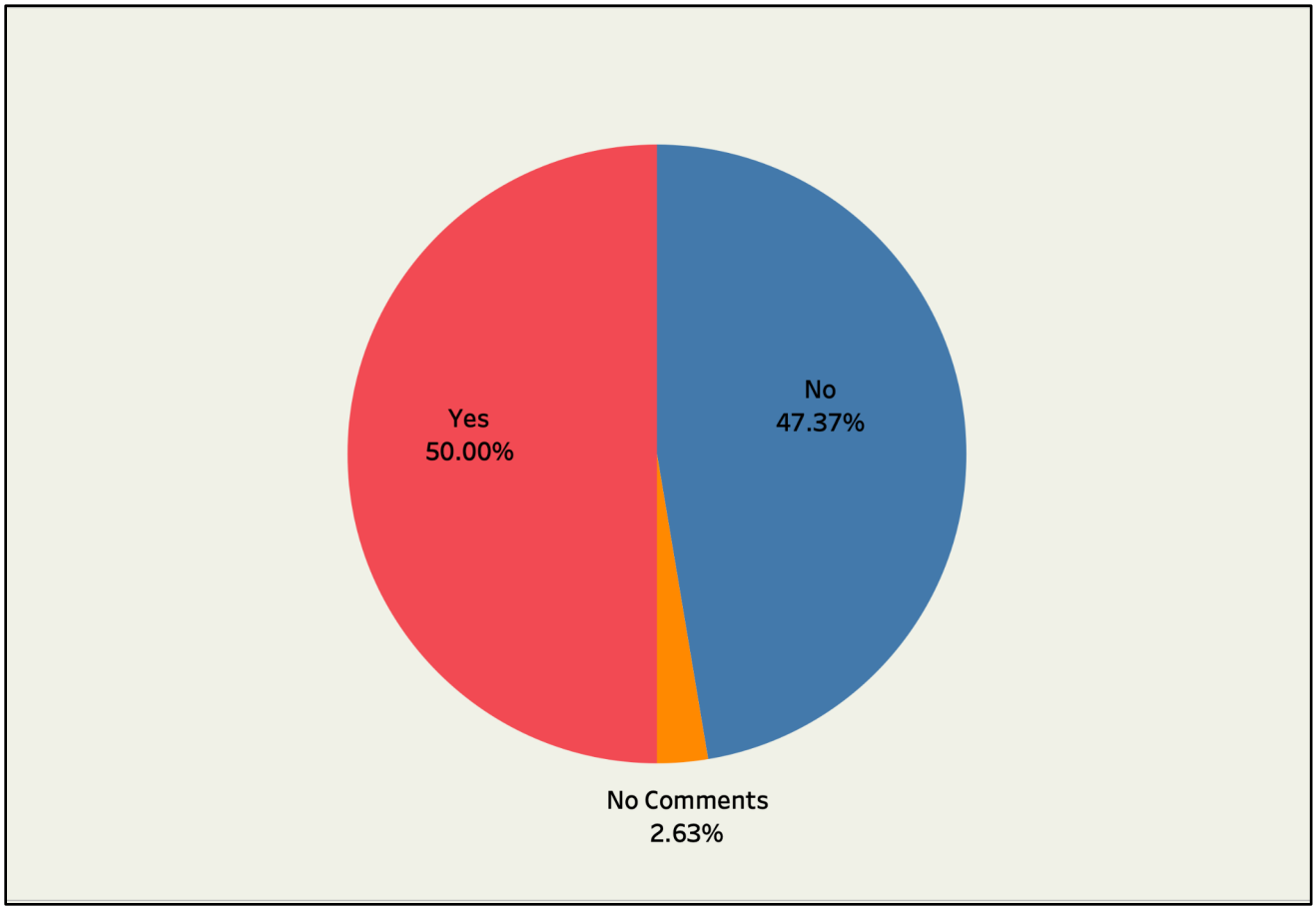


Source: Author's Own Creation

According to the results for this particular question, that there is awareness about the substitutes to eucalyptus oil amongst the general consumers. This is evidenced as 36.8% of the respondents agreed to knowing about substitutes to eucalyptus oil. Furthermore, 36.8% of respondents responded to having the perception that there are no substitutes to eucalyptus oil. 26.3% of the respondents did not have any perception about substitutes to Eucalyptus Oil.

4.1.3 (h) Impact of COVID on consumption pattern of Eucalyptus Oil

Understanding whether Consumers of Eucalyptus Oil increased their oil usage during COVID-19

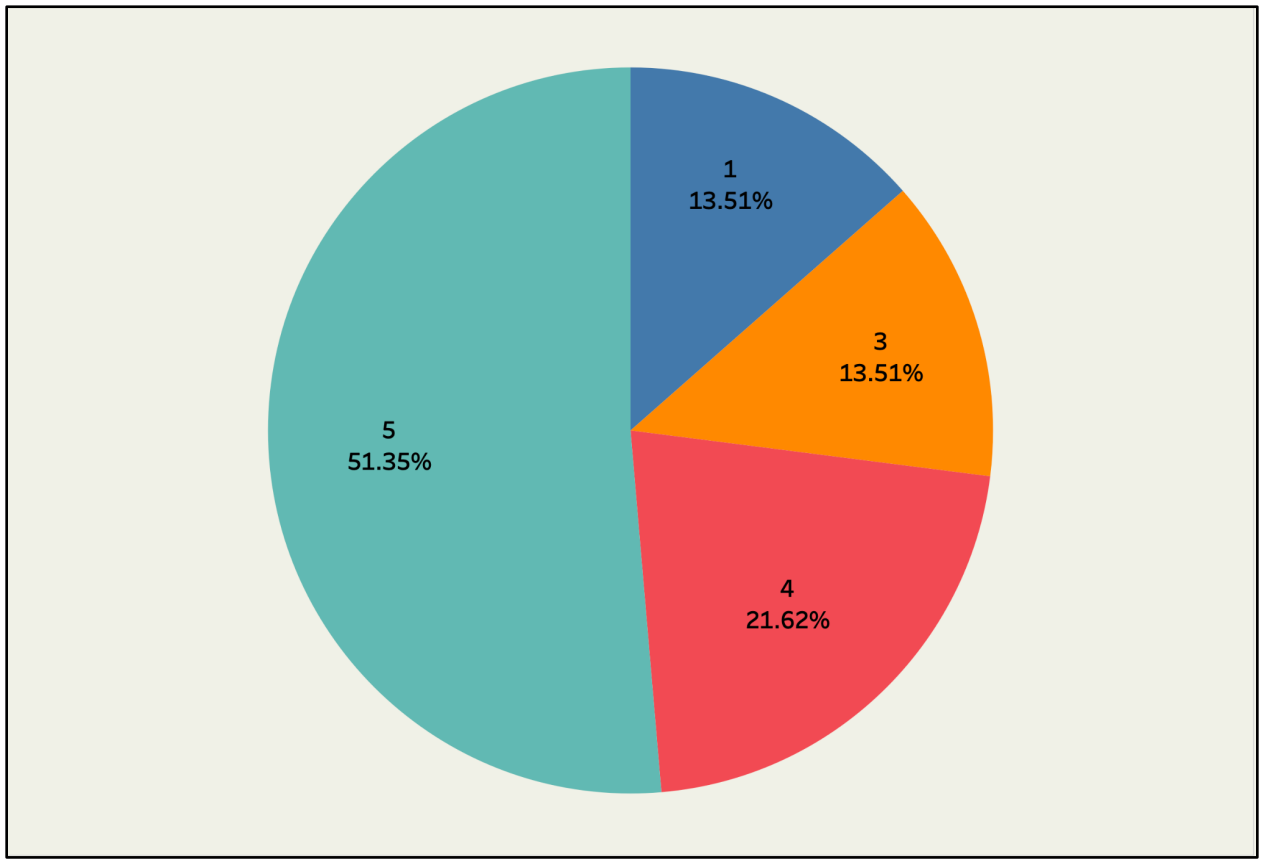


Source: Author's Own Creation

The results for this question indicates that the COVID had a positive impact on the consumption pattern of Eucalyptus Oil as 50.00% of the respondents agreed to have increased their consumption during COVID Times.

4.1.3 (i) Overall Perception

How highly consumers rate Eucalyptus Oil from 1-5 (5 being highly recommended)



Source: Author's Own Creation

According to the results given above, the overall perception of eucalyptus oil can be considered to be a positive one as 51.35% of the respondents would strongly recommend the product to other people.

4.1.4 Analysis & Interpretation of the survey results:

The results of the two surveys that were conducted during the on-field research has provided a lot of insights regarding the market that exists in Kodaikanal for Eucalyptus Oil. In particular, by analysing the results of the surveys, a clearer picture of the market demand for eucalyptus oil in Kodaikanal has begun to appear. Before venturing further and understanding how this has been achieved, it is imperative to specify the economic definition of demand and provide clarity regarding the various fundamental aspects that comprises demand as a whole and explanation regarding the meaning of price elasticity.

Demand refers to the quantity of goods that consumers have both willingness and ability to purchase. To elaborate on the above mentioned definition of demand, there are two fundamental aspects to demand: consumer's preferences and the budget constraints that each consumer faces. Consumer's preferences have an absolute dependency on the utility that is derived from that specific good. Utility is nothing but a word that verbalises the essence of the usefulness or satisfaction that one derives through purchase and use of a product be it a good or service. On the other hand, budget constraints are dependent on the price of that product and the share of the consumer's budget that that same consumer can allocate for the purchase of that product. The amalgamation of these two fundamental aspects make up the demand for any product. Furthermore, the demand for any product has a particular responsiveness to changes in price. This simply refers to the degree of change in the quantity demanded of a particular product due to changes in the price of that very product. The more the quantity demanded of a product reacts to a change in the price of that same product, the more elastic its demand is said to be and vice versa.

Having gotten clarity regarding these very crucial economic concepts, it's time now to lay out the main focus of the ensuing analysis on the market demand for eucalyptus oil. The main objective of the following analysis is to derive an qualitative estimation of the degree of market demand that exists in the eucalyptus market. In pursuit of this objective, the analysis conducted has been segregated into three main sub-aspects: the consumer preference element of the demand for the eucalyptus oil, the budget constraint element of the demand for eucalyptus oil, and the price elasticity of demand in the eucalyptus oil market.

The Consumer's Preferences for Eucalyptus Oil:

To clarify the reasons behind consumer preferences for eucalyptus oil, this analysis will first establish the primary utility that eucalyptus oil provides to its consumers. Subsequently, the analysis will assess the effectiveness of eucalyptus oil in fulfilling that utility for its consumers.

After observing the response patterns in both the consumer and producer surveys together, the main utility of Eucalyptus oil is conclusively a medical one. According to the results as per shown in Fig 4.1.3 (c) for the consumer survey, 68.42% of the consumers responded to have bought eucalyptus oil to fulfil their medical needs. Furthermore, 10.53% of the respondents indicated more than one reason for the purchase of eucalyptus oil which included medical reasons. Therefore, in summation, the medical reasons for purchasing eucalyptus oil can be attributed to a staggering majority of 78.95% of the respondents. Another result as per depicted in fig 4.1.3 (h), 50% of the consumer respondents agreed to have increased their consumption of eucalyptus oil during the COVID pandemic period. The underlying logic behind this huge number of respondents responding in this distinct manner, could potentially be explained by looking at the various medicinal properties of eucalyptus oil as indicated by the existing secondary literature regarding the same.

The secondary literature depicts that eucalyptus oil has distinct medicinal properties that make it suitable for use in five different ways: to treat respiratory issues, pain relief, wound healing, anti-inflammatory and anti-bacterial purposes. A study published in the journal Evidence-Based Complementary and Alternative Medicine found that eucalyptus oil can be effective in treating respiratory issues such as bronchitis and sinusitis due to its antibacterial and anti-inflammatory properties. Furthermore, eucalyptus oil has been found to have analgesic properties, making it useful for reducing pain. Moreover, Eucalyptus oil has also been shown to have antimicrobial properties that can help prevent infections in wounds. A study published in the International Journal of Pharmaceutics found that eucalyptus oil was effective in promoting wound healing in rats. Another study published in the Journal of Inflammation found that eucalyptus oil was effective in reducing inflammation in rats with arthritis. Thus, as evident, the medicinal properties of eucalyptus oil is one that is well documented and could easily explain the reason as to why the vast majority of the respondents responded in this particular manner.

Now that the conclusion has been drawn that the medicinal properties of eucalyptus oil are its main utility, it is possible to provide an explanation for the response patterns depicted as per in

the producer's survey. Figure 4.1.2 (b) illustrates that 44.74% of the producers experienced higher sales during the winter season, while the second largest group of 34.21% reported greater sales during the summer months. The remaining 15.79% and 5.26% of producers reported higher sales during the monsoon season and throughout the year, respectively. The reason behind sales being the highest during the winter season could potentially be attributed to the higher degree of respiratory issues that develop during those months.

Winters in Kodaikanal start from the month of November and last till February. The following table showcases the mean daily maximum and minimum temperatures that occur in Kodaikanal during these winter months and has been obtained from the Indian Meteorological Department.

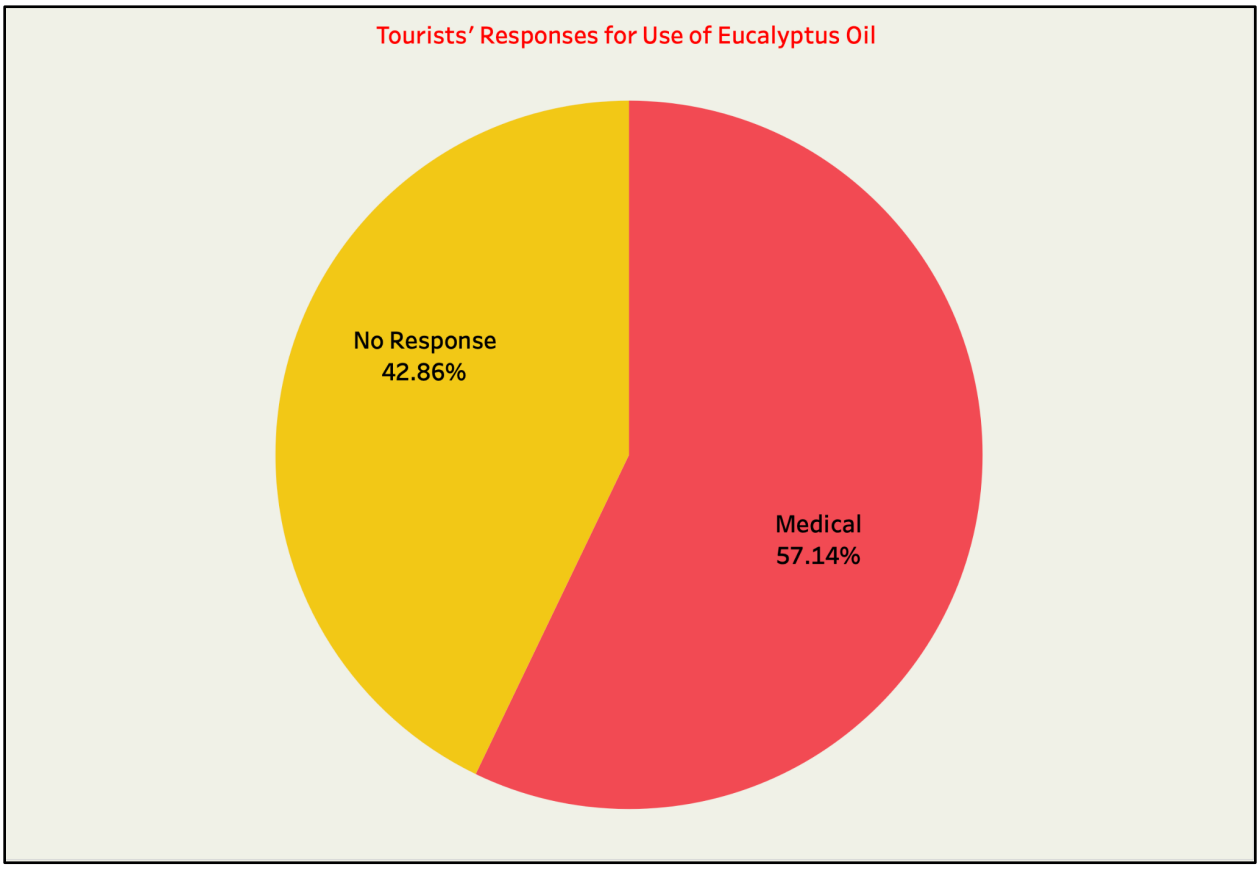
Table 4.1.4 (a) Weather table for winters in Kodaikanal

Month	Mean Temperature (°C)	
	Daily Minimum	Daily Maximum
November	10.3	16.9
December	9.4	17.4
January	8.8	18.6
February	9.1	19.4

Respiratory illnesses, such as the common cold, flu, and pneumonia, are among the most common illnesses during the winter season. This is because the cold weather can weaken the immune system and make it easier for viruses to spread. Additionally, people tend to spend more time indoors during the winter, which can increase their risk of exposure to respiratory viruses. The high sales of Eucalyptus oil during this season can further support and be explained by the medicinal properties that Eucalyptus Oil possesses such as anti - bacterial and anti - viral properties.

The high sales of eucalyptus oil during the winter months, which can be attributed to its medicinal properties, can be further clarified by examining the results presented in section 4.1.2 (a). Here, the majority of the producers perceived tourists to comprise a greater majority of their customer base than locals. 84.62% of the producers considered tourists to comprise a greater majority of their customer base whereas only 10.26% considered locals to comprise a greater majority of their customer base. The remaining 5.13% of the producers perceived there to be an equal split between locals and tourists in their customer base. Winter months are considered to be peak tourist months in Kodaikanal and it is safe to assume that many of these tourists come from very different temporal conditions and the chilly weather in Kodaikanal during the winter months might not suit all of them. Therefore, they are very likely to purchase eucalyptus oil to help with the various respiratory ailments they might develop during their stay in Kodaikanal.

Fig 4.1.4 (a) Tourists' Use of Eucalyptus Oil

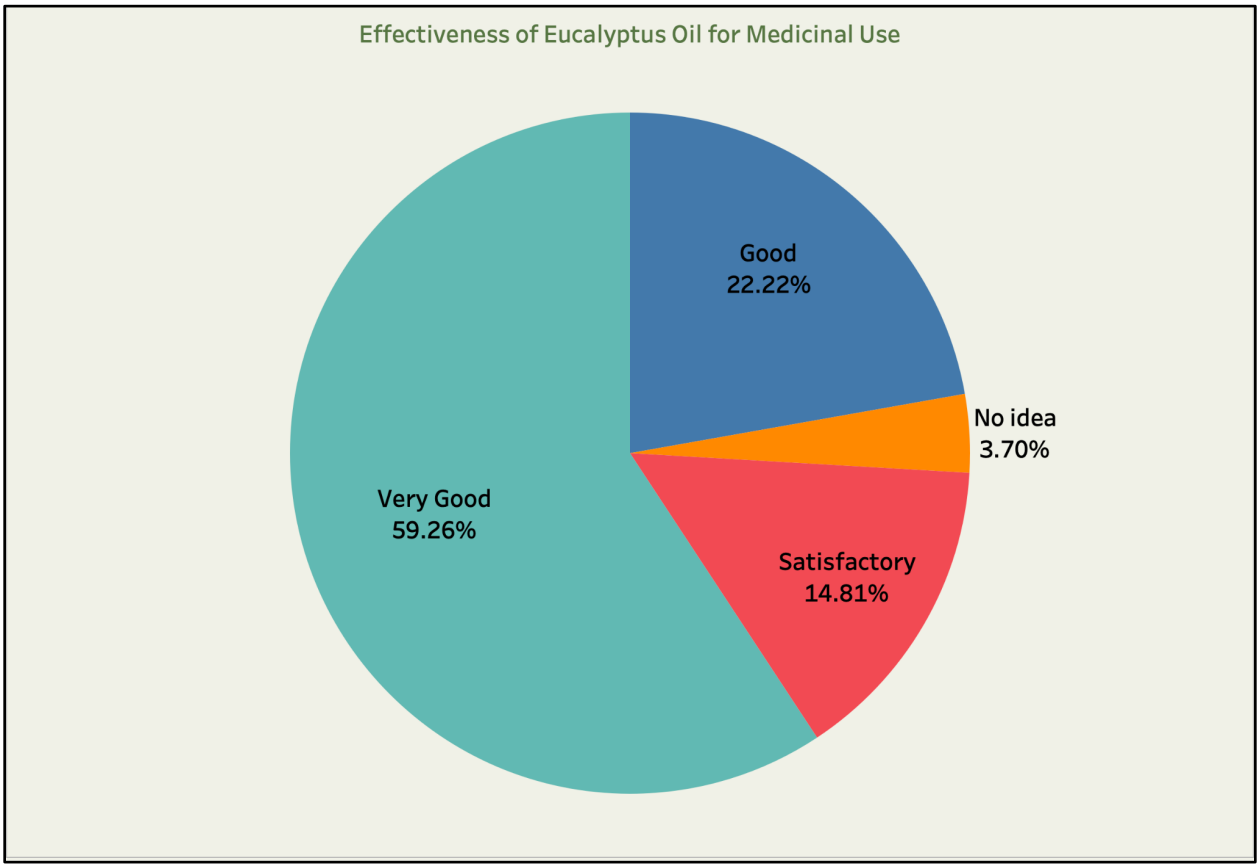


Source: Author's Own Creation

This is further supported by looking at how the consumer respondents who identified themselves as tourists responded to the question as to what their main reason for purchasing eucalyptus oil was? As seen from the infographic given above, 57.14% of the respondents that identified as tourists responded to using eucalyptus oil for medicinal purposes. However, it must be noted that not many tourists responded to the surveys as there was great hesitancy on their part whenever they were approached to fill up the survey. Therefore, though the result only suggests 57.14% of the respondents used eucalyptus oil for its medicinal properties, this number can potentially be higher if a larger sample size of tourist respondents responded to our survey. Still >50% is quite a high percentage as that signifies that two out of every three respondents bought eucalyptus oil for its medicinal properties.

Having firmly established that the main utility provided by Eucalyptus Oil is rooted in its inherent medicinal properties, the efficacy with which eucalyptus oil satisfies this particular utility must be questioned. Fig 4.1.3 (e) suggests that the vast majority of the consumer responses considered eucalyptus oil to be very good in terms of efficacy of fulfilling their respective needs for which they had purchased the product. Furthermore, the second most popular response in this survey question was good (27.78%) followed by satisfactory (16.67%). Only 2.78% of the respondents who responded to this survey had either no idea about the efficacy as they were first time buyers and had not used the product yet or they in general had no opinion about the same. This depicts that the majority of the respondents viewed eucalyptus oil to be an efficient product that more than satisfied the needs with which they had purchased it in the first place. However these figures include individuals who had purchased eucalyptus oil for other reasons also. Therefore it is important to also view how consumers who had purchased eucalyptus oil for medicinal purposes responded to this particular question in the survey.

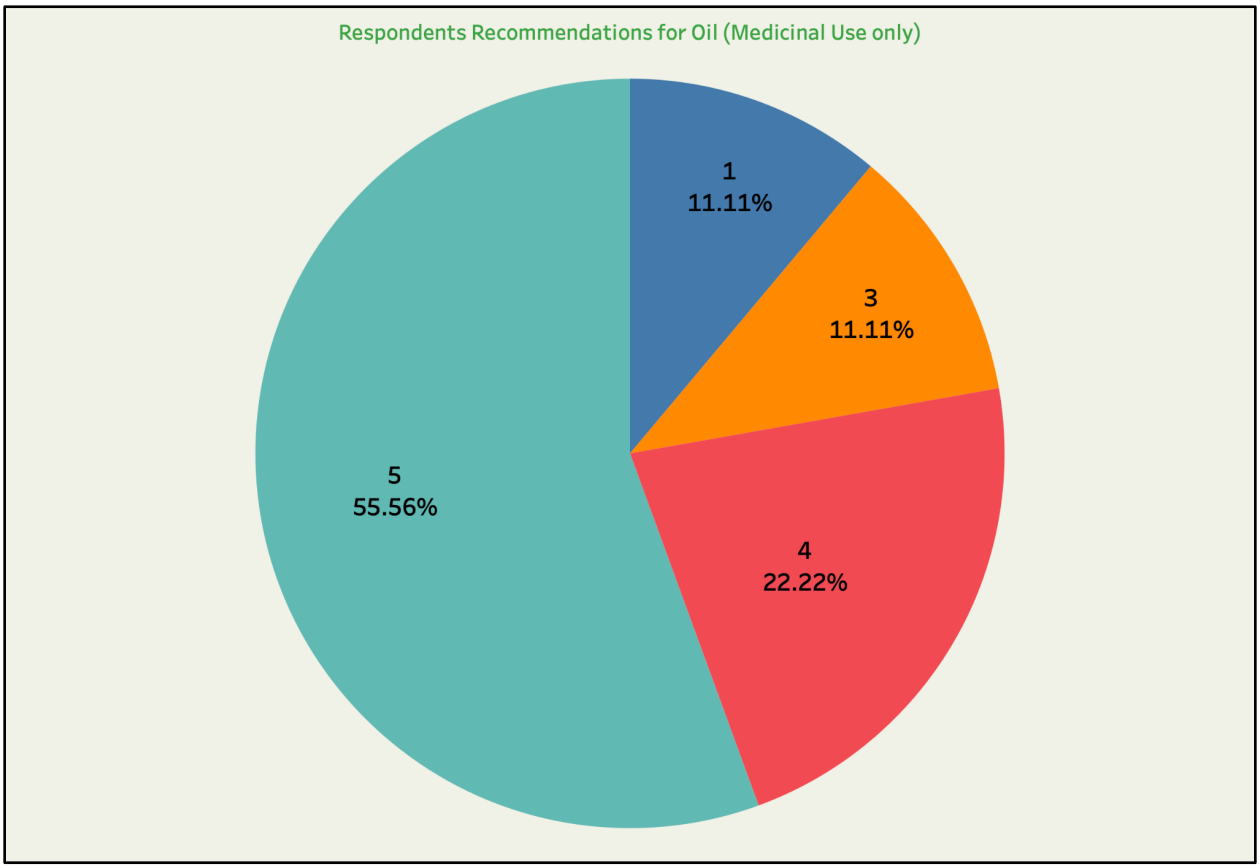
Fig. 4.1.4 (b) Consumers Perspective of Eucalyptus Oil's Efficacy for Medicinal Use



Source: Author's Own Creation

The above given infographic clearly depicts that a vast majority, 99.99% of the consumers, who had purchased eucalyptus oil for medicinal purpose responded in a positive manner with 59.26% of the respondents stating that it was very good. The remaining 37.03% of the respondents responded by stating either the eucalyptus oil was satisfactory or good from an efficacy perspective. This leads to the conclusion that eucalyptus oil's efficacy for fulfilling its main utility of medicinal purposes is mostly positive. This is further supported by how the respondents, who chose medicinal reasons as their main reasons for purchasing eucalyptus oil, responded to whether or not they would recommend the product to a third party.

Fig 4.1.4 (c) Users recommendation for using Eucalyptus Oil as for medicinal purposes



Source: Author's Own Creation

In the graph given above, the majority of the consumers, 55.56% who bought eucalyptus oil for medical purposes rated their recommendation to others at 5 which basically means that they would very strongly recommend the product to others. The next most popular response was 4 which was chosen by 22.22% of the respondents that they would provide strong recommendations to others. 11.11% of the respondents chose 3 which means that they would recommend the product to other users to some degree. Furthermore, the remaining 11.11% of the respondents chose 1 which means that they would not recommend the product at all to others. This particular result can be interpreted to be mostly positive and therefore this provides additional support for the degree of efficacy of eucalyptus oil in fulfilling the medicinal needs with which they are originally bought as consumers would not recommend the product if it weren't effective.

The Budget Constraint for Eucalyptus Oil:

To get an understanding regarding the budget constraints that each individual consumer of eucalyptus oil faces, two aspects must be explored: the budget that the consumer has allocated for purchasing that product and the prices in which the product is available. Even though the responses to the surveys could not provide definitive quantifiable data regarding these two aspects due to the qualitative nature of the study, results for Fig 4.1.3 (f) shines some light on how consumers perceive the prices that exist in the eucalyptus Oil market in Kodaikanal.

Majority of the consumers, 71.05%, perceived the market price for eucalyptus oil to be correctly priced. Equal percentage (10.53%) of consumers found eucalyptus oil to be under priced and over priced respectively. The remaining 7.89% of the respondents refrained from answering the question. As the majority of the consumers perceived the prices majorly in a positive light, it is therefore somewhat logical to assume that these same consumers would therefore perceive the product to be affordable. However, it must be taken into consideration that the income factor of these consumers remain unknown and that could play a major role in understanding the affordability aspect of eucalyptus oil.

Though there is no data that was formally collected regarding the prices charged by each individual shopkeeper, during interviews with certain manufacturers like Mr Suresh, a general market price was quoted to be around Rs 2500 per litre. The most common quantity in which eucalyptus oil is sold is 200ml. Therefore the theorised mean market price for one bottle of eucalyptus oil is Rs 500. This price as per the results in Fig 4.3.6 is one that is majorly considered fair.

The Price Elasticity of Demand for Eucalyptus Oil:

To comprehend the price elasticity of demand for eucalyptus oil three different aspects of analysis will be explored: the perception of substitutes to eucalyptus oil in the market, what happened to consumer behaviour and sales when costs increased during COVID times and the perception regarding perishability of eucalyptus oil.

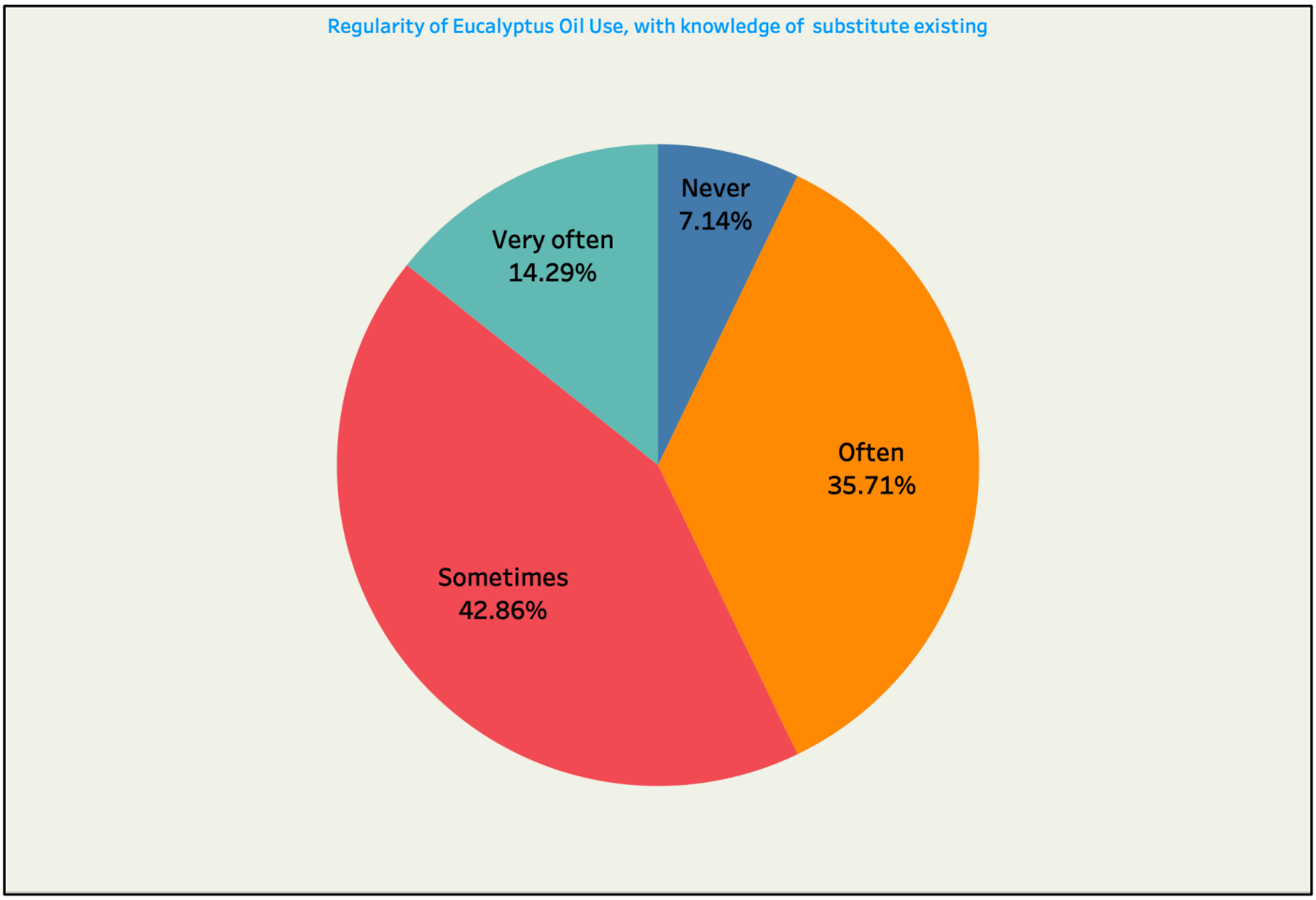
The number of substitutes a product has is a key factor that affects its price elasticity of demand. When a product has many substitutes available in the market, consumers can easily switch to a similar product if the price of the original product increases. As a result, the demand for the original product becomes more elastic, meaning that a small change in price will lead to a larger change in demand. One study conducted by economists at the University of California, Berkeley,

found that the availability of substitutes is a significant determinant of price elasticity of demand. The study analysed data from 59 industries and found that industries with a higher number of substitutes had a more elastic demand curve, meaning that changes in price had a larger effect on demand. The study concludes that "the elasticity of demand appears to depend on the degree of product differentiation or substitutability in the market" (Berry, Levinsohn, & Pakes, 1995). Therefore, the number of substitutes a product has is an important factor in determining its price elasticity of demand. When there are many substitutes available, consumers have more options and are more likely to switch to a substitute.

According to results as depicted in Fig 4.1.3 (g), a majority of consumers, 63.16%, responded to either asserting that there weren't any substitutes for eucalyptus oils or that they did not have any knowledge of any existing substitutes to eucalyptus oil. The remaining 36.84% responded that they knew of substitutes to eucalyptus oil. As approximately two in every three consumers in the sample size of the survey responded negatively towards the existence of substitutes to eucalyptus oil, it can therefore be established that even though there might exist substitutes to eucalyptus oil as a large majority of the market remains unaware about their existence, there aren't many substitutes to eucalyptus oil.

Furthermore, after analysing the responses for consumers who responded to being aware of substitutes, it can further be asserted that eucalyptus oil has a high degree of product differentiation that makes it more superior to the limited substitutes that do exist in the market.

Fig 4.1.4 (d) Use of Eucalyptus Oil by consumers despite having knowledge of substitutes

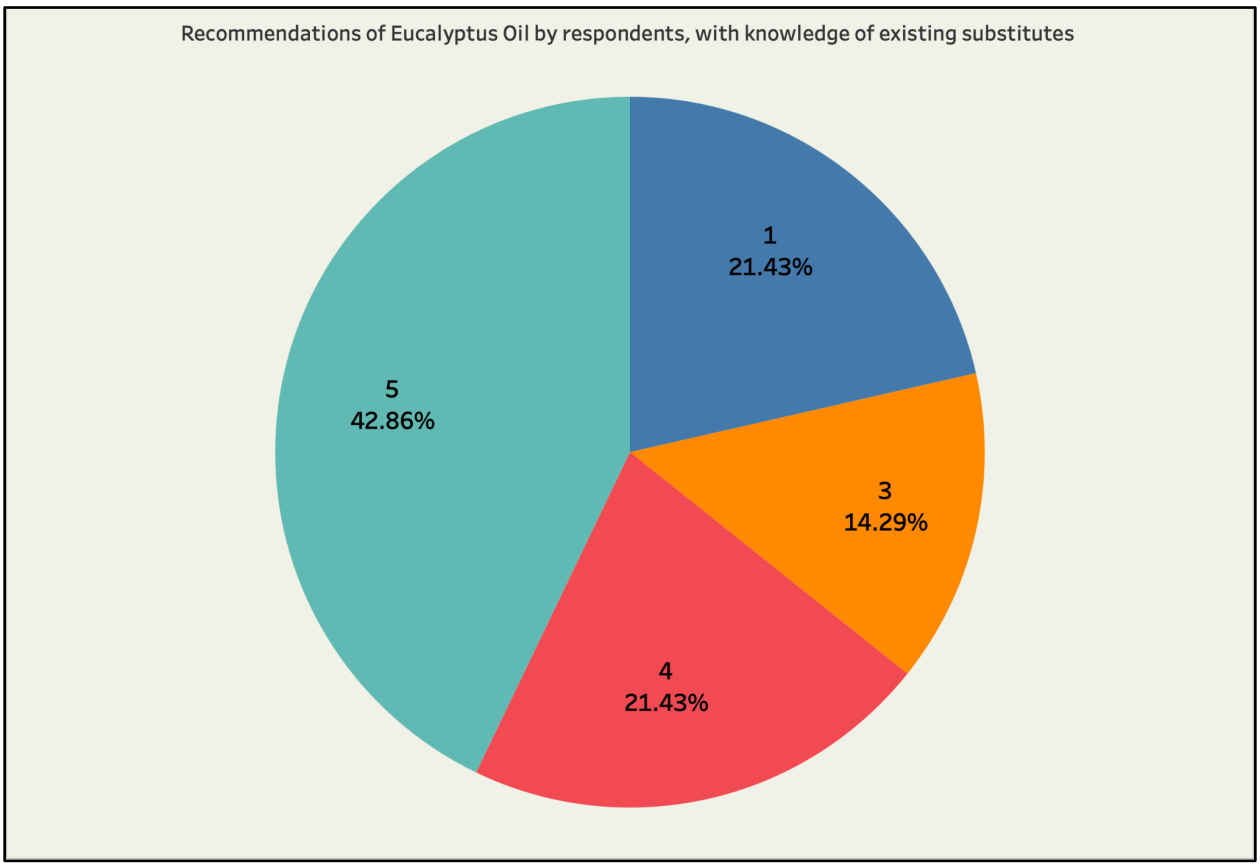


Source: Author's Own Creation

The infographic given above showcases how consumers who responded to being aware of the existence of substitutes to eucalyptus oil responded to the survey question inquiring the regularity with which they use eucalyptus oil. According to the infographic, the cast majority of these respondents, 42.86%, responded to using eucalyptus oil sometimes. The second most popular response was often with 35.71% of the respondents choosing this option. 14.29% and 7.14% of the respondents responded to using eucalyptus oil very often and never respectively. As seen clearly, a vast majority of these respondents responded to still using eucalyptus oil even while being aware of other substitutes which goes on to prove that there is some feature about eucalyptus oil that sets it apart from its assumably limited substitutes.

This point is further reinforced when seeing how consumers who responded to being aware of the existence substitutes to eucalyptus oil responded to ranking their recommendation for eucalyptus oil to others

Fig. 4.1.4 (e) Recommendations of Oil users despite consumers having knowledge of substitutes existing



Source: Author's Own Creation

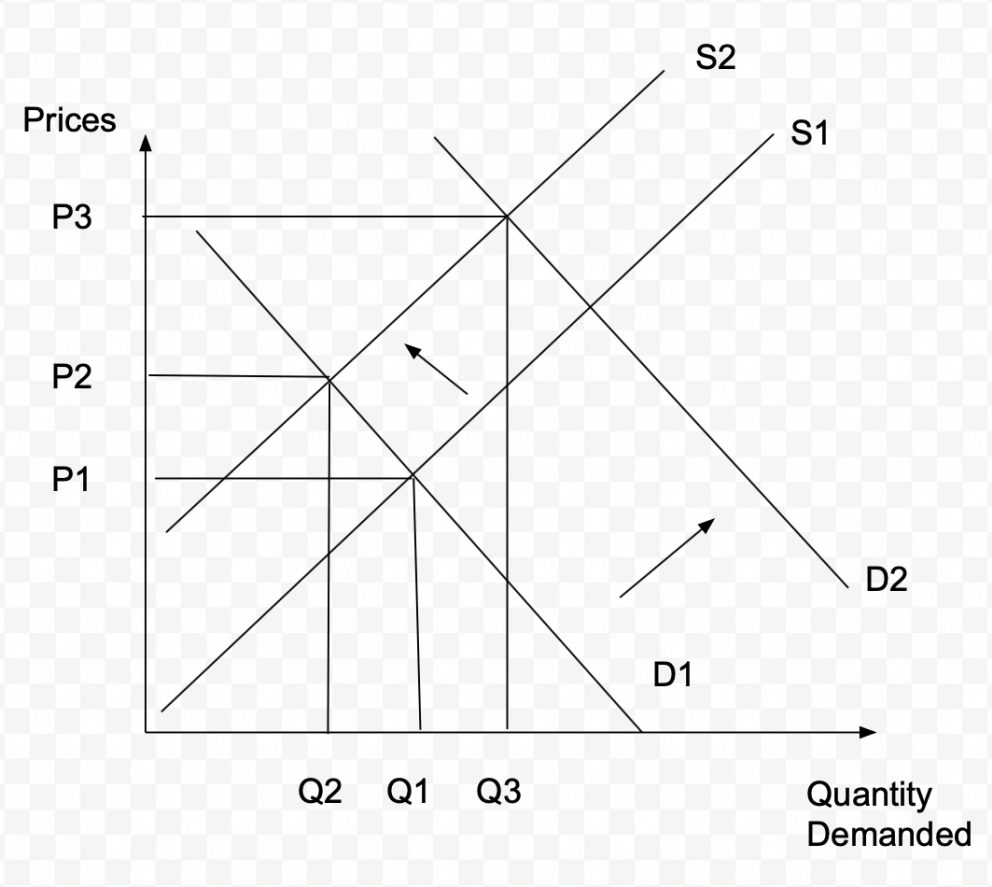
The most popular response was 5 which means very strong recommendation which 42.86% of respondents selected. The next two most popular responses were 4 and 1 which had 21.43% of respondents selecting these two specific numbers each. Lastly the remaining 14.29% selected 3. From the graph given above, it is clearly evident that a majority of these respondents would still recommend eucalyptus oil to others which further asserts that eucalyptus oil has a high degree of product differentiation that makes it more superior to the limited substitutes that do exist in the market.

To understand the price elasticity of demand for eucalyptus oil, the other aspect of exploration is to analyse what happened to consumer behaviour and sales when costs increased

during COVID times. According to the results as depicted in Fig 1.2.4, a vast majority of the producers responded to their being an increase in costs during COVID. Therefore it is only logical to assume that due to higher cost, the producer would have charged higher prices to maintain similar profit margins. By understanding consumer's purchasing behaviour to increase in price of eucalyptus oil, would shed light on the price elasticity of demand for eucalyptus oil.

According to results in Fig 4.1.3 (h), half of the consumers who responded to the survey, agreed to have increased their purchase of eucalyptus oil during COVID pandemic. This further goes to show that even though prices increased, not only did that not negatively impact the quantity demanded of eucalyptus oil, it in fact increased. This is contradictory to how prices and quantity demanded usually behave with respect to each other. However, this contradiction can be explained by using basic economic concepts.

Fig. 4.1.4 (f) Diagram depicting Impact on Eucalyptus Oil on Demand & Supply Curves during COVID pandemic



Before the COVID pandemic, the demand and supply for eucalyptus oil were represented by the demand D1 and the supply curve S1. The equilibrium prices and quantity sold in the market was P1 and Q1 respectively. During the COVID pandemic, the supply curve shifted leftwards due to increasing costs related to producing and selling eucalyptus oil. The new supply curve during the COVID pandemic became S2. This caused a change in the equilibrium price and quantity which now became P2 and Q2. As clearly seen from the graph, P2 > P1 and Q2<Q1. However, the COVID pandemic also could have potentially caused an increase in the demand for eucalyptus oil. As COVID is primarily a respiratory ailment, eucalyptus oil could be potent to combat against it. This has been strongly suggested by 2020 paper that showed that the anti - viral capabilities of eucalyptus oil could prevent SARS - CoV - 2. This has also been mentioned in some of our interviews with people on the field in Kodaikanal as well. During the interview with Dr Rajamanikam, he mentioned that eucalyptus oil was rubbed on door knobs during the COVID pandemic to reduce the spread of the disease. Therefore, due to the medicinal properties of eucalyptus oil that make it potent against battling COVID virus, it is safe to assume that the demand for eucalyptus oil would increase during the COVID pandemic. This is represented by the rightward shift in the demand curve from D1 to D2. The new equilibrium price and quantity, as achieved when D2 and S2 are intersecting, are P3 and Q3. P3 is greater than both P1 and P2 whereas Q3 is also greater than Q1 and Q2. The reason behind this disparity between the new equilibrium price and quantity as opposed to the previous equilibrium prices and quantities is that the positive change that COVID caused to the demand curve was greater than proportionate to the negative impact that it caused to the supply curve for the eucalyptus oil market. Therefore this is why even though there was an increase in price during COVID, there was still greater demand and greater sales of eucalyptus oil. Therefore, the positive change in the overall demand for eucalyptus oil is not due to the change in price for eucalyptus oil but is related to the nature of the COVID pandemic.

Another aspect that must be explored to comprehend the price elasticity of demand for eucalyptus oil is the perishability of eucalyptus oil. Perishability refers to the property of goods or services that are subject to deterioration or spoilage over time and thus have a limited lifespan or shelf life. This means that the value of the product or service diminishes quickly over time, and once it has expired or become unusable, it cannot be sold or consumed. Perishability is a critical concept in the context of industries such as food, hospitality, transportation, and tourism, where

products or services are time-sensitive and require careful management to ensure that they are sold or consumed before they become unusable.

According to the results as seen in Fig 4.1.2 (e), the majority of the producers proclaimed eucalyptus oil to be non perishable in nature. The accuracy of this perception however is somewhat vague. It is true that eucalyptus oil does last for about a year but it starts to lose its potency after that time period. Now there are no fixed time bounds that are used to differentiate a product from being perishable and non-perishable. Therefore, it is very difficult to definitively categorise eucalyptus oil as a non-perishable product but as the general perception is that it is, for this analysis, it will be assumed that the eucalyptus oil is a non-perishable product.

Non-perishable products tend to have a high degree of price inelasticity of demand because consumers are often willing to pay a higher price for the convenience or quality of the product, regardless of changes in the product's price. According to the textbook "Principles of Microeconomics" by N. Gregory Mankiw, non-perishable goods are generally less sensitive to price changes because "consumers can wait to make their purchases until the price falls" (p. 90). Additionally, consumers may perceive higher prices as an indicator of higher quality, which further reduces their sensitivity to price changes. Another credible source, a study published in the Journal of Economic Psychology by A. Constantinides and M. Stroe, found that non-perishable products are generally more price inelastic than perishable products, as consumers are more likely to compare prices across brands and stores when purchasing perishable products (p. 141). Overall, the price inelasticity of demand for non-perishable products can be attributed to a combination of consumer behaviour, the perception of quality, and the ability to delay purchases until prices fall.

As in the case of eucalyptus oil, there aren’t many other products that can be used for comparison as established previously and the overall perception of the product’s quality, as described by perception regarding its efficacy, is positive, the price elasticity of demand for eucalyptus oil can therefore be considered to be somewhat inelastic. However, more research needs to be conducted for a more conclusive result regarding the same.

To conclude, Eucalyptus unknowingly has integrated itself deep into the Kodaikanal economy. It is a source of business and livelihood for many in the region, from distilleries to the sellers. However, due to profitability, many shop owners have started importing the oil from South Africa, and China. From a demand perspective, there is definitely a need or utility behind the use

of eucalyptus oil which is mainly a medical one. There is however no input that could be generated about the budget constraint aspect related to eucalyptus oil. Lastly the survey results strongly point at eucalyptus oil being a price inelastic product, however more research needs to be conducted regarding the same for confirmation purposes.

4.2 Eucalyptus Honey

The Honey Industry of Eucalyptus Trees has been a subject of pre-field research. While allelopathy has been shown to be beneficial to the industry, it has also been found that its effect can harm the ecology. Published studies have shown that the honey-making industry in countries like Ethiopia and Rwanda is dependent on eucalyptus (Daba, 2016). However, the extent of the dependency on eucalyptus for the local honey industry in Kodaikanal remains unexplored. Further research is needed to examine the trade-off the industry faces between using eucalyptus for honey production and the potential inhibition of the growth of indigenous plant species. This presents an exciting opportunity for research.



Eucalyptus Tree

During our on-field research, we engaged with various respondents to gain a deeper understanding of the honey industry.



A local shopkeeper filling out one of the surveys

Our research findings were challenged by the information provided by our respondents, which revealed that there are two methods by which honey bees produce honey: big bee honey and small bee honey. Small bees are found in higher elevations of the Palani Hills, typically between 100m to 2400m above sea level, which is conducive to the production of Eucalyptus honey. Meanwhile, big bees are found in lower elevations, approximately between 300m to 800m. As per our discussion with Mr. Bala (Secretary, PHCC), the bees that pollinate in higher elevations do not pollinate elsewhere.

The reason elevation can be an important factor when it comes to producing honey is that there is mutual exclusivity between the bees. It can affect the types of flowers and plants that grow in a particular area, which in turn can affect the nectar that bees collect to make honey. The nectar and pollen collected by bees from these plants will have different characteristics depending on the plant's altitude. Furthermore, elevation can also affect the climate where the bees live and work. It can determine the flavour and quality of honey that is being produced by bees. The honey that

is being produced is then gathered by the tribals from the Hoopoe On Hill organisation and later sold to the shopkeepers or the consumers through their store and their website. The honey that the tribals gather is mostly harvested from the middle elevation, 800 m - 1500 m above sea level, which is also known as the coffee belt.

Based on our previous understanding about small bees producing honey on the higher elevation which has eucalyptus trees along with a few others, we can say that Eucalyptus is a flowering tree. During our research it was surprising to hear non-identical views from various sets of respondents. As there are more species of Eucalyptus Trees such as Eucalyptus Globulus also known as Blue Gum, and Eucalyptus Gunnii also known as Cider Gum, etc. It is believed that the lack of awareness among Kodaikanal about the different species that exist led to some of our respondents mentioning that Eucalyptus is not a flowering tree. While others mentioned that *Eucalyptus camaldulensis* which is also known as the Red Gum tree provides honey as and when it matures. Most of the shopkeepers and the locals weren't aware of the fact that Eucalyptus honey exists.

They have mentioned that the Honey industry does not exist and that many people have a misconception about the type of honey. We have been made aware by Mr. Bala, that small bees produce eucalyptus honey; on the contrary, a few of the shopkeepers were letting us know that the big bees produce eucalyptus honey. A few of our respondents were stating their reviews that eucalyptus is a flowering tree whereas a few others weren't agreeing with it for the reason being due to human intervention and mentioned that the eucalyptus honey industry is a false industry. It is important to distinguish between a flowering tree and a non-flowering tree because the existence of flowers plays an essential role in the collection of nectar and ultimately in the production of honey. With this in mind we did further on-field research and during one of our field visits, Mr. Karthikeyan, informed us that the bees can differentiate between eucalyptus trees and Sholas and therefore produce the honey on the Sholas. We caught sight of a honeycomb on a Eucalyptus tree on the way which contradicted the statement made by Mr. Karthikeyan.



Honeycombs seen on a Eucalyptus Tree, Perumalmalai, Kodaikanal

The shopkeepers gave us a different understanding that the bees pollinate on different trees in the same elevation and there is no way a person would be able to distinguish between normal honey and eucalyptus honey. We also got different views from different shopkeepers, a few of them voiced that they source the honey from the tribals, which is why they know it is eucalyptus honey. However, we know that the tribals harvest the honey from the middle elevation, which has coffee and banana trees; but we also know through Hoopoe On Hill, the tribals harvest eucalyptus honey and sell them to the consumers either directly or indirectly. On the other hand, a few of them mentioned that you can only differentiate between the honey if you see “Kodai Hills” mentioned on the honey bottle. With “Kodai Hills” specified on the bottle it would mean that it’s eucalyptus honey. A few of the shopkeepers were confused when we were enquiring whether it is small bee honey or big bee honey, they quoted that it is of big bee honey and that it was eucalyptus honey. Whereas, we were aware of the fact that eucalyptus honey is harvested by small bees. Few of the

shopkeepers were giving us the information that they can provide eucalyptus honey if the consumers pre-order from their shops.

Hence, the existence of honey derived from the Eucalyptus tree, and the presence of an active Eucalyptus Honey industry in Kodaikanal still remains questionable, due to no clear consensus amongst the concerned stakeholder– shopkeepers as well as consumers. This unclear consensus also resulted in an inability to conduct meaningful surveys on the field.



Bottles of Honey and Eucalyptus Oil in a shop in Kodaikanal

4.3 Eucalyptus Firewood

Firewood plays a major role in people's lives, especially the ones living in the village, as a cooking fuel over kerosene and gas in parts of Theni and Kodaikanal. Using eucalyptus as firewood has significant environmental advantages due to the tree's ability to absorb high levels of carbon

dioxide from the atmosphere while growing. This process helps to reduce the impact of global warming (Wood, 2020). We had the opportunity of interacting with the villagers of Poombarai, who collect, use and sell Eucalyptus and Wattle firewood to Kodaikanal.

Only the women of the Poombarai Village go for firewood collection, while the men stay back and do agriculture. The walk is long and tedious for the women, who walk approximately 10 Km to cut the branches–or collect fallen/dead ones–and collect it to take back to their houses. Sometimes, they may also collect the skin of the Eucalyptus tree as it can be used as firewood. The women carry a total of 40 to 50 Kg of the firewood in weight after spending about 2 hours just collecting firewood.

The women of Poombarai spend 7 hours a day, for nearly 200 days in a year, in collecting the firewood and coming back home. Age doesn't seem to limit their spirit and capacity to carry since even women above the age of 65 years carry about 50 Kg! The presence of firewood in the houses of the villagers holds a special place in the local customs. The custom for marriage involves the groom selecting a bride based on the amount of firewood she has outside her house. This is considered a symbol of the woman's good health and physical fitness, as well as her ability to take care of her husband. The importance of Eucalyptus in the village of Poombarai is explained by one of our respondents that while not all houses may have rice or money, they will all have firewood.

The task of firewood collection and its transport isn't in the least bit easy. The women face risks of getting injured by falling from the slopes, facing breathing problems like asthma. One of the respondents in the village stoically mentioned that the chances of getting hurt is high, but they still persist since it is not only for their homes, but also for their livelihoods. Few of the villagers work half-time collecting firewood and half of their time on the agricultural land, or they work only to collect firewood. After the collection of the wood, it is either used by the household itself for cooking purposes or the remaining is later sold to Kodaikanal for about Rs. 300 to Rs. 350 per load.



Local Women of the Poombarai Village carrying heavy load of Eucalyptus firewood and walking barefoot

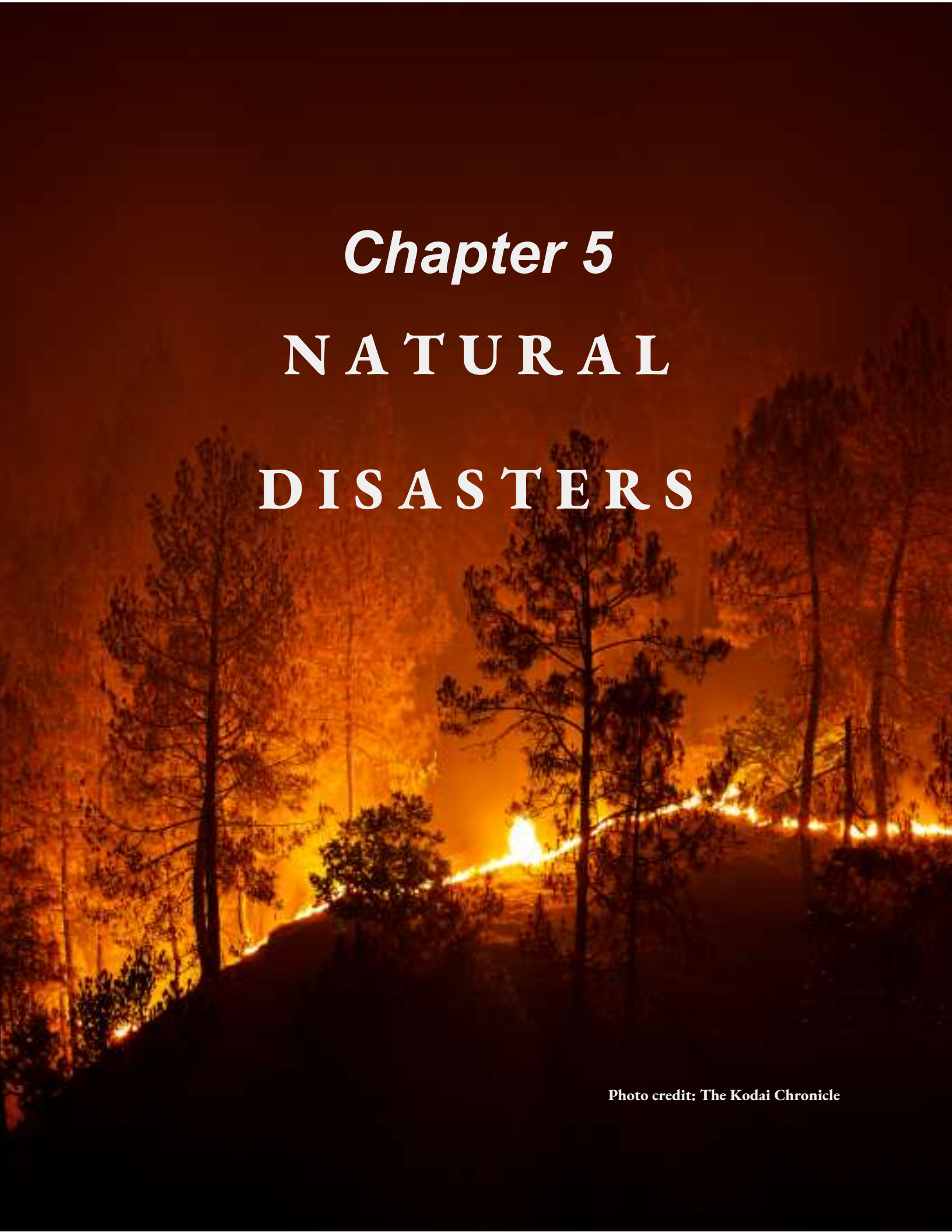
Every household in the village has Eucalyptus logs stored within their houses either on their roofs or in their storage space, therein using the wood for cooking. The houses are extremely small, and the firewood is stored dangerously close to the "*chulha*". This exposes the firewood to catching fire, in the event of which, the entire house may burn down. Despite this, when asked about their preference for using wood or kerosene, the womenfolk agreed that they would prefer to use Eucalyptus wood for three reasons: Firstly, it is very efficient and easily available. Secondly, Eucalyptus and Wattle can last longer when burning for cooking, (~5 hours) when compared to pine trees and other forests (10 to 15 mins). Thirdly, Wattle branches have high water content

which makes it heavier for people to carry. On the other hand, the branch of Eucalyptus Trees is dry, and water isn't stored in the branch, but rather in the trunk. Due to the weight difference, one can carry only one load of wattle branches at a time, whereas in the case of Eucalyptus, two loads can be carried. The potential to burn longer than native species and its easy availability also ensures that the house remains warm during the old winter months.Due to this, the demand for firewood is the highest in winter.



Stock of Eucalyptus firewood stored outside a villagers home, Poombarai Village

While Eucalyptus firewood plays an important role in the lives of the Poombarai villagers, not all are happy with its presence.. Due to its vast growing nature, it has disrupted the fertile land and made it unfit for cultivation. For example, around a decade ago, an area of approximately 3000 to 4000 acres was suitable for cultivation. However, due to the rapid and forceful expansion of Eucalyptus trees, the land became infertile and devoid of vegetation. Thorns and wild animals such as Pigs, Bisons, etc, create a disturbance in the daytime due to a lack of food and water with the lands being taken over by Eucalyptus.



Chapter 5

NATURAL DISASTERS

Photo credit: The Kodai Chronicle

In this chapter, the role and impact that Eucalyptus trees have had in the Natural Disasters of Kodaikanal– more specifically, Forest Fires and Cyclone Gaja– have been discussed. The damage Eucalyptus trees caused due to the falling during Cyclone Gaja was immense. Cars, compound walls, and even sections of buildings were destroyed when they fell. This chapter looks at the role that Eucalyptus trees have played in each.

5.1 Forest Fires

Forest fires are denoted as incidents where a destructive fire breaks out in a forest or an area of woodland. Areas which are home to tropical moist deciduous forests and tropical dry deciduous forests are prone to forest fires (Mohanty & Mithal, 2023). The Dindigul district which harbours the hill station, has higher chances of a forest fire occurring, with the percentage being as high as 216%. Most recently itself, Kodaikanal had a forest fire, destroying nearly 10 hectares of land. Although no fauna was hurt, the fire did not allow nearby residents to breathe with ease as the surrounding area was engulfed in thick smoke. Officials do suspect the main cause for this to be heat waves which reacted with the eucalyptus trees' barks and oil (*The Indian Express*).



Slightly blackened trunks of the Eucalyptus trees ; the blackening of the tree trunks is due to being burnt during forest fires

Contrary to what the secondary research suggests, in our discussion with the teachers and students of the Sholai school, we found out that natural forest fires are a very rare occurrence in the city of Kodaikanal. Even Mark Antrobus goes on to mention that he hasn't seen a natural forest fire in Kodaikanal in a long time. The major causes of forest fires in the city of Kodaikanal (as commented on by Dr. Rajamanikam) are increased tourism and intentional fires set by farmers. He explained that as a result of increased tourism in the area, tourists throw liquor bottles near the grasslands and forests which ends up causing forest fires, or as they like to call them, *hill fires.* Mr. Mark also mentions that a spark from a burnt cigarette is then enough to start the fire which further causes a lot of destruction. As far as the intentional fires are concerned, in our interview with the people of Sholai school, we found out that farmers end up creating fires so that the land clears and gets fertilised. This in turn helps them with agriculture and these fires can be contained and be stopped from spreading. Mr. Karthikeyan says that the new grass that is grown post the burning grows faster and feeds the animals better.

All the primary contacts have unanimously agreed that natural forest fires occur in the months of March, April and May when the season is hotter and drier. According to Mr. Karthikeyan, one of the main causes of natural forest fires is an increase in the temperature of the area. Additionally, by what is suggested by the secondary research, scholarly articles prove that *eucalyptus globulus* does leave behind a smoggy miasma (Michelle, 2019). When the temperature increases, the trees release a gas known as *isoprene* which is colourless and extremely flammable which ends up breaking fires (Winters et al, 2009). When asked Dr. Rajamanikam about his take on eucalyptus tree's role in causing forest fires, he comments that not even 5% of the forest fires in the area are due to eucalyptus trees. Strangely, according to the beliefs of our points of contact, Eucalyptus trees don't start the fire but they end up spreading the fire greatly which causes a lot of destruction. The discussion with the members of the Palini Hill Conservation Council continued to tell us that leaf litter of the eucalyptus trees might end up causing a fire as well but the eucalyptus plays a greater role in spreading it. Mr. Mark explains that this is mainly due to the presence of the volatile oil that is present in the eucalyptus trees. Besides that, when we questioned a local working in the Sholai school asking him why eucalyptus trees spread a fire so intensely, he reasons that it is due to the fact that eucalyptus forests don't have any windbreaks. This ends up spreading a fire more than usual.

As the secondary research suggested, it is agreed upon by the local and Mark Antrobus that eucalyptus grows back really fast once the fire is out. As Mark puts it, “Eucalyptus feed on the fire and they are fire resistant.”. He mentioned that we could see burnt Eucalyptus trees which have grown back at Dolphin Nose. During our site visit to Dolphin Nose with Mr. Murugesh, we saw burnt eucalyptus trees which had black trunks fully alive and grown.

This suggests that the fire does not end up hurting eucalyptus trees which are actually the cause of the spread of the fire but instead, affect the other species living around. However, a point made by Mark to note is that the Shola forests are fire resistant i.e. they don’t end up burning. A possible explanation for this phenomenon was given by the local. He explained that as shola forests are evergreen, they never dry out. This is why they can’t aid fire. So in this particular case, the grasslands and the fauna end up getting affected by the fires caused.

To summarise, forest fires are not that very frequent in Kodaikanal today. In case there is one, it is mainly due to increased tourism or because of agricultural purposes. If a fire starts near and around eucalyptus trees, they end up spreading that fire rapidly. This has adverse effects on grasslands (destroying them further) and various fauna species found in the region. Shola forests don’t end up getting as affected as they are evergreen in nature. Lastly, even eucalyptus trees don’t get affected as they’re fire prone; they’ll just grow back almost immediately once the fire is out.

5.2 Cyclone Gaja

Cyclone Gaja was the sixth named cyclone of 2018 North Indian Ocean Cyclone season. The North Indian Ocean Cyclone season was the most active North Indian Ocean cyclone season post 1992. It started to form on November 5 near the Gulf of Thailand as a low-pressure system. By the time it reached the Bay of Bengal on 10th, the system intensified and then finally on 11th, it changed to a cyclonic storm. Cyclone Gaja finally hit South India on November 16. The cyclone had severe impacts on the South Indian states, particularly Tamil Nadu (*Study Report on Gaja Cyclone, 2019*).

Kodaikanal being a part of Tamil Nadu faced a lot of problems during the cyclone. According to an article published by Times of India, cyclone Gaja, after hitting the delta districts that had the warnings, also passed through the neighbouring Dindigul district. The impact it had on the district was dramatic. The major effect was in the regions of Kodaikanal–which also happened to be in the eye of the cyclone. It is recorded that more than 6000 trees were uprooted and fell on the roads along with electricity poles and the damaged houses (Ananth, 2018). The

article also states that 12,647 hectares of crops under cultivation were ruined, with maize crop getting affected the most.



Fallen Eucalyptus tree trunk (foreground): a victim of Cyclone Gaja. In the background Eucalyptus Trees can be seen.

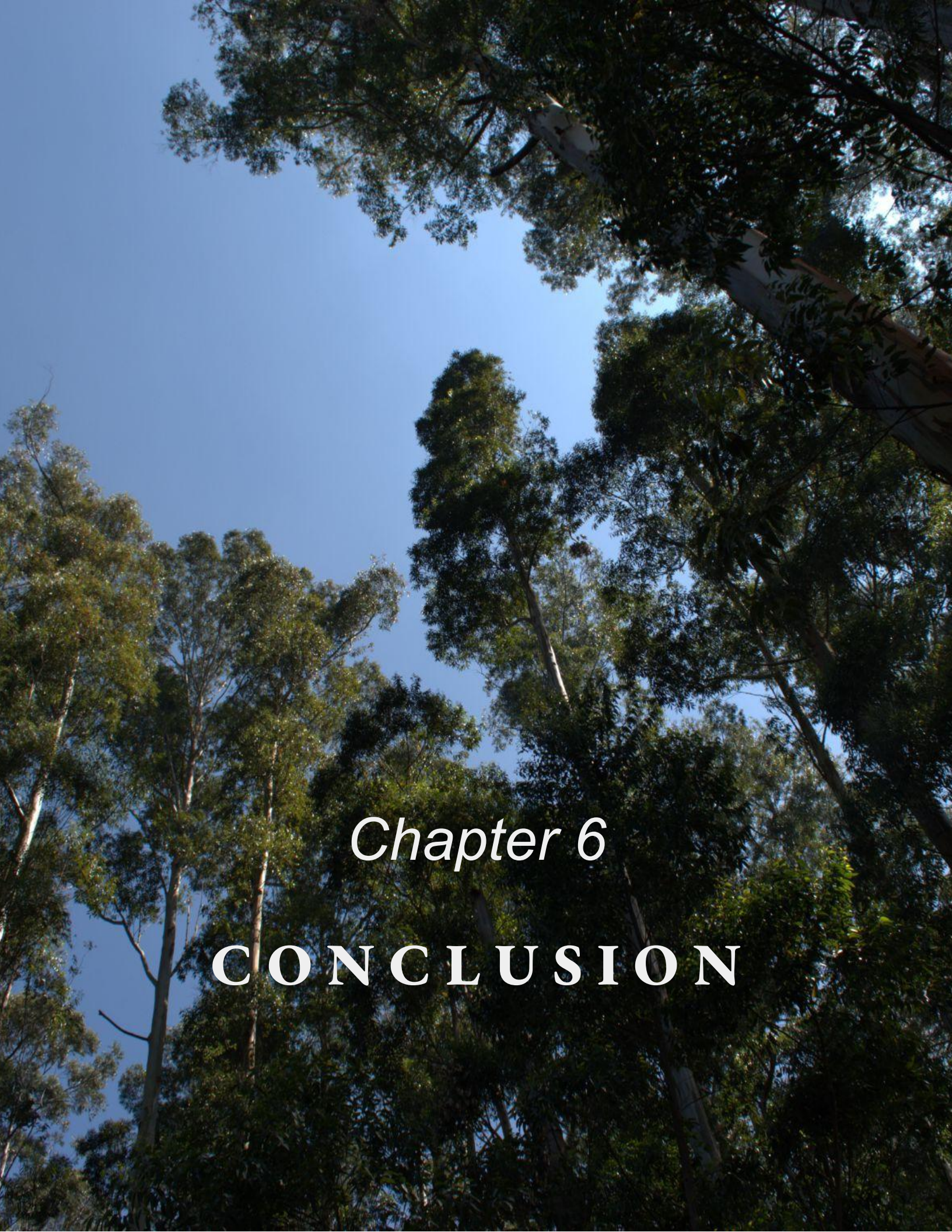
What's interesting is that during the field work, our points of contact made a parallel between the Cyclone Gaja and the presence of eucalyptus in the area. When having a discussion with Mark Antrobus for the first time, we found out that during the cyclone, out of all the trees that fell, the majority of them were eucalyptus trees. According to Mr. Kartieya, within seconds of the cyclone hitting Kodaikanal, over 10,000 trees fell in an area of about 15 acres. He along with Dr. Rajamanikam agreed that the majority of the trees that fell were eucalyptus trees. During our field visit, we got to know that of all the types of eucalyptus trees found in Kodaikanal, E. grandis was the one which fell the most. Grandis is used for timber and paper as the oil content (as told by

our respondents) is primarily low. In Mr. Kartieya's opinion, there weren't a lot of native shola trees that fell because they are short and more sturdy when compared to the eucalyptus trees; eucalyptus trees in his words are, "not sustainable and stable". When asked by Dr. Rajamanikam about his take on why more eucalyptus trees fell, he gave us two reasons: the first one being because there are more eucalyptus trees present than shola trees and the second one being that since eucalyptus trees have shallow roots, they can be uprooted easily. Therefore, in cases of storms and high winds, they swirl and fall down easily. Mark Antrobus agreed with this. He explained the whole procedure with great detail. The shallow roots are not strong enough to support a tall tree like Eucalyptus against the strong wind forces of a cyclone. Furthermore, due to its tall height, the tree easily bends in the direction the wind pushes it. In a cyclone, due to the changing wind direction, the roots keep getting loose while the trunks bend heavily in opposite directions with the wind (almost like a pendulum). Eventually, the trunks snap and the roots get uprooted, and the tree ends up falling. This is what happened when the cyclone hit Kodaikanal.

Once the trees fell and the cyclone died out, Mr. Karthikeyan pointed out that the people weren't allowed to remove the fallen or damaged trees from the vicinity by court's order. He said that this action was taken because the authorities wanted the trees to decompose and make the soil fertile. He goes on to say that the trees could only be used for timber and not for commercial purposes. In an article written by Jagannath, he states that the Union Ministry of Rural Development had rejected the Tamil Nadu government's request for special permission under the Mahatma Gandhi National Rural Employment Guarantee Act to cut fallen trees and to remove debris in districts that were hit by the Cyclone Gaja. In conclusion, "Government of Tamil Nadu said the Centre has allowed only pitting and planting under the MGNREGA as against the state's request to cut fallen trees and replantation in cyclone-affected districts" (2019).

Eucalyptus trees ended making things worse for the city of Kodaikanal when the cyclone Gaja hit the place. From what is gathered, over 85% of the trees that fell were eucalyptus trees. The other tree species which competed in numbers with the eucalyptus trees were the other invasive species, pine trees. The main reason that eucalyptus trees fell were because of their shallow roots and tall structure (which makes them more vulnerable to falling). Post the cyclone, the people weren't allowed to clear the fallen trees unless special permission was taken from the authorities and to date when you enter the forest areas, you can see fallen trees as a result of the Cyclone Gaja just like we did during our field visits with Mr. Karthikeyan and Murugesh sir.

Overall, Eucalyptus trees have ended up playing an indirect role during natural disasters in Kodaikanal. Even though they might not be the main cause of forest fires as suggested by the secondary research, one thing that the primary contacts confirmed was that they spread the fires very quickly. When it comes to cyclone Gaja, the majority of the trees that fell were eucalyptus and pine trees which caused severe damage in Kodaikanal.



Chapter 6

CONCLUSION

The research report set out to give an overall picture of how eucalyptus trees have impacted Kodaikanal since the time they were first planted in the 1860s by the Britishers. Throughout the course of the report, it looks at different variables and tries to come to a conclusion on how eucalyptus has affected that particular variable.

The first thing that was explored was allelopathy. Through the secondary research it was found that eucalyptus trees release an allelopathic compound which ends up inhibiting the growth of other plant species. This phenomenon holds true for the plant species in Kodaikanal as well, as was seen and confirmed by the interviewees during the on-field research. Solutions on how this can be avoided was also provided during the field visit; the first one being ring-barking of the eucalyptus trees (to completely cut off the water and food supply to the trees) and the second one being not growing crops in the vicinity of eucalyptus trees. Coming to the second aspect of shola forests, the majority of the shola forests disappeared in Kodaikanal. Although eucalyptus trees weren't the only reason for this to happen, it did play a role as the trees deteriorated the soil quality and water levels for shola trees to be able to grow and live properly. However, the interesting point here is that Shola trees are finally regrowing under the shade of eucalyptus trees. There are many explanations as to why this is happening but the most common answers are the fact that eucalyptus trees are providing an ideal environment for the shola trees to grow back and that eucalyptus is no longer hampering the growth of these trees, although the scientific explanation on how this is able to happen is still unexplored and not within the scope of this study. Last aspect in the ecological lens was grasslands. Just like the shola forests, shola grasslands have been outcompeted by the eucalyptus so much that there are barely any grasslands left in Kodaikanal. On the contrary, unlike the case with the shola forests, grasslands are showing no signs of regenerating as of today. Although people believe and hope, whether or not Kodaikanal will get back the ecosystem in the future in reality is still unknown.

Looking at the economic lens, the first aspect that was analysed was that of eucalyptus oil derived from the eucalyptus trees. The conclusion obtained from the interviews of eucalyptus oil manufacturers is that there isn't a lot of profitability in the business especially if the scale of production is low. This is due to high production costs associated with extracting eucalyptus oil using various different distillation methods. Although, when looked at it from the employment point of view, the whole process of making eucalyptus oil gives jobs to a lot of locals which is their main source of income. To speak of the shop owners and retailers, to increase their

profitability, they have started to import the oil from other countries as that is economically viable for them. This is alarming since it will have adverse effects on the local extraction industries. Speaking of consumers of eucalyptus oil, the survey analysis shows that there is high preference for eucalyptus oil in Kodaikanal as the utility derived from the product is great mainly when it comes to its medicinal uses. Commenting on the budget constraints of the consumer however is not possible due to the lack of data that is available. However, what can be said is that the majority of the consumers find the pricing of Rs.500 for a bottle of 200ml of oil affordable.

When it comes to eucalyptus honey, not a lot can be said as there is a lack of information among the people of Kodaikanal themselves. Although secondary data suggested the presence of a product like eucalyptus honey, with certain companies even selling them, there was no convincing consensus amongst the consumers, shopkeepers or even the points of contact to ratify the same. While some of them answered positively, acknowledging eucalyptus honey to exist, others blatantly refused. Thus, the clarity on the existence of such a product provides scope for research, as the people who responded positively mentioned the local tribal community prepare and produce eucalyptus honey.

Lastly, locals believe that using eucalyptus firewood for their household chores is more efficient than using other firewoods found in the area. Out of the many reasons stated by the villagers of Poombarai, the important ones were that they burn for longer periods of time and at the same time heat their houses during the times of winters. Although eucalyptus firewood cannot be used for commercial purposes as stated by the government, it is used for personal purposes by the households living in the area. It further acts as a source of income for the villagers, since they are able to sell the unutilised firewood to the people of Kodaikanal town.

To conclude, whether Eucalyptus trees should remain in Kodaikanal is far more complex, and ambiguous, than simply stating yes or no. The stakeholders affected on both sides will be impacted heavily. Leaving nature to take its due course may also not be the most viable option, since the seeds of the Eucalyptus can lead to the growth of more Eucalyptus trees, repeating the entire cycle of allelopathy and high water consumption again. Simply cutting them and removing them from the ecosystem on an immediate basis, because of its ecological damage, will result in a void being opened in the economy of the town. Distilleries like Mr. Suresh's will be heavily impacted, and along with them, the workers who earn from the sales of the Eucalyptus leaves. Furthermore, it can cause locally manufactured Eucalyptus oil to fizzle out of competition as

imported Eucalyptus oil from China and South Africa can take over completely, a practice that is already happening as of today.

Limitations of the study:

- The most important limitation of the study was the time constraint we had for our on-field research. As this research is part of our academic curriculum, we only got 9 days of field research, it wasn't sufficient to come up with a stronger conclusion for the given study.
- Additionally, the lack of our expertise as undergraduate students when it came to conducting scientific experiments using tools like quadrats in the field was a barrier to getting more statistical data and analysis for our ecological aspects.
- The responses that were collected as a part of our survey was limited which can be perceived as a sign of inaccurate results of the study. Many consumers had a bias and were hesitant to fill out the survey forms being handed out, since they assumed us to be marketers.

Scope for future research:

As mentioned above, there are two research gaps that this report can provide for future exploration. One of them is on the Eucalyptus Honey in Kodaikanal. While certain companies do sell Eucalyptus Honey, acknowledgements and confirmations about its presence and existence were also given by certain respondents and shopkeepers. The reason for research on this aspect could be since all the contacts who affirmed the existence of Eucalyptus Honey in Kodaikanal all had a unanimous response– it is the local tribes who manufacture this sort of honey. Hence, exploring this aspect can hold potential research value.

Another point of research could be done along the same lines as this report by researchers with far greater experience and expertise than us. We believe we have just explored the tip of an iceberg, and have presented a foundation for the economic vs ecological impacts of Eucalyptus in Kodaikanal. Through this report, we have aimed to provide an unbiased view of how the presence has impacted different stakeholders, a point that can be further analysed intricately to arrive at a more singular conclusion.

Alternatively, this report can also be used to study the impacts that other invasive species had on the town of Kodaikanal, or other places in India.

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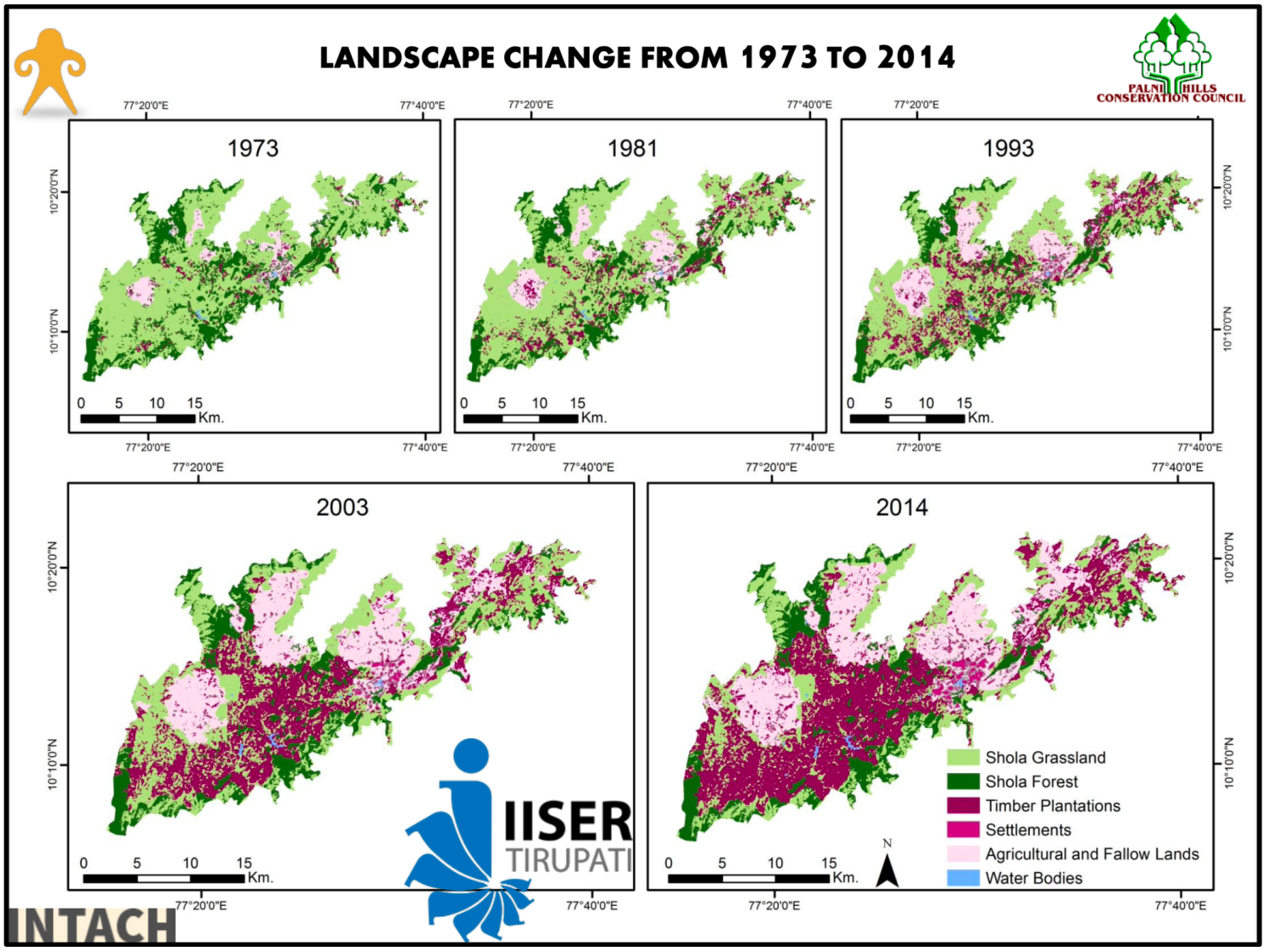
Appendix

I. Map of Kodaikanal with all our site visits



Source: Author's own creation

II. Map of Kodaikanal showing loss of grasslands through the years.



Source: Mark Antrobus, President, Palni Hills Conservation Council, Kodaikanal

III. Questions for Consumer Surveys for Eucalyptus Oil

Consumers (Surveys)

1. I am a..

நான் ஒரு..

- **Resident |** குடியிருப்பாளர்
- **Tourists |** சுற்றுலா பயணிகள்

2. How Often do you use Eucalyptus Oil?

நீங்கள் எவ்வளவு அடிக்கடி யூகலிப்டஸ் ஆயிலைப் பயன்படுத்துகிறீர்கள்?

- **Very Often |** அடிக்கடி
- **Often |** அடிக்கடி
- **Sometimes |** சில நேரங்களில்
- **Never |** ஒருபோதும்

3. For what reasons do you use Eucalyptus Oil?

என்ன காரணங்களுக்காக யூகலிப்டஸ் ஆயிலைப் பயன்படுத்துகிறீர்கள்

- **Medical Reason |** மருத்துவக் காரணம்
- **Industrial Reason |** தொழில்துறை காரணம்
- **Perfumery Reason |** வாசனை திரவியம் காரணம்
- **Other |** மற்றவை:

4. How effectively does Eucalyptus Oil fulfil the reasons you buy them for?

யூகலிப்டஸ் எண்ணெய் நீங்கள் வாங்கும் காரணங்களை எவ்வளவு திறம்பட நிறைவேற்றுகிறது

- **Very Good |** மிகவும் நல்லது
- **Good |** நல்ல
- **Satisfactory |** திருப்திகரமாக
- **Not that well |** நன்றாக இல்லை
- **Other |** மற்றவை:

5. Where do you purchase Eucalyptus Oil from?

யூகலிப்டஸ் ஆயிலை எங்கிருந்து வாங்குகிறீர்கள்

- **Small Shopkeepers |** சிறிய கடைக்காரர்கள்
- **Online |** நிகழ்நிலை
- **Big Supermarket Chains |** பெரிய பல்பொருள் அங்காடி சங்கிலிகள்
- **Other |** மற்றவை:

6. How affordable is Eucalyptus Oil?

யூகலிப்டஸ் எண்ணெய் எவ்வளவு மலிவானது

- **Under Priced |** கீழ் விலை
- **Correctly Priced |** சரியான விலை
- **Over Price |** அதிக விலை

7. Do you think there are many substitutes for Eucalyptus Oil?

யூகலிப்டஸ் எண்ணெய்க்கு பல மாற்றுகள் இருப்பதாக நீங்கள் நினைக்கிறீர்களா

- **Yes |** ஆம்
- **No |** இல்லை
- **Don't Know |** தெரியாது

8. Did you increase your eucalyptus oil consumption during COVID times?

கோவிட் காலங்களில் யூகலிப்டஸ் எண்ணெய் உபயோகத்தை அதிகரித்தீர்களா

- **Yes |** ஆம்
- **No |**இல்லை

9. On a scale of 1 to 5, how likely are you to recommend eucalyptus oil to other people?

1 முதல் 5 வரையிலான அளவில், யூகலிப்டஸ் எண்ணெயை நீங்கள் மற்றவர்களுக்கு எவ்வளவு பரிந்துரைக்கலாம்

Very Unlikely | மிகவும் சாத்தியமற்றது

- **1**
- **2**
- **3**
- **4**
- **5**

Very Likely | அநேகமாக

IV. Questions for Producer Surveys for Eucalyptus Oils

SHOPKEEPERS (Surveys)

1. Who purchases oil more?
யார் அதிகமாக எண்ணெய் வாங்குகிறார்கள்?

- **Locals | உள்ளூர்**
- **Tourists | சுற்றுலா பயணிகள்**

2. Which season is it highest in demand?
எந்த பருவத்தில் அதிக தேவை உள்ளது?

- **Summers | கோடைக்காலம்**
- **Monsoons | பருவமழை**
- **Winters | குளிர்காலம்**

3. When was Eucalyptus Oil highest in demand?
யூகலிப்டஸ் எண்ணெய் எப்போது தேவை அதிகமாக இருந்தது?

- **2019-2020**
- **2020-2021**
- **2021-2022**

4. Did the cost of raw materials increase during COVID?
கோவிட் சமயத்தில் மூலப்பொருட்களின் விலை அதிகரித்ததா

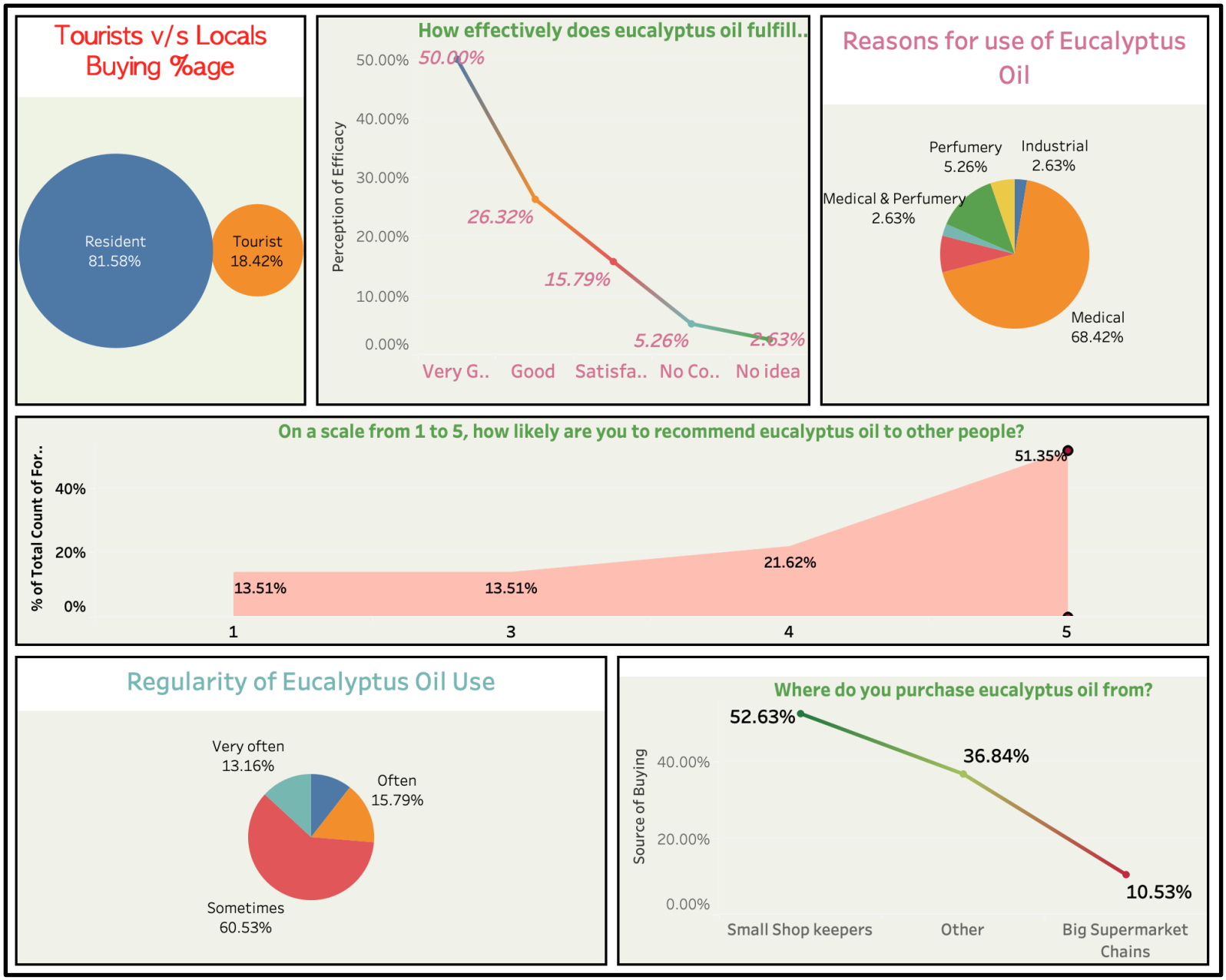
- **Yes | ஆம்**
- **No | இல்லை**

5. Is Eucalyptus Oil perishable in nature?
யூகலிப்டஸ் எண்ணெய் இயற்கையில் அழியக்கூடியதா?

- **Yes | ஆம்**
- **No | இல்லை**

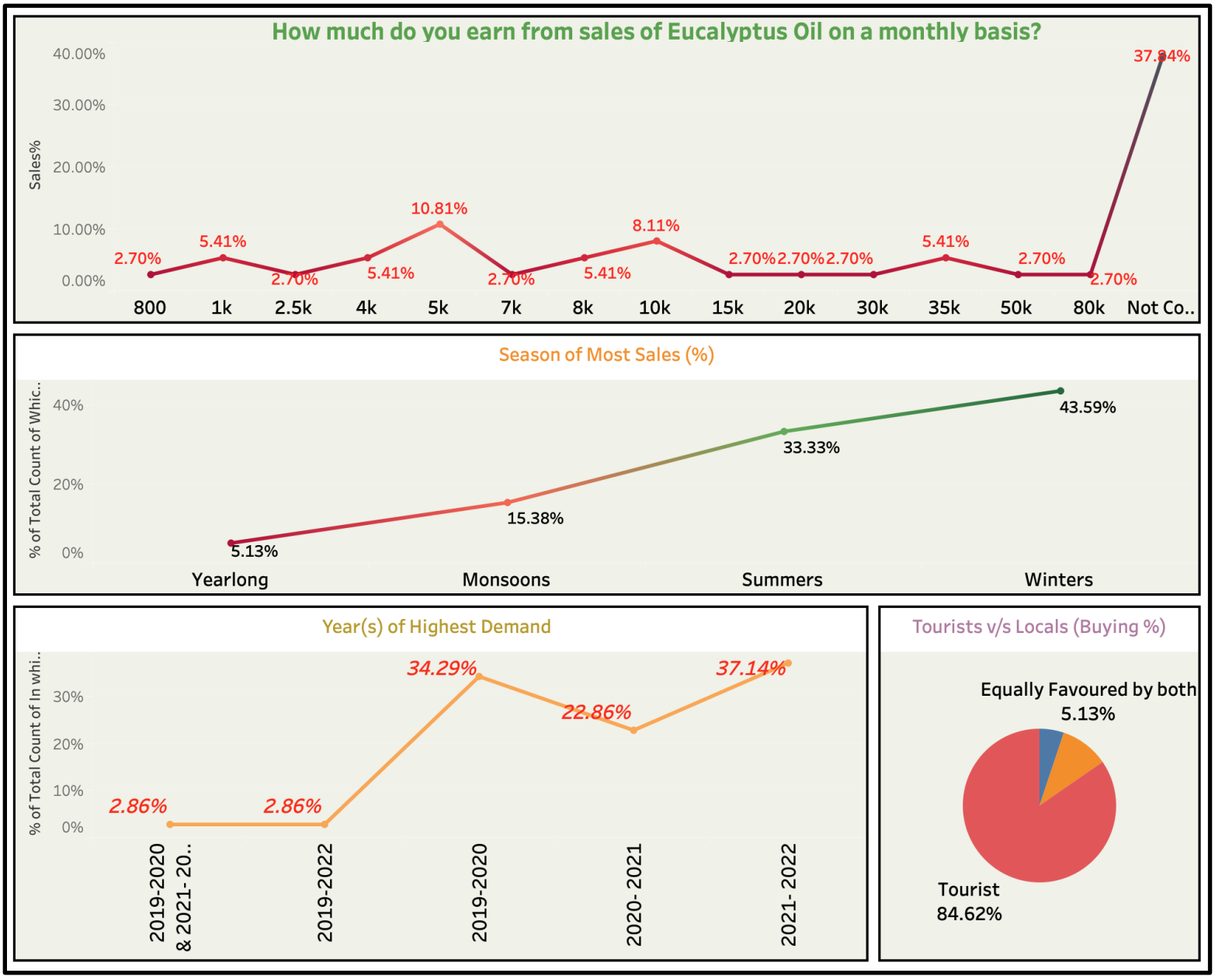
6. How much do you earn from sales of Eucalyptus Oil on a monthly basis? (Fill in the blank)
யூகலிப்டஸ் ஆயிலின் விற்பனை மூலம் மாதந்தோறும் எவ்வளவு சம்பாதிக்கிறீர்கள்? (கோடிட்ட இடங்களை நிரப்புக)

V. Dashboard showing most important graphs based on Consumer Survey responses



Source: Author's Own Creation

VI. Dashboard showing most important graphs based on Consumer Survey responses



Source: Author's Own Creation









LIST OF INTERVIEWS

S. No	Method	Interviewee
1	Focus Group Discussion	Members of the Palini Hills Conservation Council
2	Personal Interview	Dr. Rajamanikam
3	Personal Interview	Mr. Kartikeyan
4	Personal Interview + Site Visit	Mr. Suresh (Owner of Mani Oil Distillery)
5	Personal Interview + Site Visit	Mrs. Jenyz Satori
6	Personal Interview	Mr. Murugesh
7	Focus Group Discussion	Sholai School
8	Personal Interview	Mr. Bala
9	Questionnaires	Shop owners
10	Questionnaires	Residents and Tourists

Glossary

- **வணக்கம் எப்படி இருக்கிறாய்**? - Hello, how are you?
- **மரம்** – Tree
- **நாங்கள் மலை ஏறுகிறோம்** – We are climbing the hill
- **உங்களை சந்தித்ததில் நல்ல இருந்தது**- It was nice meeting you
- **நன்றி** – Thank you
- **அக்கா** – Sister
- **எண்ணெய்** – Oil
- **காட்டு தீ** – Forest Fire
- **காடு** – Forest
- **தேன்** – Honey
- **எனக்கு பசிக்கிறது** – I am hungry
- **நான் தூங்க செல்கிறேன்** – I am going to sleep
- **உங்கள் சாப்பாடு நல்ல இருக்கு** – Your food is very tasty
- **விவசாயம்** – Agriculture
- **விலங்குகள்** – Animals
- **பறவைகள்** – Birds
- **மலை எரிகிறது** – The hill is burning
- **இது அழகாக இருக்கிறது** – This is beautiful
- **ஏரி** - Lake

DIP 2022-23



Thank you