Master's thesis

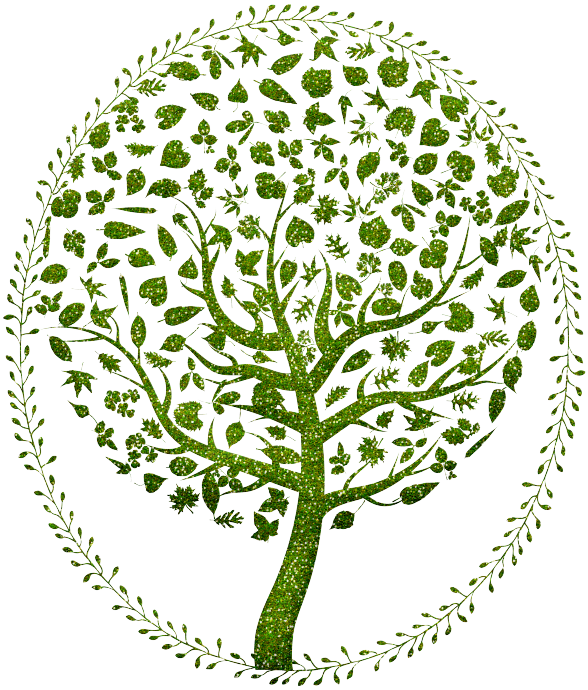
NTNU
Norwegian University of Science and Technology
Faculty of Humanities
Department of Music

Mads Heggen

Resonant footprints:

A framework for assessing sustainability and cultural preservation in traditional string instrument production

Master's thesis in musicology
Supervisor: Tore Størvold
June 2023



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Abstract

This thesis examines the sustainability of the music industry with a specific focus on the production of musical instruments, particularly those in the violin family. By adopting an interdisciplinary approach that integrates environmental, social and economic perspectives, this research aims to understand the environmental impact of instrument production and explore strategies for promoting sustainability in the industry. Throughout the research, a framework for assessing sustainability in the music industry is proposed. This framework highlights the importance of stakeholder collaboration, transparency in data collection and the integration of multiple sustainability considerations. It emphasises the need for continuous research, innovation and education to drive positive change in the industry. The findings of this thesis contribute to the growing field of ecomusicology and ecoorganology by providing insights into the complexities of sustainability in the music industry and other cultural and/or traditional industries. By considering the environmental, social and economic dimensions of instrument production, this research aims to make it easier to make decisions and promote a more sustainable and responsible approach to music-making.

Keywords: ecomusicology, ecoorganology, sustainability, music industry, musical instruments, cultural sustainability, sustainability in music

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1 Introduction

The focus on sustainability, climate, and climate change have seen a drastic increase in media, communities, and academia over the past few decades. Increased awareness and action will be crucial to meeting the UN Sustainability goals for 2030 and preventing humanitarian crises, recently underlined by the UN IPCC Sixth Assessment Report published in 2021, assessing climate change's current and future forecasts and impacts. According to the report, only drastic cuts in carbon emissions would help prevent global environmental issues in the future. The consequences are global and affect all. The report also highlights the increasing risks associated with climate change, including more frequent and intense heat waves, droughts, and extreme weather events, as well as sea level rise and ocean acidification. These risks can affect human health, food security, water resources, and economic growth.[1] A more sustainable approach to living is needed.

Sustainability is the concept of meeting the needs of the present without compromising the ability of future generations to meet their own needs. It is a holistic approach to ensuring the long-term viability of human society and the natural environment. One key aspect of sustainability is the responsible management of natural resources, including forests. Deforestation, the loss of forested areas, is a significant threat to sustainability. Forests provide essential ecosystem services, such as carbon sequestration, water filtration, and habitat for various species. The loss of forests has significant impacts on the environment, including impacts on air and water quality, climate change, and the loss of biodiversity. In addition to the environmental impacts, deforestation can negatively impact local communities that rely on forests for their livelihoods. The loss of forests can lead to the loss of traditional ways of life, as well as economic and social disruption. For our measures to have a significant enough impact, given the findings of the report, changes have to be implemented across all fields.

There are areas where research and efforts on sustainability are scarce, and music, or musicology, is one of these areas. In the context of musicing being among the world's most widespread and culturally diverse professions and recreational activities, one can question why we have only recently begun researching the activity's environmental impacts.[2] Most of the current research on *ecomusicology* – the science of environmental and ecological matters in music – is aimed at understanding how we can use music to mobilise or strengthen engagement, knowledge, and focus on climate change – in other words, on music as a tool. Research on the music industry's actual impact on the environment is, however, limited. Matt Brennan explains that music, more often than not, is viewed as a non-material form of art – even though it can be one of the most material-sensitive on a broader scale. With concerts in minor and major forms, parties, CDs, vinyl records, headphones, studios, and musical instruments, there are many variables related to creating, listening and experiencing music.[3] These ways of consuming music are all directly or indirectly related to the art forms' environmental impact. One can argue that music has developed a form of cultural dissonance, where

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[1] IPCC. (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V. et al. (eds.). *Cambridge University Press*, Cambridge, United Kingdom and New York, USA.

[2] Vinge, J.; Røyseng, S.; Salvesen, G. U.; Skrebergene, S. (2022). Musikerne og klimakrisen. I S. Røyseng; H. Stavrum; og J. Vinge (Red.), *Musikerne, bransjen og samfunnet*, p. 248

[3] Brennan, Matt. (2021). The infrastructure and environmental consequences of live music. In Devine, Kyle; Boudreaut-Fournier, Alexandrine (ed.), *Audible Incrastructures*. p. 117.

consumption contradicts the values it promotes – much like a water bottle company producing plastic bottles that pollute water. A large concert can house tens of thousands of people, and every person adds to the total by commuting, buying food and drinks, and socialising with friends.

When conveying the subject of music, these issues are typically not addressed, and subjects are more often than not directed toward music's cultural, economic, and human benefits. This thesis addresses this issue and focuses on *ecoorganology* – the science of musical instruments with global ecosystems in mind. The term ecoorganology is relatively new, only recently defined by Aaron Allen in an unpublished article. He describes it as expanding from the established organology fields to a more "comprehensive, ecocentric focus on musical instruments and music cultures as parts of broader ecosystems''. Allen further divides it into two main paths: one derived from quantitative scientific approaches (life cycle analysis), the other more literary-analytical in its conception (sustainability centred).[4] The first is a more quantitative, scientific approach that uses tools such as life cycle analysis to evaluate the environmental impact of musical instruments. This can include examining the materials used to make the instruments, the energy and resources required to produce them, and their disposal or recycling at the end of their life. The second and literary-analytical approach to ecoorganology focuses on the cultural and social aspects of musical instruments and their impact on sustainability. This can involve studying the role of musical instruments in different music cultures and traditions and how these practices can be adapted to support more sustainable practices. Throughout this thesis, the term ecoorganology[5] is used to refer to both on a broader scale. With ecoorganology in mind, I analyse the environmental impacts of string instruments mainly from a life-cycle analysis point of view. Furthermore, and regarding its impact, a comparison will be made between what is viewed as an "authentic" and mass-produced string instrument. Deforestation, mining operations, and pollution from manufacturing can affect communities, and research on this area is scarce.

Readers may find the subject or approach atypical from what is normally portrayed in musicology research. The approach will include the mathematical, scientifical, and analytical materials typically not used in music; research found more often in fields such as material science, engineering, and biology. It may not even be desirable for musicians, the music industry, and their followers, such as myself, to point out flaws in an already competitive, downplayed and marginalised profession. Cuts in funding and education alongside more strict regulations can significantly affect both large and small parties in the industry. Brennan (2021) argues that scientific research

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[4] Allen, Aaron S. (2023). Ecoörganology. *Sounds, Ecologies, Musics*. Edited by: Aaron S. Allen and Jeff Titon. Oxford University Press. DOI: 10.1093/oso/9780197546642.003.0002, p. 19 (unpubliushed, due to be published later this year).

[5] *— Allen argues for using "ecoörganology" instead of "ecoorganology" (p. 34). This is called a diaeresis, and is used when you have two vowels next to one another that should be pronounced as separate syllables. The use of "ecoörganology" offers spelling clarity, but does not align with common English language practices, especially outside academic circles. Incorporating this complicates text, creating barriers for accessibility—especially for non-native speakers. Most new spelling reforms also often advocate for simplicity. The word "cooperation" exemplifies the argument. Most speakers instinctively know to pronounce "cooperation" as co-operation. Including a diaeresis (coöperation) would align with the pronunciation, but it is not standard practice and can lead to confusion. Being a new field, such complications should be avoided. The three morphemes "Eco-", "-organ-" and «-ology" are relatively common words, at least in in their context, and we can presume that they are separable by most people.*

used against the music industry and its consumers can be unwelcome.[6] While this may be true, the same can likewise be said for many other fields. Broadening the historical barriers of musicology is crucial in developing and making it current and of public utility. Raising awareness of environmental issues through scientific research, both in general and within the field of music, can also help alleviate the concerns we are facing. With raised awareness among the general public, not considering sustainability may even be considered negligent.

Globally, illegal logging is a big problem. Not only does it pose a threat to endangered species, but it also plays a role in the ongoing biodiversity crisis and climate change. Despite international agreements, such as CITES, 10-30% of all imported wood has been illegally logged, presumably depending on the country. Due to their economic worth and desirable features, several of these trees, particularly ebony (Diospyros) and rosewood (Dalbergia), are under heavy use. Acoustic musical instruments made of these woods are among the goods that employ them. Globally, the genus Diospyros has about 700 species. More than 200 species are unique to Madagascar – one of the most biodiverse places on earth.[7]

This introduction has attempted to provide a brief summary of the topics related to the framework proposed in this thesis, which aims to address the issue of deforestation in the musical instrument industry by promoting sustainable practices, in particular for the violin family of instruments. The procedures and their possible results are further examined in the following chapters, detailing established literature, research findings and comments related to these. Another goal of this framework is to broaden and strengthen the field of musicology, or more specifically, ecomusicology, by providing a more scientific and analytical approach to understanding the environmental impact of musical instruments. The language used when speaking about arts and sustainability can, for both musicologists and other -ologists in arts and humanities alike, can often seem "new age" or "alternative" with words such as "earth", "art", "music", "forest", "tones", "instruments", "dance" and "climate" used in conjunction with each other. A more scientific and analytical approach can strengthen the reliability of such research, make it more current and, most importantly, more desirable to be read by a broader audience. By promoting a sustainable approach that includes using wood from sustainably managed forests and looking for alternatives to wood for instrument manufacturing, we can protect forests and ensure their long-term viability for future generations. Providing more research into the field is one of the key ways of finding the right solutions. Ultimately, this framework advocates for a more inclusive and holistic approach to sustainability that acknowledges the importance of music and culture as vital components of sustainable communities, where culture thrives alongside social, economic, and environmental well-being. By taking a sustainable approach, we can protect forests and ensure their long-term viability for future generations. Providing more research into the field is one of the key ways of finding the right solutions. One of the goals of this thesis is to advocate for a more inclusive and holistic approach to sustainability, which acknowledges the importance of music and culture as vital components of sustainable communities. By recognizing the contributions of cultural practices, we can work towards creating a more sustainable world where culture thrives alongside social, economic and environmental well-being.

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[6] Brennan 2021, p. 120

[7] Jahanbanifard, M., Gravendeel, B., Lens, F., & Verbeek, F. (2019). Ebony wood identification to battle illegal trade. *Biodiversity Information Science and Standards*, *3*. https://doi.org/10.3897/biss.3.37084

1.1 A note about sustainability

One of the challenges with sustainability is that it can be ambiguous and open to interpretation. For example, what does it mean for something to be sustainable? Is it sustainable if it can continue for a certain time frame, or does it need to be able to continue indefinitely? Another challenge with sustainability is that it can be difficult to measure, especially when dealing with complex supply chains for products with multiple materials and origins – such as the cello. How do we determine whether an ecosystem, a community or an economy is sustainable? What metrics do we use to assess sustainability, and how do we weigh different factors against each other in order to make a determination? Similar questions can be raised with related terminologies, such as ecosystem services. One of the challenges with the concept of ecosystem services is that it is often difficult to quantify the value of these services, as they can vary depending on multiple factors. Additionally, there is often a lack of information about the services that an ecosystem provides, which can make it difficult to fully understand the role that the ecosystem plays in supporting communities.

Peter Glavič tries to access the term 'sustainability' in his article *Review of sustainability terms and their def*initions. The text discusses the growing importance of terminology in the field of sustainable development as awareness of sustainability increases. The spread of sustainability terms and their definitions is increasing due to the availability of various information sources. This results in the emergence of new terms or the extension of existing ones. However, there has been a lack of critical attention given to the definitions and their semantic meanings. The result is confusion in usage due to the multitude of definitions, with some terms having similar or slightly different meanings. The text summarises definitions of terms and presents a hierarchical classification of them.[8] Glavič does not analyse the term sustainability itself, but rather its sub-hieratical terminologies. As the term sustainability is broad in its nature, the notes from Glavič are still relevant. The understanding and communication of sustainability terms, their definitions and how they relate to one another is essential for promoting sustainable development within our societies. Using more specific terminology in a precise manner, when needed, will therefore be beneficial in this thesis, and using Glavičs findings can form a solid baseline. Timothy Cooley also highlights different ways of viewing sustainability within music in his work *Cultural Sustainabilities : Music, Media, Language, Advocacy.* The text highlights the viewpoints of Aaron S. Allen, who claims that sustainability is better understood as a lens rather than a thing. This suggests that sustainability can be applied as a perspective to analyse and evaluate various circumstances. Similarly, Robert Baron and Thomas Walker emphasise that the use of the term "sustainability" has the power to change how we perceive existing arrangements and practices.[9] Many authors have also criticised the term 'sustainable development'. It has, for instance, claimed that 'development' is rooted in Western colonial capitalist narratives and that it poses obstacles to sustainability. Others have said that it is necessary to separate 'sustainability' from its counterpart for clarity and to separate it from the ignorance of structural issues. In contrast, 'sustainability', despite its reputation as a buzzword, carries less historical baggage, and its context-specific nature

[8] Glavič, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. Journal of cleaner production, 15(18), 1875-1885.
[9] Cooley. Timothy. (2019). Cultural Sustainabilities : Music, Media, Language, Advocacy. *University of Illinois Press*., p. 186

invites asking questions and examining assumptions.[10]

There are several models depicting sustainability, but the most widely used one is 'The three-pillar model of sustainability', which is a widely accepted concept and includes both social, economic and environmental dimensions. It is often depicted as three intersecting circles representing society, environment, and economy, with 'sustainability' being in their meeting point in the middle. Other depictions show them three literal pillars or as three circles encompassing each other.

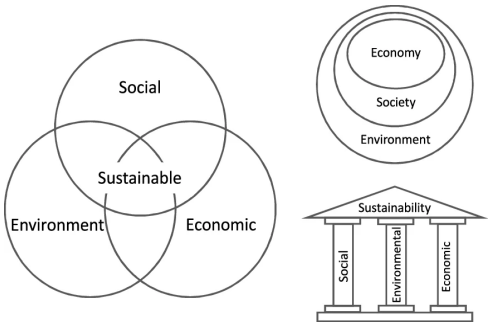

Figure 1: Three ways of depicting sustainability graphically. Figure retrieved from Purvis et al.[11] The left-most figure shows the three parts as interconnected venn-diagrams, the bottom-right figure shows it as actual pillars holding up sustainability, and the top-right figure shows the parts as circles encompassing each other.

Some researchers, such as Francesca Sabatini, advocate for cultural sustainability as a fourth pillar of sustainable development. She argues that the cultural aspects of human communities are unable to be entirely covered under other value systems, such as the social or economic pillars. Hence, cultural sustainable development is the only concept capable of covering all parts of culture and its complex interactions with the social, economic and environmental dimensions. Culture has often been devalued to a utilitarian role with respect to other sustainability pillars. In the context of culture, we can presume that a 'utilitarian role' implies that culture is perceived mainly as a tool to accomplish other objectives within the social, economic or environmental dimensions. In this perspective, the value and significance of culture, such as its artistic and symbolic aspects, are often overlooked or downplayed in favour of its practical contributions to achieving sustainable development goals.[12] This falls in line with previous research within the field of ecomusicology. This is something we will look more closely at later in the thesis and implies not only considering music and other cultural expressions as tools for promoting sustainability but also examining how these practices contribute to the social, economic, environmental—and cultural—aspects of a sustainable society.

Aaron Allen has also written about the term sustainability, in particular in his work *Sounding Sustainable; or, The Challenge of Sustainability*. Here he addresses that the challenges of sustainability involve physical, natural and social sciences, as well as arts and humanities. Music and sound studies can contribute to sustainability by advocating for ethically informed and aesthetically valuable music, sounds, and ways of living. However, it is essential to differentiate between sustaining cultural practices that are

[10] Purvis, B., Mao, Y., & Robinson, D. (2018). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5 .
[11] Purvis et al. (2019)
[12] Sabatini, F. (2019). Culture as fourth pillar of sustainable development: Perspectives for integration, paradigms of action. European Journal of Sustainable Development, 8(3), 31. https://doi.org/10.14207/ejsd.2019.v8n3p31, p. 39

beneficial versus those that harm the environment or perpetuate social injustices. To expand the idea of sustainability in music and sound studies, he argues for four interconnected aspects that should be considered: 1) embracing the change-oriented meaning of sustainability, 2) recognizing the foundational role of the environment, 3) viewing sustainability as a framework or lens and 4) incorporating aesthetics into sustainability discussions. By doing so, scholars can better understand and address the ethical implications of valuing certain sounds and cultural actions.[13]

1.1.2 Sustainability in this thesis

Though varying viewpoints on sustainability continue to exist, a general agreement on the meaning is forming. Identifying what is sustainable and what is not is important for understanding the concept, and having clear distinctions can help reduce uncertainties. In our case, focusing on deforestation, basing such parameters upon data from CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and the IUCN Red List of Threatened Species can be a good place to start. We can assume that if a species has been put under trade restrictions on the CITES list or falls within the 'Threatened' category of the IUCN Red List (as illustrated below), using them for the production of musical instruments does not meet the needs of the present without compromising the ability of future generations to meet their own needs, as the species survival can be substantially harmed by such production.

CITES is a treaty that regulates international trade in certain species of wild animals and plants to ensure their survival. It was signed in 1973 and now has 183 member countries. The species protected under CITES are listed in three appendices, with varying degrees of protection depending on their conservation status. The parameters it is based upon include: the species' biological status, trade volume, and the impact of trade on their survival. The species listed in Appendices I, II, and III have varying degrees of regulation and monitoring.[14] Appendix I has species threatened with extinction. Trade of these species is permitted only in exceptional circumstances. Species in Appendix II are not necessarily threatened, but the trade must be controlled to avoid utilisation which can influence their survival. Appendix III species are protected in at least one country.

The IUCN Red List of Threatened Species is a system for evaluating the extinction risk of species worldwide. It is maintained by the International Union for Conservation of Nature (IUCN). The list categorises species into nine threat categories, ranging from "Least Concern" to "Extinct." The parameters the IUCN Red List is based upon include: species distribution and abundance, population size and trends, as well as threats to the species and its habitat. The IUCN Red List provides information on the global conservation status of species and is used as a basis for policy and action to conserve biodiversity and ecosystem services.[15]

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[13] Allen, Aaron. (2019). Sounding Sustainable; or, The Challenge of Sustainability. In *Cultural Sustainabilities: Music, Media, Language, Advocacy*, edited by Timothy J. Cooley, p, 43-46. Urbana-Champaign: University of Illinois Press.

[14] What is CITES? CITES. (n.d.). Retrieved January 29, 2023, from https://cites.org/eng/disc/what.php

[15] *The IUCN red list of threatened species*. (n.d.). IUCN Red List of Threatened Species. Retrieved June 9th, 2023, from https://www.iucnredlist.org/about/background-history

Figure 2: The IUCN Red List of Threatened Species, running from 'Least concern" (right) to 'Extinct' (left). In addition to these seven levels, there are also 'Data deficient' and 'Not evaluated' categories.[16]

Material waste

In the context of forestry, wood consumption and luthiery, material waste refers to the parts of the wood that are discarded during harvesting, processing, transportation, and consumption. This waste can result from a variety of factors and vary depending on how widely we define the process. It can encompass factors such as imperfections in the tree, problems during the cutting process, or inefficient utilisation of the tree. Moving down to the art of constructing the instrument itself, the amount of material waste produced in luthiery can vary depending on the type of wood used, the tools and techniques employed, and the design of the instrument. Material waste in the production of musical instruments can include small off-cuts, irregularly shaped pieces, and parts of the wood that do not meet the desired specifications—which, in some cases, can be the whole tree. We have already established that luthiers are specific in their choice of materials as well as specific trees of a species.

When detailing material waste in wood, it is important to establish what waste actually means. Not all of the waste generated from trees can be considered "waste". Some of it can be used for chip wood, firewood, or other purposes after its intended lifespan. It is also important to consider that the amount of waste generated during the processing can be significant. For example, sawmills often produce sawdust, chips, and slabs as waste products, which can then be used for fuel or other purposes. Should these be counted? Furthermore, wood can, depending on its treatment, last anywhere from years to decades. How long should its lifespan be before it is considered to be wasted? Such considerations can seem unnecessarily detailed. Sustainability must hence be seen in its context of use rather than comparing one thing with a separate one. Wood wastes are often divided into two categories: industrial waste from within the foresting industry, and final wastes, which come after the use of the products. The majority of the first category is seen as by-products and is not legally defined as waste. Waste can, according to a European directive, be defined as "any substance or object which the holder discards or intends or is required to discard".[17] Because sawdust, chips, and slabs often are used for other purposes, these should not be considered as waste.

Despite numerous studies on material waste in various industries, few to none have focused on the production of musical instruments. This knowledge gap makes it difficult to access the production, as it involves the use of a wide range of materials, such as endangered species of wood, metal and plastics. Such research can help identify

[16] File:Status iucn2.3.svg. (2022, May 29). Wikimedia Commons, the free media repository. Retrieved January 29th, 2023 from https://commons.wikimedia.org/w/index.php?title=File:Status_iucn2.3.svg&oldid=659707639

[17] Besserer, A., Troilo, S., Girods, P., Rogaume, Y., & Brosse, N. (2021). Cascading recycling of wood waste: A review. *Polymers*, *13*(11), 1752. https://doi.org/10.3390/polym13111752

ways to reduce the amount of waste generated during the production process and promote more sustainable practices. Furthermore, it can also help manufacturers and consumers make informed decisions on the materials used in the production of musical instruments and their potential impact on the environment. Increasing awareness about the potential environmental impact of using these materials in the manufacturing process, as well as the material waste in instrument production, can help drive changes in the industry.

Criteria

In concussion, we can base the term sustainability upon the following criteria, covering at least one of them:

> **Criterion 1:**
> The species of wood used in the production process is not listed in Appendix I or Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora).
>
> **Criterion 2:**
> The species of wood used in the production process is not listed within the 'Threatened' category of classifications in the IUCN Red List of Threatened Species.

The IUCN Red List and CITES list are, as we have detailed, both global conservation tools aimed at protecting endangered species. The Red List provides a comprehensive classification system of the conservation status of species, while CITES provides an international agreement that regulates the trade of those endangered species. Both lists are used by governments, decision-makers and scientists to guide conservation efforts. They may not include all endangered species, as there may be insufficient data on their status. Furthermore, CITES regulations can sometimes be difficult to enforce, and illegal trade remains a significant threat to their survival—which, as is examined in this thesis, can be the case in string instrument production. We can also assume that there may also be differences in data availability due to cultural or political factors, such as conflicts.

Policy interventions and incentives can play a significant role in promoting sustainable practices in the production. By analysing existing policies and regulations, as well as exploring potential new policy initiatives or incentives, researchers can contribute to the development of a policy framework that encourages more sustainable instrument production without stifling cultural heritage.

Criterion 3:
Measures that limit the material waste from the production process are implemented.

For criterion 3, it is difficult to provide a specific percentage that would universally apply to all wood production. The ideal percentage would depend on the type of wood, the manufacturing process and our specific industry. However, a general guideline would be to minimise waste as much as possible while maintaining efficient production. There are three types of wood waste: (1) untreated timber waste, (2) engineered wood waste and (3) preservative-treated or painted wood waste.

In order to not over-generalize this criterion, some methods can be used in assessing the management of material waste and excess materials. These methods can help identify suitable waste reduction techniques, recycling practices and sustainable sourcing methods. By incorporating such methods, luthiers can effectively minimise waste, maximise resource efficiency and contribute to a more environmentally responsible approach within their craft. There are already established methods in place for other industries to base this upon, such as Dalalah et als. article on an integrated framework for the assessment of environmental sustainability, which is aimed at wood waste in the construction industry.

Waste management	When addressing waste management within the luthier industry, we can consider how waste products resulting from musical instruments are treated, whether through recycling or disposal. The production processes generate many material wastes. Although less so than in comparison to other sectors, some of these can negatively impact the environment, particularly when using oils, adhesives and wood preservatives for instruments. Common waste byproducts in the luthier industry include wood offcuts, sawdust, shavings, veneer scraps and excess adhesive/oil materials.
Reuse of products	Repurposing discarded materials promotes sustainable manufacturing and recycling. Waste wood or previously used wood products from instruments can be transformed into valuable raw materials for alternative applications, both in and outside the industry. Implementing such strategies within the luthier industry not only reduces waste but also contributes to a more environmentally responsible and sustainable approach to crafting stringed instruments.
Environmentally friendly materials	This involves using environmentally friendly materials in the instrument production. Examples include the use of sustainable alternatives to endangered species as well as non-synthetic or less harmful oils and adhesives.

Table 1: This table is an adaptation of three criteria from Dalalah et als. article on an integrated framework for the assessment of environmental sustainability.[18] These criteria guide the evaluation of environmental sustainability within the luthier industry, addressing waste management, reuse of products and the use of environmentally friendly materials. By considering these aspects, luthiers can work towards more sustainable practices, reducing waste generation, promoting resource efficiency and minimising the environmental harm.

[18] Dalalah, D., Khan, S. A., Al-Ashram, Y., Albeetar, S., Ali, Y. A., & Alkhouli, E. (2022). An integrated framework for the assessment of environmental sustainability in wood supply chains. *Environmental Technology & Innovation*, *27*, 102429. https://doi.org/10.1016/j.eti.2022.102429

The twelve sustainability goals do cover not only environmental and natural phenomena but also social structures through the degradation of ecosystem services and unequal power structures in local societies.[19] A fourth criterion encompassing a social factor can hence be beneficial for including the impacts of deforestation not quantifiable in the context of deforestation. However, it is important to note such social factors are inherently a part of the already established criteria and will or can be caused by one or more of them being fulfilled.

Criterion 4:
Deforestation in a specific area or region does not cause the loss of ecosystem services.

This criterion assesses the degradation of ecosystem services that local communities depend on for their livelihoods, respecting the rights and interests of indigenous and other marginalised groups, as well as promoting the inclusion of local workers in the production process. Ecosystem services refer to the benefits that people derive from ecosystems, as such, the nature we surround ourselves with. These benefits can be direct, such as food, fibre, fuel, materials and water, or indirect, such as fresh air, water filtration, pollination, climate regulation, the hosting of endangered species and recreational activities. Ecosystem services can also be cultural, such as hosting spiritual or aesthetic values. These services are an important part of human well-being and the functioning of societies, economies and cultures. The concept of ecosystem services helps us to understand the value of nature and the importance of protecting and restoring ecosystems.[20] While deforestation, as such, is a part of the ecosystem services human societies use, ensuring that future generations can utilise the same services is, as we have explored, a key part of acting sustainably in finding materials. In Criterion 4, it is specified that it excludes the service of hosting endangered species, and hence this criterion implies services not related to hosting specific wood but to the direct and indirect and direct benefits mentioned above.

Lastly, taking cultural sustainability into account will also be a focus point in this thesis. This would be a natural component when discussing inherently cultural subjects, which musical instruments undoubtedly are. Understanding the role of Sabatini's proposed cultural sustainability in the context of music production is crucial, as it emphasises the preservation and promotion of cultural diversity, heritage and traditions. The cultural aspects of human communities, as we have detailed, are unable to be entirely covered under other value systems. Musical instruments are an essential part of various cultural expressions and have a significant impact on the identities and histories of communities worldwide. With that, we encounter an issue regarding the value of such cultures, which is something we will be detailed in the following chapter. One of the challenges in preserving cultural heritage lies in the tension between tradition and the modern world. As the music industry evolves, incorporating new materials and technologies, it is vital to strike a balance between adopting innovative practices and preserving the unique attributes that make traditional instruments culturally valuable.

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[19] United Nations. (n.d.). The 17 goals | sustainable development. United Nations. Retrieved March 17, 2023, from https://sdgs.un.org/goals
[20] Myhre, Trude. (2023). økosystemtjeneste. *Store norske leksikon*. Retrived March 12th, 2023 from https://snl.no/%C3%B8kosystemtjeneste

1.1.3 Placing a value on nature and culture

Evaluating the loss of ecosystem services is a complex task, and we can see a clear development in recent years Costanza et al.'s article on the subject from 1998 summarises the issue they had in that time with opening line: "How do we develop meaningful indicators of ecosystem services when we have no markets for them?" as well as with the question of if we at all should place a value on ecosystem services.[21] The growth of the world and markets in general has however made demands for scientists to verify the value of these services, for instance, in large infrastructure projects such as roads. Morgan M. Robertson's more recent study from 2006 analyses today's methods of assessing the value of such services. Placing a value on ecosystems poses challenges due to their complex and interconnected nature, as well as the difficulties of quantifying ecosystem services and nature in general, which is, however, still a concern. The phrase "units of ecosystem function" might not have a clear meaning yet, as pointed out by the study,[22] but it highlights the need to develop an understanding of the value of ecosystem services. It is also important to note that science is an evolving field and that collaboration between policy-makers, scientists and economists could form methods for determining the values that are more reliable in the future—which ultimately benefit both entrepreneurs and the environment. Morgan highlights issues with an often used method of evaluation and proposes additions to improve upon it.

Robertson also highlights that the techniques used to evaluate commodities in ecosystem service markets have not yet reached the level of stability found in most markets. Unlike selling more 'common' things, such as bread, the sale of ecosystem services requires information that scientists cannot provide in a universally accepted way. Robertson hence questions whether scientists will ever be able to provide such information without disrupting the mechanics of the market. He also raises questions on the mismatch in agenda between scientists and economists/ politicians—that relying on noneconomic information in economics creates a sort of paradox. While scientists may view the increase of ecological distinctions as destabilising, capitalists see it as an opportunity to multiply the value of their assets. This mismatch raises questions about the compatibility and long-term sustainability of the collaboration between science and capital in the commodification of ecosystems. He points out that scientists and regulators may be tempted to produce 'erroneous' scientific data to support the commodification of ecosystem services.[23] Robertson's insights on the evaluation of ecosystem service commodities have relevance in the production of musical instruments. The evaluation of ecosystem services, like the preservation of forests for sustainable timber sourcing, presents challenges in terms of obtaining universally accepted scientific information. This raises questions about the stability and reliability of metrics used to assess the environmental impact of the production of musical instruments. It emphasises the need for interdisciplinary collaboration and dialogue among stakeholders—and interdisciplinarity is something we are now actively working on with this thesis—involved in the production and trade of musical instruments. Achieving a sustainable approach to the making of musical instruments requires that we address

[21] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., van den Belt, M. (1998). The value of ecosystem services: Putting the issues in perspective. *Ecological Economics*, 25(1), 67–72. https://doi.org/10.1016/s0921-8009(98)00019-6.

[22] Robertson, M. M. (2006). The Nature That Capital Can See: Science, State, and Market in the Commodification of Ecosystem Services. Environment and Planning. D, Society & Space. p. 367

[23] Robertson 2006, p. 383

these challenges so that scientific knowledge, economic considerations, environmental preservation and luthiers 'harmoniously' align to mitigate deforestation and promote long-term sustainability in the violin family instrument industry.

We will not be detailing this much more in this thesis, but being aware of these issues is important when assessing sustainability in any field. Does the worth of a cello or violin justify using endangered species such as ebony? And how do we compare cultural values with those derived from ecosystems? From a cultural standpoint, the use of materials like ebony is often seen as essential for creating instruments that produce superior sound and are more enjoyable to play—at least from a traditional point of view, as some studies suggest that this is not always true. We can assume that the traditions in luthiering and the value placed on the sonic qualities of the instruments are points that contribute to their cultural significance. On the other hand, from the ecological perspective, the importance of preserving endangered species and maintaining biodiversity comes into play. The use of such materials in the production can contribute to habitat loss, deforestation and the decline of the population of the species, which ultimately disrupts ecosystem services. Comparing cultural values and ecosystem-derived values is inherently difficult, as these values are often not directly comparable and may be perceived differently by various stakeholders. While it may be challenging to compare these values, looking at sustainable alternatives and responsible practices for sourcing wood can help preserve both the cultural values and the health of ecosystems. David Throsby is among the researchers that have tried to debate the process of determining the value of cultural goods. In this article *Determining the Value of Cultural Goods: How Much (or How Little) Does Contingent Valuation Tell Us?* Throsby proposes two different ways of placing value on culture. The first (a) is an individual value. In this case, the value of cultural goods is recognized by the individual, and the individual's willingness to pay (WTP) reflects the total value. If a person is unwilling to pay for the benefit enjoyed by others, these others can still express their WTP on their own behalf. Therefore, the value is eventually considered in any assessment of demand for the cultural good. Another way is by determining a collective value (b). In these cases, the value does not reflect individuals but rather groups, such as a society or humankind. This value category is unique to cultural goods because it derives from the nature of culture and art. Culture can be defined as the set of beliefs, traditions, and customs that identify a group and bind its members together, while art serves as a particular manifestation of these shared experiences, expressing aspects of the human condition as interpreted by artists. Therefore, the value of cultural goods discussed here is identified in relation to the group, rather than the isolated characteristics of individuals. Throsby highlights that this type of value is not going to be captured by expressions of individual WTP, indicating a challenge in quantifying the collective value of cultural goods.[24] Thorsby also discusses the distinction between economic and cultural value. The economic value consists of direct use values, as in what you pay for the cultural good, while cultural value is, in his words, "multi-dimensional, unstable and contested", reflecting attributes like aesthetic properties, spiritual significance, historical importance and authenticity. These attributes are also considered in the economic valuation.[25]

[24] Throsby, D. (2003.). Determining the value of cultural goods: How much (or how little) does contingent valuation tell us? *Journal of Cultural Economics*, 27(3), 275–285. https://doi.org/10.1023/A:1026353905772, p. 278–279

[25] Throsby 2003, p. 279-280

Similar themes have been studied within music. In Rebecca Dirksens article *Haiti's Drums and Trees: Facing Loss of the Sacred* she explores the central role of the tanbou (drums) in the Haitian experience, which are seen as providing necessary access to spiritual forces. However, the trees from which these instruments are crafted are being severely threatened by deforestation and climate change. The author uses the life story of Charles Charlesine, an octogenarian drummaker, to explore how environmental changes are causing shifts that irrevocably alter this form of cultural heritage, which is viewed as crucial to Haitian society. The study poses the question of how Haitians are confronting the apparent loss of the sacred, particularly in relation to the tanbou and trees.[26]

Whether we are dealing with an impact assessment or economic valuation, such an evaluation or analysis would be beneficial in a more extensive and detailed sustainability assessment, although not carried out in this thesis due to its interdisciplinary dependencies. Criterion 4 recognizes that the sustainability of musical instrument production is not only about environmental impacts but also social impacts, including the unequal power structures and negative social consequences that can arise from the degradation of ecosystem services. By prioritising social equity in the production process, this criterion ensures that the benefits of musical instrument production are shared fairly among all stakeholders and that the production process respects and enhances local social structures. It also acknowledges that social impacts can arise from the fulfilment of other sustainability criteria and should be considered in the sustainability assessment or life-cycle analysis. It is important to create a multidisciplinary approach that involves the expertise of ecologists, cultural experts such as musicologists, economists and policymakers. By involving different fields, it may be possible to develop methods for assessing and comparing the cultural and environmental values, allowing for a more informed decision-making process. By prioritising social equity in the production process, the benefits of producing musical instruments of any type can be shared fairly among all stakeholders, while also respecting local social structures.

Kevin Dawe has touched upon the subject in his article *The Cultural Study of Musical Instruments*. He argues that music and culture are intrinsically intertwined, and musical instruments play a significant role in constructing and maintaining cultural and social identity. These instruments are embodiments of culturally-based belief and value systems and serve as potent social and cultural phenomena. They turn from just being "things" into meaningful aspects of individual and collective musical worlds, developing a "social life" and acquiring power, agency and cultural memory. Musical instruments evolve and emerge as part of ongoing convergences of developments in music, culture, design and technology. The study of musical instruments today should take into consideration the relationship between music, culture and technology. This complex, intense, and interacting network challenges the senses, extending both the human body and mind. The traditional boundaries separating musical instruments from other objects, technologies and academic disciplines must be questioned, Dawe argues.[27] Dawe's argument highlights the significance of musical instruments in shaping cultural identity,

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[26] Dirksen, R. (2019). Haiti's Drums and Trees: Facing Loss of the Sacred. *Ethnomusicology*, 63(1), 43–77. https://doi.org/10.5406/ethnomusicology.63.1.0043

[27] Dawe, Kevin. (2012). The Cultural Study of Musical Instruments. in *The Cultural Study of Music: A Critical Introduction*, edited by Martin Clayton, Trevor Herbert, and Richard Middleton, p. 195-197

but it is important to note that the study of musical instruments should not neglect their materiality. The physical characteristics of instruments, such as their materials and construction, can have a significant impact on the sound they produce and their cultural significance. Furthermore, while the relationship between music, culture and technology is undoubtedly complex and interdependent, it is essential to recognize the potential power dynamics at play in the evolution of musical instruments. Power dynamics may be something we are more familiar with when in the field of ethnomusicology, but it is relevant for our case too. For example, the historical development of musical instruments such as the piano or violin is closely tied to European and Western cultural traditions and has been dominated by white, male composers and performers. This dominance has resulted in the marginalisation of other musical traditions and cultures that have different instrument designs and playing techniques. We can assume that this can have an effect on what we perceive as 'good' and 'bad' materials in the construction of such instruments. By seeing the power dynamics in musical instruments, we can critically examine how cultural and societal values influence the development of instruments and challenge existing power structures that may perpetuate inequality and exclusion in the musical world.

1.2 Methodology

This section of the paper addresses the research methodology used in the theoretical materials outlined later in the thesis while exploring possible biases and paradigms they can bring. The first part will detail the quantitative approach and methodology aspects in general, followed by a more detailed outline of the social life-cycle analysis (S-LCA) approach developed by Aaron Allen, which will then be debated and adjusted. This section will also outline some previous research on ecological and sustainability perspectives in the research on musical instruments. With limited literature available on this specific subject, the thesis draws upon research from various fields, including fields not typically interdisciplinary with musicology and/or ecomusicology. The methodology employed in this research combines quantitative and qualitative approaches, analysing existing data and research to form conclusions on the sustainability of musical instruments. In particular, the research investigates the sustainability challenges unique to the violin family of instruments, with a focus on the environmental implications of wood production, specifically endangered species such as ebony. By adopting a sustainability assessment approach centred on deforestation, this thesis aims to provide a more comprehensive understanding of the environmental impacts associated with the production of string instruments and identify strategies to reduce the negative impact of this particular industry.

One of the main challenges faced in writing the thesis was as outlined the lack of established literature. Although extensive research has been carried out on climate change, sustainability and music as separate areas, and in some cases joined, only some writers have been able to draw on any systematic research into musical instruments' impact on the environment and/or in a sustainability-centred approach. Research on the subject has been mostly restricted to limited comparisons of music as a tool to promote an understanding of climate, in studying how music festivals can better adjust to compensate for their carbon footprint or in qualitative studies of how the industry and consumers view the matter.[28] A limitation of research materials, both scientific and informal, prompts the need to tap into other fields to fulfil the research goals. Due to the

[28] Brennan 2021, p. 117

limitations of what the field of musicology traditionally brings of materials in maths and STEM, as well as the scope constraints of the thesis, the research from these fields builds upon already established data instead of making new calculations.

There has, however, been some relevant research carried out by pioneers in the field. We briefly touched Devine's research in our introduction. In his book *Decomposed: The Political Ecology of Music*Kyle Devine examines the materiality of recorded music and its impact on the environment. He takes a closer look at the history and production processes of various recording formats, such as vinyl records, cassette tapes and CDs, to uncover the environmental consequences and ecological costs associated with the creation, distribution and disposal of them.

Method	**Description**
Life Cycle assessment	Examines the entire lifecycle of a product, from raw material extraction to manufacturing, transportation, use, and disposal. This approach allows Devine to quantify the ecological footprint of vinyl and CD records. Takes into account the entire lifespan of music formats, from raw material extraction and processing to manufacturing, distribution, consumption, and eventual disposal or recycling, to understand the cumulative environmental impact.
Historical analysis	Provides context for the environmental impacts of music production by studying the development of the music industry over time. Devine explores how technological advancements, changes in consumer preferences and economic factors have influenced the industry's ecological footprint (for instance, the move from vinyl to CD and, at last, data).
Case Studies	Present specific instances or examples of environmental issues related to music production and consumption to illustrate broader themes and arguments.
Comparative analysis	Compares the environmental impact of physical music formats with that of digital streaming services, examining energy consumption, carbon emissions and waste generation.
Interviews and anecdotal evidence	Supplements research with interviews and anecdotal evidence from industry professionals, musicians, and consumers, offering insights into attitudes, practices, and experiences related to music consumption and its environmental implications.

Table 2: A brief overview of the different methods and their descriptions, which was found in Kyle Devine's book *Decomposed: The Political Ecology of Music*. Sourced from the book.[29]

Devine's methods have both strengths and weaknesses. On one side, the use of lifecycle analysis provides a comprehensive view of the ecological footprint of vinyl and CD records, taking into account the entire life cycle of these products and the flow of materials through various stages of production, consumption and disposal. This is also relevant for the type of materials these are made of—typically plastic. These methods are also helpful in identifying inefficiencies and waste generation points, which can help

[29] Devine 2019

guide the industry towards more sustainable practices. The fact that Devine uses historical data adds context to the discussion and allows the reader to understand how the industry's ecological footprint has evolved over time—due to things such as technological advancements, preferences in consumers and economic factors. On the other hand, methods such as case studies and interviews may be subject to biases and may not necessarily represent the industry as a whole, despite the fact that they can be helpful in providing examples and insights from industry stakeholders. There is a risk of picking case studies or interviewees that align with Devine's perspective or argument, potentially skewing the analysis. Furthermore, the reliance on industry reports and data can be problematic if these sources are not transparent, accurate or up-to-date. Despite these concerns, Devine's multi-factor approach to assessing the environmental consequences and ecological costs of music production offers a valuable contribution to the discourse on the music industry's sustainability and the need for more responsible practices.

Another central piece of research in the field of ecoorganology, is Aaron Allens yet unpublished article on *Ecoörganology: Toward the Ecological Study of Musical Instruments on Earth* (title may not be the same for the final published article). He phrases ecoorganology as being a parallel study of musical instruments using a framework that emphasises environmental impacts along with social and aesthetic matters. Whether formal, informal, systematic, critical, new, old, named or even unnamed, organology exists where there are musical instruments. He proposes the use of a Life cycle assessment to analyse musical instruments, in his example music medium—portable music players (such as MP3-players). Although musicologists may not be life cycle scientists, he argues that adopting an LCA approach for ecoorganology can be achieved through collaboration with scientists or working with existing data and analyses. Even just employing a basic abstract framework can help connect social and musical worlds with resources and sustainability, as well as distant people and landscapes that are not immediately implicated in traditional music culture studies.[30] Allen also explores ecoorganology through an ecocritical lens, and proposes that this can be a more flexible alternative to Life Cycle Assessment (LCA) for analysing environmental concerns and artistic practices. Allen adopts a four-part sustainability framework that includes esthetics, environment, equity, and economy, extending the typical three-E approach. This framework is used for heuristic purposes rather than as a goal to be achieved, and each part is guided by an ethical question. Allen's intention is not to judge LCA and sustainability against each other, but to acknowledge their utility in different situations and emphasise the importance of an environmental humanities approach in examining culture.[31]

While Aaron Allen's ecoorganology research presents the Life Cycle Assessment (LCA) and ecocritical lens as two potential methods for assessing the sustainability of musical instruments, neither may be optimal for evaluating the sustainability of the violin family. This is because both approaches might make too general results, and the core issue lies primarily in the wood production part, especially regarding ebony—as we have and will establish further upon in this thesis. Allen's LCA approach, though effective in analysing environmental impacts and resource usage for many instruments, may not provide the specific insights needed to address the unique sustainability challenges of the violin family. Similarly, the ecocritical lens, with its four-part sustainability framework, may not focus sufficiently on the particular concerns related to wood

[30] Allen (2023, unpublished), p. 6-7
[31] Allen (2023, unpublished), p. 12-13

production and the use of ebony in these instruments. For a more targeted assessment of the sustainability of musical instruments in the violin family, it may be necessary to develop a specialised method that specifically investigates the wood production process, the use of ebony, and the related environmental and social impacts. Such a tailored approach could offer more actionable insights and better inform sustainable practices within the industry. A more specialised approach to assessing the sustainability of musical instruments in the violin family will be elucidated later in this thesis. This methodology aims to address the unique challenges associated with wood production, specifically endangered species of wood such as ebony, and maybe provide actionable insights to inform sustainable practices within the industry.

Aaron Allen has made other works where these concerns are somewhat addressed. In this work *Fatto Di Fiemme': Stradivari's Violins and the Musical Trees of the Paneveggio* he addresses the use of specific types of wood from a specific region—and its potential effect on the local environment. The Val di Fiemme, part of the Parco Naturale Paneveggio in Italy, has been providing resonance wood for constructing quality musical instruments for centuries due to its unique microclimate. This region is closely tied to the city of Cremona, home to renowned luthiers such as Antonio Stradivari. The Val di Fiemme's unique microclimate produces the ideal resonance wood, but only a small percentage of harvested trees yield a trunk with true resonance wood. He also discusses the myth-orientated part of wood quality. The renowned luthier Antonio Stradivari contributed to the development of the ideal violin sound, perfecting the measurements and proportions of the instrument. However, Stradivari's fame has generated a myth that has driven up the value of his instruments, with a focus on the secret to his craftsmanship. Much of the value of a Stradivari violin lies in its life history, the combination of ecological and cultural factors that create value throughout the entire process, from instrument to music to craft to forest—not necessarily the material or sonic qualities of the instrument itself. Nevertheless, it does create a myth-culture surrounding what is and should be best. While Aaron Allen does address the myth-oriented culture, he may fall into it himself on some instances through the romanticization of Paneveggio forest. While the Paneveggio forest has a significant place in the history of violin-making, the text tends to romanticise its importance, especially in relation to Stradivari. It is essential to recognize that other sources of wood and forests have also contributed to the craft, and the Paneveggio forest should not be overly glorified. The text does, furthermore, as we have explored, touch upon the cultural values and myths surrounding Stradivari's instruments and their impact on sustainable practices in the Paneveggio forest. However, a more in-depth exploration of the cultural factors, such as how the demand for high-quality instruments has shaped the industry and influenced environmental practices, could provide a more comprehensive understanding of the subject. The comparison between the Paneveggio forest and the Mata Atlântica in Brazil[32] is interesting, but it can give the impression of oversimplifying complex ecological and social issues. The factors contributing to deforestation and conservation in different regions are diverse and unique, and generalising these issues may not accurately represent the challenges faced by each forest.

It is, however, important to note that ecoorganology is only a new subfield within the already established field of ecomusicology. In addition to the aforementioned researchers, many others have detailed this field. One of them is Jeff Todd Titon, who in his article The Nature of Ecomusicology details the field as a field that studies the relationships between music, culture and nature. Titon highlights two main ways that

[32] Allen 2012, p. 30

ecomusicologists approach the subject: music as a representation of nature and music interacting with nature. Ecomusicology originated from literary ecocriticism and started with a focus on the composer's treatment of nature.[33] While Titon's discussion of ecomusicology provides valuable insights into the field, it can be argued that his analysis presents a somewhat narrow view of sustainability in music. In particular, his two ways of examining ecomusicology—focusing on music as a representation of nature and music as interacting with nature—do not fully capture the actual impact of music on the environment and sustainability. It does, for instance, overlook the music industry's resource consumption and waste production: The creation, distribution, and consumption of music, both physical (such as CDs, vinyls and instruments) and digital (such as streaming, and downloading), involve the use of natural resources and generate waste. This aspect of sustainability in music is not fully explored in Titon's two ways of approaching ecomusicology. Furthermore, it neglects the carbon footprint of live performances and touring. Live performances and touring by musicians, bands and orchestras contribute to greenhouse gas emissions through transportation, energy consumption at venues, and waste generation. Titon's framework does not address the environmental impact of these activities. While Titon's analysis of ecomusicology offers valuable insights, it may be considered too narrow because it does not fully address the actual environmental impact of music and its potential to contribute to sustainability in various ways. A more comprehensive approach to ecomusicology would explore the multifaceted connections between music, the environment, and sustainability beyond representation and interaction.

Another researcher, Chris Gibson, also argues for that existing analyses of the relationship between music and the environment are insufficient in addressing the ecological crisis. He argues that musicians are inspired by environmental concerns and entangled in the crisis through their material and embodied relations with ecosystems, primarily through their musical instruments. The author foregrounds three themes: materiality, corporeality, and volatility, to make sense of the unfurling forces in the relationship between music and the environment.[34] This is, however, also the point at which Gibson also falls into the same roads as many other researchers in the field. An argument against the idea that Gibson's discussion, especially regarding corporeality, is that it is too 'alternative'. Such language can alienate or confuse readers unfamiliar with it, making it difficult to communicate important information and ideas. Additionally, relying too heavily on these concepts can sometimes obscure or oversimplify the complexity of the issues at hand, leading to less nuanced analyses and potentially flawed conclusions. Therefore, scholars need to find a balance between using accessible language and concepts while still maintaining accuracy in their work. On the other hand, the physicality of playing a musical instrument, the sensation of the materials in one's hands and the sound vibrations through the body are all crucial to the experience of creating and performing music. Ignoring or downplaying these aspects of music-making would be neglecting an essential part of the art form. In the context of assessing sustainability, these aspects are, however, not too relevant.

[33] Titon, Jeff Todd. (2021). The nature of ecomusicology. *Música e Cultura: revista da ABET*, vol. 8, n. 1, p. 8

[34] Gibson, C. (2019). A sound track to ecological crisis: tracing guitars all the way back to the tree – ERRATUM. *Popular Music*, 38(3), 588–588. https://doi.org/10.1017/S0261143019000217

1.2.1 Methodology in this thesis

This thesis generally builds upon a quantitative approach, analysing data and existing research to form a conclusion to the problem for discussion. One potential problem with quantitative research is that it often relies on statistical techniques to analyse data, and these techniques can be complex and challenging to understand. This can make it difficult for people who are typically not trained in statistics, such as musicologists, to evaluate the validity of the results. Quantitative research is also commonly associated with the positivist paradigm. A paradigm is the underlying philosophical assumptions and beliefs that guide the research process. Positivism involves researchers finding a single reality that can be measured and understood; thus, it does not integrate human interest and dismiss that reality can differ.[35] Additionally, quantitative research often involves reducing complex phenomena to numerical data, which can be a simplification that does not accurately capture the full complexity of the studied phenomena. This can lead to results that are overly simplistic or that do not accurately reflect the reality of the situation. Such simplification can also be present when people who are not trained in this approach utilise statistical data and not accurately interpreting or using them in a manner that portrays them in a biassed or imprecise manner.
Despite its limitations, quantitative research has several important benefits in our context. These benefits include precision, objectivity, generalizability, replicability, and the ability to perform statistical analysis. These benefits have positive implications for the field of ecomusicology/ecoorganology—a new but growing discipline that still lacks standards and frameworks for conducting research:[36] [37]

1. **Precision**: Because quantitative research involves collecting and analysing numerical data, it can be very precise. This allows researchers to identify patterns and relationships with a high degree of accuracy. Another benefit is its effectiveness in providing an overview of the already established literature and research.[38] Concerning this thesis, this can, for example, be seen in narrowing down the type of wood and its deforestation numbers, as well as in comparing these to production numbers for the studied musical instrument.

[35] Sletnes, Kari. (2022): positivisme. *Store norske leksikon*. Retrieved December 8th, 2022 from https://snl.no/positivisme
[36] Grønmo, Sigmund. (2022): kvantitativ metode. *Store norske leksikon*. Retrieved December 8th, 2022 from https://snl.no/kvantitativ_metode
[37] Kaiser, Matthias. (2015). Kvantitativ metode. Retrieved December 8th, 2022 from https://www.forskningsetikk.no/ressurser/fbib/metoder/kvantitativ-metode/
[38] Tjora, Aksel Hagen. (2021). Kvalitative forskningsmetoder i praksis (4. utgave.). *Gyldendal*, p.35–38

2. **Objectivity**: Quantitative research is generally seen as more objective than qualitative research because it relies on numerical data rather than subjective Vinge observations or interpretations. Musicology and other humanities often deal with research where such considerations are necessary. Still, in this case, it would be beneficial to omit such an approach due to the analytical nature of the subject at hand in this thesis.
3. **Generalizability**: Because quantitative research often involves large samples, the results of a study can be generalised. This allows researchers to draw broader conclusions about the phenomena, which, when dealing with global ecosystems, deforestation and sustainability, is an appropriate approach. Nature sees no borders, and viewing data on a broader scale is hence a natural approach.
4. **Replicability**: The methods used in quantitative research are often standardised or easy to replicate, which makes it possible for other researchers to redo and verify the results. As musicologists typically do not have the required skills to create such methods, having standards and replicable methods to go by will ease the process of finalising the results.
5. **Statistical analysis**: Quantitative research often involves the use of statistical techniques, which can aid researchers in identifying trends and patterns in the data that may not be apparent to the naked eye due to their large scale. This can provide valuable insights into the numbers behind the data found and makes it easier to grasp the findings regarding deforestation and sustainability.

A large proportion of the studies handled in this thesis build upon quantitative approaches but are interpreted and compared. Hence, the interpretivism paradigm will also be relevant to some degree. Interpretivism is commonly associated with qualitative methods and considers the human element. Some materials used are based upon this approach, such as Vinje J. and Brennan.[39] [40]

Hence, establishing new approaches incorporating research from other fields is necessary. In doing so, careful considerations of what to include and how to use the data have been made to avoid misinterpretations. In particular, mathematical equations have been handled with care. Calculating environmental impact is a complex procedure and involves approaches not commonly learned in musicology. Although theoretical and analytical, such calculations are also skill-reliant. Perhaps the most notable disadvantage of this approach is that over-generalizing can promote misinterpretations. Using established data and calculations while referencing them has, on an empirical basis, in the context of this thesis, been identified as the best approach with the tools and skills at hand. Over-generalizing environmental impacts without specific expertise can lead to misleading information, which may cause poorly-informed decisions that could do more harm than good. To avoid this, relying on established data and methodologies, such as life-cycle assessments, carbon footprint calculations, assessments and other frameworks, provide a solid foundation for accurate evaluations. By citing established research and methodologies, a more reliable assessment of the sustainability impact can be made. This approach ensures that decision-makers, such as string instrument manufacturers and material suppliers, as well as consumers, have accurate and credible information to rely on.

[39] Vinge et al. (2022), p. 248
[40] Brennan (2021), p. 117

1.2.2 Sustainability assessment methodology

Sustainability assessment methodologies are important tools for evaluating the environmental, social and economic impacts of products and services throughout their life cycle. When examining sustainability in musical instruments, various assessment methods can be employed to evaluate the environmental and social impacts associated with their production, use and disposal. One commonly used approach is life-cycle assessment (LCA), which considers the environmental impacts of a product or service throughout its entire life cycle, from the extraction of raw materials to disposal. There are, however, other sustainability assessment methodologies that can be used to evaluate sustainability. Each approach has its strengths and weaknesses, and the choice of methodology will depend on the specific sustainability issues being addressed and the goals of the assessment. In this chapter, we will be detailing what previous researchers in the field of ecomusicology / ecoorganology have used, as well as what the focus will be on in this thesis.

The life-cycle assessment approach to ecoorganology research was introduced by Aaron Allen in his introductory, unpublished article for the field. Allen divides the field as a whole into two main paths: one derived from quantitative scientific approaches (life cycle analysis), the other more literary-analytical in its (sustainability-centred) methodology. Allen sections the S-LSA analysis (social life cycle analysis) into materials, production, consumption, and disposal.[41] Life Cycle Assessments (LCAs) are a group of methods used to evaluate the environmental impact of a product or service, from its raw material acquisition and production, consumption or use, and lastly, disposal. Such assessments are used to consider factors including resource consumption, emissions, and disposal concerns. The International Standards Organization (ISO) has established guidelines for LCAs through ISO 14040 and ISO 14044, which include four stages: outlining the intentions of the study, gathering data through a life-cycle inventory (LCI), evaluating the ecological, resource, and human-health consequences through a life-cycle impact assessment (LCIA), and interpreting the results. LCAs are, however, subject to criticisms such as inadequate boundaries, incomplete data sets, and lack of consideration for social factors. To address these criticisms, a subfield of social life cycle analysis (S-LCA) has emerged, which incorporates location-specific data, management approaches, as well as qualitative and semi-quantitative indicators to consider the social and socio-economic aspects of a product's life cycle and the perspectives of stakeholders such as workers, local communities, and future generations.[42]

Aaron Allen's introduction of the life-cycle assessment (LCA) approach has been influential in assessing various aspects of the music industry, including the environmental impacts of materials and processes involved in the production and consumption of musical instruments. While the LCA methodology provides valuable insights, focusing on a sustainability assessment with an emphasis on deforestation could yield more meaningful results, particularly when examining string instruments in the violin family, such as violins, violas, cellos, and basses. Life-cycle assessments provide a valuable framework for understanding the environmental impacts of various stages in a product's life, from raw material extraction to disposal. However, the LCA approach tends to be limited in scope and often excludes critical factors such as habitat destruction, biodiversity loss, degradation of ecosystem services and deforestation of endangered species, which are of particular concern for the violin family of instruments. This approach would hence provide a more comprehensive picture of the environmental

[41] Allen (2023, unpublished), p. 2
[42] Allen (2023, unpublished), p. 12-13

impact and help identify strategies to mitigate the negative impact of this particular industry than a more broad LCA would be able to do in our scope. By incorporating a sustainability assessment with a focus on deforestation, researchers can obtain a more comprehensive understanding of the environmental impacts associated with the production of string instruments. Examining the effects of deforestation on endangered and not yet endangered species of wood used in string instruments, such as Ebony and Rosewood, researchers can contribute to the development of more sustainable practices, inform international trade regulations, and lighten the ecological impacts associated with the manufacturing of these instruments.

Indicator	Description
Source of materials	- Percentage of sustainably sourced woods (ebony, spruce, maple) used in instrument production. - Use of certified woods from responsible forestry programs. - Minimising unused wood left on the forest floor.
Deforestation impact	- Rate of deforestation associated with the harvesting of wood. - Area of natural habitats impacted or lost due to deforestation.
Ecosystem services impact	- Loss of species and ecosystem services due to deforestation and habitat destruction.
Social and cultural impact	- Working conditions and fair labour practices within the supply chain, including harvesting, processing and manufacturing of the instruments. - Engagement with local communities and their involvement in decision-making processes related to resource management and instrument production.

Table 3: This table presents an overview of key sustainability indicators to evaluate the environmental, social and cultural impacts of wood sourcing in the production of musical instruments in the violin family of instruments. By using these indicators (and others), manufacturers, suppliers, and consumers can make informed decisions to minimise negative impacts and promote sustainable practices within the industry. The indicators are based on sources used in the above and below information in this thesis. These indicators are explained and expanded upon in chapter three of this thesis.

1.2.2 Data acquisition

In the course of conducting research for this thesis, I encountered challenges in acquiring data specifically related to ebony wood suppliers. I was unable to obtain comprehensive and reliable information on the supply chain, environmental impacts and socioeconomic aspects of ebony wood production and trade. This unavailability of data can be attributed to several factors, such as not contacting the correct information points, the lack of transparency in the supply chain and potential legal or regulatory constraints that hinder the disclosure of such data. Furthermore, ebony wood is a valuable and, in some cases, controversial material, which can lead to additional challenges in obtaining accurate and detailed information from suppliers. On several occasions, especially with global suppliers of musical instruments, I was refused to get

any sort of information regarding the suppliers or amounts of ebony due to ‘industry secrets’.[43]

Given these limitations, the primary focus of this thesis shifted to developing a framework for future research in ecoorganology and/or ecomusicology. The aim is to provide a comprehensive foundation that encompasses key aspects of ebony wood production, trade and environmental impacts, as well as potential ways for improving the sustainability and transparency of its supply chain. This framework is intended to enable future researchers to build upon this work and address the identified knowledge gaps, ultimately contributing to a more thorough understanding of the ebony wood industry and its implications for both the environment and communities involved in its trade. This research framework is designed to be adaptive and flexible, accommodating the dynamic and complex nature of the supply chains. It can be used to guide future investigations into the production and trade of musical instruments, including the evaluation of environmental sustainability practices, economic impacts and social equity issues. This thesis also advocates for increased collaboration among researchers, industry participants, and policymakers in order to facilitate access to relevant data and encourage a holistic approach to problem-solving in this sector.

1.3 Musicology without music

In his book *Decomposed*, Kyle Devine coined the phrase "musicology without music": a concept that questions the traditional boundaries of musicology by focusing on the material aspects of music, such as its production, distribution, and consumption. The shift towards music streaming has transformed the way we access and consume music, leading to a misconception that digital music is environmentally benign. The environmental costs of the digital music industry are, however, far from negligible, and adopting the concept of "musicology without music" is crucial to addressing these hidden impacts. This approach is particularly relevant in the context of climate change, where the environmental impacts of the music industry are increasingly becoming more relevant. The concept of "musicology without music" acknowledges that music is not just an art form but also deeply intertwined with social, economic, and environmental factors. He argues that this type of music research should not start as a musicology of music, but rather describe the situations where music can come to be in the first place.[44] In the age of digital music streaming, for example, the environmental costs of music consumption are often overlooked. The energy required to power servers, data centres, and other technological infrastructure required for streaming is significant, and the carbon footprint of the music industry as a whole is substantial. By considering the material aspects of music, we can work towards a more sustainable and equitable music industry while also gaining a deeper appreciation for the music itself. The concept of "musicology without music" serves as a powerful framework for examining the material aspects of music. By considering the environmental, social and economic factors that shape the music industry, researchers can develop a more comprehensive understanding of its impacts and work towards a more sustainable and equitable future for music, and as well expanding upon the field of musicology, strengthening its contemporary relevance.

"Musicology without music" can be applied to fields beyond environmental aspects and sustainability, such as the social, cultural and economic factors that shape the music

[43] Personal communication (phone call with supplier), May 2023.
[44] Devine, Kyle. (2019). Decomposed: The political ecology of music. *MIT Press*., s. 21-22

industry. These are already in place and established, for example, in the field of ethnomusicology. As an example, we can look at the production of vinyl records. Instead of simply analysing the music itself, we can focus on the physical properties of the records: the types of vinyl used, the manufacturing processes involved, the design of the album cover art, and so on. We can also look at the social and economic factors that influenced the production and distribution, such as the rise of radio and television, the emergence of youth culture and the impact of major record labels on independent artists. By exploring these material and cultural aspects of music, we can gain a deeper understanding of how music functions as a cultural and social artefact beyond its sonic qualities alone. This is an example of "musicology without music" because we are not primarily interested in the music itself but rather in the material and culture that surrounds it. You could discuss the ethical implications of the music industry, such as fair compensation for artists, equitable access to music, and the responsible use of resources. "Musicology without music" can serve as a framework to assess these ethical aspects and help identify areas where improvements can be made. You could also touch on the potential for interdisciplinary collaboration between fields between musicology and fields beyond the typical interdisciplinary fields used today—such as sociology, anthropology, economics and environmental studies—by adopting STEM fields such as environmental studies or even health sciences. By adopting the "musicology without music" approach, scholars from various disciplines can work together to develop a more holistic understanding of the music industry and its impacts on society and the environment. By a “holistic” approach, we are taking a comprehensive and integrated approach that considers all relevant aspects, factors, and relationships in the context of the subject being studied. In the case of "musicology without music," a holistic approach would involve examining not only the music itself but also its interconnected social, economic, environmental and cultural dimensions. By doing so, one can gain a more complete and well-rounded understanding of the music industry and its impact on society and the environment. A holistic approach emphasises the interconnectedness of various elements and recognizes that they often influence each other in complex ways. This approach encourages researchers to consider multiple perspectives and disciplines when analysing a subject, leading to a more thorough and insightful understanding of the topic at hand.

2 The anatomy and material composition of string instruments

The following part of this thesis moves on to describe in greater detail the anatomy of string instruments. The string family of instruments, also referred to as the violin family, has remained largely unchanged since their transition from the Baroque to the current standardised form. The neck and fingerboard have been slightly lengthened, and steel strings have been added in favour of gut strings. On the other hand, most keyboard and wind instruments have undergone significant modifications to adapt to changing repertoire, new technology, and larger performance spaces.[45] Changes in the type of wood in various parts of the instruments are, however, common and affect the tonal qualities; some to accommodate for sound and others to move away from using endangered species of wood. Research comparing violin fingerboards made of ebony, Brazilian rosewood, and Indian rosewood suggested changing sound qualities: the ebony fretboard's tone was clear and harmonic, and rosewood resulted in a softer and more delicate sound.[46] One of the limitations of this claim is that it does not consider the individual human interpretation of sound and predisposes a myth-oriented selection bias to favour "authentic" instruments, the latter of which is commonly seen in the music industry. Another problem with this approach is that it fails to consider the players' artistic abilities when switching between instruments. We will not be detailing the sonic differences between materials in detail, but such considerations are worth noting.

While there are variations in the types of materials used in and the sonic properties of individual instruments, the general structure of the modern string instruments remains the same and can form a standardised description. When examining the materials and construction of string instruments, it is important to consider the historical context and cultural significance of these instruments. The development and evolution of string instruments have been influenced by factors such as regional preferences, cultural exchange, and the availability of materials. For example, the Cremonese school of violin making in Italy, led by masters like Antonio Stradivari and Giuseppe Guarneri, has had a profound impact on the violin's development as an instrument. These are, however, not the only schools. Lastly, we must also take into account that the globalised nature of the music industry, combined with the increasing awareness of sustainability and ecological concerns, has driven innovations in instrument making. The use of alternative materials, the development of synthetic strings, and the exploration of new construction methods are all part of the ongoing evolution of string instruments. With these considerations in mind, a comprehensive understanding of string instruments should go beyond their anatomy and construction to encompass their historical, cultural and social dimensions, as well as their place within the broader musical landscape. In this thesis, I will, however, not be detailing these considerations in their full extent due to their comprehensive nature and rather describe a standardised approach.

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[45] Pickett, S. G. (2021). Tradition and Innovation in American Violin Making. Retrieved June 9th from https://purl.lib.fsu.edu/diginole/2020_Summer_Fall_Pickett_fsu_0071E_16468, p. ix

[46] Liu, M., Peng, L., Lyu, S., & Lyu, J. (2020). Properties of common tropical hardwoods for fretboard of string instruments. *Journal of Wood Science*, 66(1). https://doi.org/10.1186/s10086-020-01862-7, p. 1–3

In the following presentation, we will be detailing the components of a cello as an example of the string instrument family as a whole. The cello serves as a representative example to explore the various aspects of string instrument production and its broader implications. By dissecting the cello into its constituent parts and examining the materials, craftsmanship and ecological footprint involved, we gain a deeper understanding of the environmental impact and cultural significance of string instruments.

2.1 An overview of the string instrument family

When performers play string instruments, they adjust the pitch by pressing the strings to the fingerboard, which is a part of the neck of the instrument. The fingerboard can contradict the reduction in the resonance frequency of the soundboard, the outwards-facing part of the instrument's body, making the instrument sound stronger and more uniform. Thus, the wood used for fingerboards should have good wear resistance, high hardness, and high stiffness while maintaining flexibility. These are in "authentic" instruments made from ebony, Brazilian rosewood, or Indian rosewood. The remainder of the neck, such as the back and the scroll at the top, is typically made out of spruce, which is also used for the fingerboard of many modern cellos. The same applies to the tuning pegs attaching the strings to the neck at the top. The tailpiece links the strings to the cello's body on the lowest end. While traditionally made of the same materials as the fingerboard, it is often made of steel, spruce, or another type of wood in modern cellos. The tailgut is what connects the cello's tailpiece to the endpin collar. The tailgut of a more modern cello has threads at both ends and is attached to the tailpiece with an adjustment screw. In contrast to other instruments in the string family, the cello also has an endpin connected to the adjustment screw, which can be shortened and lengthened by moving it in and out of the instrument's body.[47] This is typically made of stainless steel. Studies have been made on the effects of different endpin materials without significant changes.[48] The strings span from the tailgut to the pegbox at the top; they vibrate and transfer vibration to the body to resonate and amplify the sound. There are four strings on a modern string instrument, and their tuning differs between each of them. On a modern cello, they are typically tuned to the A, D, G, and C pitches, with A being the highest pitch at 221 or 220 Hz. Of other smaller components, we also have the bridge holding and creating tension on the strings, typically made out of maple – and lastly, a spruce soundpost wedged inside, dispersing the sonic vibrations throughout the instrument.[49] [50]

Having detailed the smaller components, we will now move forward to the instrument's body and larger structure. The soundboard on the top of the instrument, featuring two f-holes where air can flow through and resonate sound outwards, is typically made of spruce. Often, specific types of spruce from one location are preferred. As was pointed out in the introduction to this thesis, such specific usage can introduce issues in both local and global biodiversity. One example of this is the desire for spruce

[47] Liu, p. 1–3
[48] Fleming, C. R., Stypowany, C. R., Celmer, R. D., Vigeant, M. C. (2011). Study of the effects of different endpin materials on cello sound characteristics. *The Journal of the Acoustical Society of America*, 130(4), 2429–2429. https://doi.org/10.1121/1.3654733.
[49] Liu, p. 1–3
[50] Bucur, V. (2016). Handbook of materials for string musical instruments. Springer. 1st ed.. *Springer International Publishing*., p. 43, 78

originating from Val di Fiemme, Italy, which is considered to have ideal conditions for the growth of resonance wood, bettering the quality and sound of the instrument. Allen points out that largely myth-oriented opinions and romanticised stories, often not backed by scientific data, have contributed to both threatening and preserving biodiversity among species of wood used in Western classical instruments.[51] The same can be said for the bridge and back of the instrument, which is made of Field maple. Ideally, these should originate from France (Vosges Mountains), which, according to Pickett (2021), is recognized as the best location for wood for string instruments bridges in particular.[52] However, it is unclear what these claims are based upon and which sources Pickett used. The author offers no explanation for the distinction between variations in materials or origin locations of wood in bridges, nor any other relevant data that could point towards the reason as of why this source preference is prevalent.

Instrument	**Component**	**Material**
Violin/viola cello/double bass	Body	Spruce (top)
		Maple (back, sides, neck)
	Fingerboard	Ebony or rosewood
	Tailpiece	Ebony or rosewood
	Bridge	Maple
	Strings	Steel or gut
	Sound post	Spruce or cedar
	Tuning pegs	Ebony or rosewood
	Fine-tuning screws	Metal
Violin/viola	Chin rest	Ebony, rosewood, carbon fibre or plastic
Cello/double bass	Endpin	Carbon fibre or metal + rubber/plastic

Table 4: Overview of components and materials in the modern string instrument family. Based on information from the above section and its sources. It is important to note that these descriptions are based on standards and that variations occur. For instance, the fingerboard can also be made out of spruce, or the instruments as a whole can be made out of outer materials. There are also instruments made entirely of carbon fibre. As we will explore further in the thesis, new material research can play a significant role in our paths moving forward.

[51] Allen, Aaron. (2012). 'Fatto Di Fiemme': Stradivari's Violins and the Musical Trees of the Paneveggio. In *Invaluable Trees: Cultures of Nature*, 1660-1830, edited by Laura Auricchio, Elizabeth Heckendorn Cook, and Giulia Pacini, 301–15. Oxford: Voltaire Foundation, p. 301, 311
[52] Pickett, p. 527

In addition to the aforementioned components, there can be several smaller pieces inside the instruments, such as blocks of wood strengthening the construction or a contraction holding the endpin of a cello in place. Furthermore, the instrument is typically varnished and glued together using various types of raw and synthetic materials. Historical documents reveal a variety of substances used in creating these varnishes, such as oils, solvents, pigments, resins and siccatives. Modern technology has allowed for some understanding of the composition and structure of the varnish but not the specific sources or preparation methods. Research utilising micro-analytical, historical, and archaeological approaches has allowed for the reproduction of varnishes similar to those used on Old Italian instruments.[53] Most luthiers use animal glue, such as hide glue, due to its reversibility and sonic qualities. Hide glue is made from rinsing and boiling animal hide.[54] Varnishes and glues are not considered in the scope of this thesis but are worth examining closer, as researchers have not treated the sustainability for these in much detail for music instrument production specifically. The craftsmanship and maintenance of the instruments can also play a role in their sustainability. Ensuring proper care, regular adjustments and repairs can prolong the lifespan of an instrument and reduce the need for frequent replacements—as in with any other tool or object.

The concept of organology can also be extended to how researchers understand musical instruments. This can be exemplified through the instruments' historical context, cultural significance and the role they play in different musical traditions. Understanding the social and cultural dimensions of musical instruments can be an important factor when assessing their sustainability. It requires acknowledging the diverse perspectives and practices associated with instrument-making and use, as well as the potential impact on local communities and cultural heritage. John Tresch and Emily I. Dolan discuss these themes in their paper *Toward a New Organology: Instruments of Music and Science*. Their work explores the concept of organology and its relevance to examining instruments as cultural artefacts, taking into account their physical properties, materials, construction techniques and cultural significance The paper highlights the need for a more comprehensive approach to studying musical instruments, one that goes beyond mere classification and taxonomy. Tresch and Dolan emphasise the importance of understanding the social, cultural and historical contexts in which instruments are created and used.[55] This perspective aligns with the aim of this thesis to consider the broader sustainability implications of instrument production in the violin family, encompassing ecological, social and economic dimensions. By drawing from the ideas presented we can recognize the importance of material culture in understanding musical instruments and their role in society. It highlights the interconnectedness of sustainability, craftsmanship, cultural heritage and environmental impact. This broader perspective allows for a more nuanced and holistic understanding of the sustainability challenges facing the music industry.

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[53] Bucur, V. (2016). The Varnish. In *Handbook of Materials for String Musical Instruments*. Springer, Cham. https://doi.org/10.1007/978-3-319-32080-9_9

[54] Weisshaar, H., Shipman, M. (1988). Violin restoration: A manual for violin makers. *Hans Weisshaar & Margaret*., p. 249

[55] Tresch, J., Dolan, E. I. (2013). Toward a New Organology: Instruments of Music and Science. *Osiris (Bruges), 28*(1), 278–298. https://doi.org/10.1086/671381

2.2 An overview of materials

This section describes the material composition of string instruments in greater detail, with descriptions of the various species of wood, their prevalence, and other related data. 10 to 30 per cent of all imported wood has been illegally obtained or logged, despite international agreements such as CITES. For musical instrument production in particular, several species of ebony (Diospyros) and rosewood (Dalbergia) are under heavy use.[56] The illegal actions have resulted in the degradation of diverse ecological systems in regions of the world that possess high levels of biodiversity, particularly within forests. These actions have also frequently impacted the livelihoods of individuals who are dependent on the utilisation of forests as a source of ecosystem services. Instruments with specific types of wood are seen as more professional and are valued higher than their counterparts. Makers have tried to find alternatives that are of similar quality and more resource-responsible, but players continue to insist on expensive—and ecologically destructive materials.[57] This has not only prompted manufacturers of instruments in the violin family to look for similar materials but also for other groups of instruments, such as guitars. Many backwoods traditionally valued for their properties in guitars are today not only costly but also scarce and sourced from unsustainable origins. The low availability and rising expenses associated with traditional woods have prompted guitar manufacturers to investigate alternative options. These encompass lesser-known species of tropical woods with higher availability, temperate woods such as maple and walnut, laminates and synthetic materials like carbon fibre or fibreglass.[58]

The approach used in this investigation is generalised. Several species of wood, or in theory all, can be used in the production. We can assume that on some scale, which may or may not be notable, other wood species within and outside the genus mentioned below are used due to their resonance qualities. A recent study accessed a characterization of the properties of indigenous southern African wood species and their suitability for violin construction. The results showed that yellowwood (*Podocarpus latifolius*) and sapele (*Entandrophragma cylindricum*) were suitable species for violin construction.[59] This can indicate expanding upon the standardised types of wood without losing sonic qualities is possible. A reasonable approach to tackle this issue is to assume that most luthiers use the standardised materials and methods described. The following does furthermore not rule out the influence of other factors in the production process.

It is also important to note that the long-term sustainability of musical instruments is an issue with multiple factors, which requires an approach encompassing not only the materials used but also, for instance, the practices involved in their production, use and maintenance. Furthermore, the identity of the manufacturer that uses the materials may play a significant role in the sustainability of the instrument. Does it make any difference if a large factory manufacturer uses endangered materials, as opposed to a skilled luthier? This is something we will explore later on.

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[56] Jahanbanifard (2019)

[57] Allen, Aaron. (2011). Prospects and Problems for Ecomusicology in Confronting a Crisis of Culture. *Journal of the American Musicological Society, 64*(2), p. 419

[58] Carcagno, S., Bucknall, R., Woodhouse, J., Fritz, C., Plack, C. J. (2018). Effect of back wood choice on the perceived quality of steel-string acoustic guitars. *The Journal of the Acoustical Society of America, 144*(6), 3533–3547. https://doi.org/10.1121/1.5084735.

[59] Meincken, M., Roux, G., Niesler, T. (2021). An African violin – The feasibility of using indigenous wood from southern Africa as tonewood. South African Journal of Science, 117(11/12). https://doi.org/10.17159/sajs.2021/11175, p. 1-2

2.2.1 Ebony (Diospyros)

Diospyros is the leading genus in the pantropical family *Ebenaceae* and the source of ebony wood. More than 800 species of trees and bushes belong to this family. The heartwood, or interior section of a trunk of a typical ebony tree, is durable and ranges in colour from dark brown to black, making it highly prized for use in the construction of high-end furniture, decorations, and in our case, for musical instruments. About 40 different *Diospyros* species have heartwood reported as being dark or marbled in colour.[60] The majority of these species of ebony are endangered. One example is trees from the Madagascar rainforest areas, *Diospyros celebica*. This species of ebony was most recently assessed for The IUCN Red List of Threatened Species in 1998, making the data largely outdated, and hence they must be interpreted cautiously. It is, however, listed as vulnerable under criteria A1cd. The number of mature trees has, in addition to consumption, also declined due to large parts of the habitat being converted to crops.[61] With an increased world population and no listings in CITES Appendices, we can assume that these data have not improved for the better. Another species of ebony central in the production of musical instruments is the Central African forest ebony, *Diospyros crassiflora*, which is a small tree native to the Congo Basin. Its prevalence was last accessed in 2018, and it is listed as vulnerable.[62] Commercial exploitation of these species raises concerns about the long-term sustainability of their trade and the survival of their populations. The species is found to be widespread but not abundant, with potential threats including forest conversion for agriculture and hunting of large mammals, which are critical for seed dispersal. Another commercially available alternative is the near-threatened *Dalbergia melanoxylon*. This is, however, not regarded as a type of ebony but as African blackwood. Musical instrument production is not the only driver of its deforestation. Ebony is also used in Chinese furniture and threatens some of the world's most valuable and endangered old-growth forests.[63]

Some species of ebony have not had much research conducted on them, such as Diospyros melanoxylon, which is not assessed in the IUCN Red List, but has been assessed under local country-specific red lists.[64]

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[60] Jahanbanifard, M., Beckers, V., Koch, G., Beeckman, H., Gravendeel, B., Verbeek, F., Baas, P., Priester, C., Lens, F. (2020). Description and evolution of wood anatomical characters in the ebony wood genus Diospyros and its close relatives (Ebenaceae): A first step towards combatting illegal logging. *IAWA Journal, 41*(4), 577–619. https://doi.org/10.1163/22941932-bja10040.

[61] World Conservation Monitoring Centre 1998. Diospyros celebica Bakh. *The IUCN Red List of Threatened Species 1998*: https://doi.org/10.2305/IUCN.UK.1998.RLTS.T33203A9765120.en.

[62] Schatz, G.E., Lowry, II, P.P., Onana, J.-M., Stévart, T. & Deblauwe , V. (2019). Diospyros crassiflora. *The IUCN Red List of Threatened Species 2019: e.T33048A2831968*. http://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T33048A2831968.en.

[63] Deblauwe, V. (2021). Life history, uses, trade and management of Diospyros crassiflora Hiern, the ebony tree of the Central African forests: A state of knowledge. *Forest Ecology and Management, 481*, 118655. https://doi.org/10.1016/j.foreco.2020.118655

[64] Weerakoon, D.K. & S. Wijesundara Eds. (2012). The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora. *Ministry of Environment*. Colombo, Sri Lanka, p. 253

Type of ebony	Native range	Status
Gaboon Ebony (*Diospyros crassiflora*)	West and Central Africa (Gaboon, Cameroon, Madagascar)	Endangered
Madagascar Ebony (*Diospyros celebica*)	Southeast Asia (Indonesia)	Vulnerable
Ceylon Ebony (*Diospyros ebenum*)	India and Sri Lanka	Exports banned
Mun Ebony (*Diospyros mun*)	Vietnam and Laos	Critically endangered
East Indian ebony (Diospyros melanoxylon)	India and Sri Lanka	Endangered

Table 5: Many types of ebony are endangered. This overview shows some of the most common types, their native range and their current endangerment status.[65] According to the IUCN, as indicated with the exception of Diospyros melanoxylon.

The endangerment status of the various species of ebony trees shows that the issues are widespread. The species is facing challenges in naturally regenerating due to its over-consumption in many industries. In the Sulawesi natural forest of Indonesia, studies indicate that the potential ebony tree population significantly dropped from 92% to 23% between 1970 and 1990. Today, as of 2020, locating ebony trees in conservation zones is difficult, with only a small number of pole-sized trees observed.[66]

The nature of ebony makes it challenging to access the individual trees before they are cut down, as highlighted by the CEO of Swiss Wood Solutions (SWS), who was approached by luthiers looking for alternatives to ebony and interviewed by String Magazine regarding the issue for ebony trees in particular, in February 2022:[67]

> *"The oldest ebony trees contain the largest proportion of jet-black wood, the kind that is prized for string fingerboards, piano keys, cabinets, and furniture. However, the tree's exterior does not readily reveal its contents (the younger wood contains blonde streaks). Therefore, much of what loggers cut down is abandoned on the forest floor. "They cut 20 trees and only one is taken from the forest," said Chanana. "If those forests would be sustainably managed, you would leave those younger trees standing so they could grow, and then cut them when the time is right."*

Comments such as these show how far-reaching the deforestation impact can be. The comment highlights a broader issue regarding unsustainable practices in the harvesting of natural resources. Inefficient logging methods, driven by the demand for specific wood qualities, lead to excessive deforestation and significant waste, as numerous trees are cut down and abandoned on the forest floor. This not only has damaging environmental consequences, but it also undermines the potential for sustainable forest management. Chanana, like many environmentalists and conservationists, is pushing for a more responsible approach. There is no data as to how widely this method is practised, but a general consensus would be that leaving younger trees to grow and only harvesting them at the appropriate time, would be a more efficient use of the forest resources. This would not only help preserve the valuable ebony wood but also contribute to the overall health of the ecosystem.

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[65] Kemp, Hannah. (2023). *Ebony Overview, Types & Facts | What is Ebony Wood?*. Retrieved June 9th, 2023, from https://study.com/academy/lesson/ebony-overview-types-facts.html.

[66] Kiding Allo, M. (2020). EBONY (Diospyros celebica Bakh) CONSERVATION. *IOP Conference Series: Earth and Environmental Science, 522*(1), 12018. https://doi.org/10.1088/1755-1315/522/1/012018.

[67] Wise, B. (01.02.2022). Tough Choices: Companies are Exploring Sustainable Alternatives to Tropical Hardwoods for Stringed Instruments | Strings Magazine. Strings Magazine. Retrieved June 9th, 2023 from https://stringsmagazine.com/tough-choices-companies-are-exploring-sustainable-alternatives-to-tropical-hardwoods-for-stringed-instruments/

2.2.2 Spruce (Picea abies)

Picea abies, commonly known as Norway spruce, European spruce, or in the musical instrument industry, resonance wood, is a wood species that is highly valued and central in use in making string instruments. This species of tree is widespread and dominant in forests of northern and northeastern Europe but is also dominant in various forests in Italy. *Picea abies* is not endangered and is listed as 'least concern' in The IUCN Red List of Threatened Species. The population is stable.[68] A variety of spruce known as "hazel" spruce of the same species, which has a specific structural anomaly of indented annual rings, is also highly sought after by luthiers. It is, however, more difficult to work with and not synonymous with high-quality instruments.[69] These types of trees occur mostly in the forests of the Swiss Alps above an elevation of 1200 metres,[70] which, with a predominant consumption concentrated to a single area or elevation, can lead to population decline in local areas. The Paneveggio region of the Italian province of Trentino, known as "la foresta dei violini" (the forest of violins), stands as another example of this. Due to the ideal microclimate conditions that have existed for centuries, it has good conditions for resonance wood. While the spruce is a widely distributed species and not endangered, producing high-quality wood for musical instruments requires specific growth conditions that are only found in a few regions around the world, such as the Val di Fiemme in Italy. Furthermore, even in the ideal microclimate, only a small percentage of harvested trees yield the necessary resonance wood. Luthiers can use only a small portion of that trunk, and mature spruce is around 150-200 years old. Hence, the remaining suitable population is limited. Other areas with resonance wood are found in Alaska and the Adirondacks.[71] This puts pressure on specific populations of spruce in specific areas.

There are several identifiers luthiers can use to identify resonance spruce. It is whitish-yellow and uniform, and it should be free of knots, resin pockets, and other defects. The wood is graded in five classes based on annual ring width and regularity, with the best quality having the narrowest and most regular annual rings. Traditional methods used by violin makers, such as the tap-tone method, can be related to several wood physical and acoustical parameters, including colour, annual ring width and regularity, and the sound emitted when tapped.[72] The high demand for resonance spruce highlights the importance of sustainable management. While Picea abies is not endangered, the ideal growing conditions for resonance wood are limited to specific areas, putting pressure on specific populations of spruce in these regions. It is, therefore, essential to monitor the harvesting and use of these trees to ensure that their populations are not overexploited, leading to a decline in their numbers. We can also ensure that only mature spruce trees that meet these criteria are harvested, and the remaining trees are left to continue growing and providing future generations with the resonance wood they need for high-quality instruments.

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[68] Farjon, A. (2017). Picea abies. *The IUCN Red List of Threatened Species 2017: e.T42318A71233492*. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T42318A71233492.en.
[69] Bucur, V. (2016). About Traditional and New Wood Species for String Instruments. In *Handbook of Materials for String Musical Instruments*. Springer, Cham. https://doi.org/10.1007/978-3-319-32080-9_17
[70] Unesco. (2011). The knowledge of hazle spruce as tone wood. Knowledge concerning nature and the universe. Tyrol. Retrieved January 28th, 2023 from https://www.unesco.at/en/culture/intangible-cultural-heritage/national-inventory/news-1/ article/ the- knowledge-of-hazel-spruce-as-tone-wood.
[71] Allen 2012, s. 301-202, 304, 309
[72] Bucur, About Traditional [...] 2016

2.2.3 Curly maple (Acer pseudoplatanus)

Figure 3: The flamed textures of Acer pseudoplatanus.[73]

Acer pseudoplatanus is commonly known as curly maple, flamed maple, ripple maple, fiddle-back or tiger stripe. Historically, this wood has been utilised in the production of string musical instruments, specifically for the back, neck, and ribs, which were cut radially, also known as "quartersawn". The famous instrument maker Stradivari predominantly used this type of wood for his instruments. Each part of a violin or viola is typically made of two symmetrical pieces, although rare exceptions exist where a single piece is used. For example, Stradivari created pieces sawn in the LT plane without flamed figures, possibly for less prestigious clients. The back plates of larger instruments, such as cello and double bass, are exclusively composed of two pieces. Large pieces of curly maple are rare and highly valued, often used for creating high-quality Master instruments.[74] *Acer pseudoplatanus* is widespread and dominant in forests throughout most of the European continent. It is not endangered and is listed as 'least concern' in the IUCN Red List.[75] Its unique aesthetic properties and desirable sonic qualities have made it a popular choice for the violin family of instruments throughout history. The wood's distinct visual patterns, such as curly grain, fiddle-back figure, flame grain or partially quilted grain, combined with its excellent resonance, contribute to the instruments' acoustic performance and overall appeal.[76] Given its widespread distribution and dominance in European forests, Acer pseudoplatanus is an abundant and sustainable resource for instrument makers. Its classification as 'least concern' on the IUCN Red List ensures that using this wood for instrument construction does not pose a significant threat to its overall population or the ecosystems in which it grows. However, the popularity of Acer pseudoplatanus raises questions about the potential impact of overharvesting—particularly for large, high-quality pieces that are desirable for many luthiers, similar to the mentioned spruce from the Paneveggio region of the Trentino province. These types of materials are, as we have investigated, often local and endemic to specific regions and even elevations above sea level. It is, therefore, important to adopt sustainable forestry practices and responsible sourcing to ensure the long-term availability of this resource. The resonance properties of wood can vary based on its characteristics, which leads to the classification of wood into different quality classes. For instance, maple wood with curly grains is highly valued by luthiers due to its unique three-dimensional optical effect, which contributes to the overall aesthetic and acoustic qualities of the instrument.[77] Myth-oriented opinions and romanticised stories, can also have an impact on the harvesting and preservation. In some cases, myths and legends have led to the overharvesting of certain woods, as we touched upon earlier in the thesis

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[73] Royalcraft. (n.d.). Flame Maple - (acer pseudoplatanus). Retrieved May 20th, 2023 from http://royalcraft.de/tonewood.php#flamedmaple.
[74] Bucur, About Traditional [...] 2016
[75] Crowley, D., Rivers, M.C. & Barstow, M. 2017. Acer pseudoplatanus (errata version published in 2018). *The IUCN Red List of Threatened Species 2017: e.T193856A125923004*. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T193856A2286517.en.
[76] Dinulica, F., Savin, A., Stanciu, M. D. (2023). Physical and Acoustical Properties of Wavy Grain Sycamore Maple (Acer pseudoplatanus L.) Used for Musical Instruments. *Forests, 14*(2), 197. https://doi.org/10.3390/f14020197
[77] Dinulica et al. (2023)

2.2.4 Rosewood (Dalbergia)

Rosewood is sparsely used for the violin family of instruments, but are sometimes used for smaller parts such as chin rests and tails. However, this thesis also mentions other instruments, such as guitars, where the use of this species of tree is more prevalent. Hence, it is worth detailing.

In the production of musical instruments, several species of rosewood can be used. The most commonly used species of rosewood for these instruments are:

1. *Brazilian Rosewood (Dalbergia nigra):* This species is highly valued for its rich, warm tone and is considered to be one of the finest tonewoods for stringed instruments. However, due to overharvesting, Brazilian rosewood is now protected under international trade restrictions under CITES and is rarely used in new instrument production.[78]
2. *East Indian Rosewood (Dalbergia latifolia)*: This species is also highly prized for its tonal properties and is widely used in the construction of musical instruments. It is more readily available than Brazilian rosewood and is commonly used as a substitute. However, the high demand and growing rarity has resulted in excessive harvest and an illegal trade. It is listed in Appendix II of CITES, categorised as 'Vulnerable'.[79]
3. *Madagascar Rosewood (Dalbergia baronii)*: This species is similar in tone to Brazilian rosewood and is sometimes used. However, like Brazilian rosewood, it is now protected under international trade restrictions.[80]

Other species of rosewood, such as African Blackwood Rosewood (Dalbergia melanoxylon), Honduran Rosewood (Dalbergia stevensonii) and Cocobolo Rosewood (Dalbergia retusa), are also used in the production of musical instruments.[81]

Most species of this genus are subject to trade restrictions. Such problems have been seen in cases already, such as in the production of Gibson guitars. The guitar manufacturer facilities were raided by the U.S. Fish and Wildlife Service in 2011 due to suspicions of using illegally imported rosewood from Madagascar and ebony from India in their guitars. Gibson made a settlement in which they agreed to pay a 300 000 USD fine, forfeit claims to about 262 000 USD worth of wood seized during the raid, and contribute 50 000 USD to the National Fish and Wildlife Foundation to promote the conservation of protected tree species.[82]

While not prevalent in violin instruments, the use of rosewood in musical instruments in general, such as guitars, make it a topic of discussion in the context of cultural sustainability. The trade restrictions imposed on most species of rosewood highlight the need for more sustainable alternatives in the production of musical

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[78] Taylor, V., Kecse-Nagy, K., Osborn, T. (2012). Trade in Dalbergia nigra and the European Union. *TRAFFIC INTERNATIONAL*, p. iii - iv

[79] Arunkumar, A. N., Warrier, R. R., Kher, M. M., & Teixeira da Silva, J. A. (2022). Indian rosewood (Dalbergia latifolia Roxb.): biology, utilisation, and conservation practices. *Trees (Berlin, West), 36*(3), 883–898. https://doi.org/10.1007/s00468-021-02243-3, p. 898

[80] Calvano, S., Negro, F., Ruffinatto, F., Zanuttini-Frank, D., & Zanuttini, R. (2023). Use and sustainability of wood in acoustic guitars: An overview based on the global market. *Heliyon, 9*(4), e15218. https://doi.org/10.1016/j.heliyon.2023.e15218

[81] Calvano 2023

[82] Gillespie, N. (2012). Gibson Guitar Settles Federal Case That Resulted in 2011 Armed Raid; Pays $300,000 Fine. Reason.com. Retrieved June 9th, 2023 from https://reason.com/2012/08/07/gibson-guitar-settles-federal-case-that/

instruments. Notable cases, such as the Gibson guitar raid, emphasise the significance of compliance with international trade regulations and the potential consequences of using endangered wood species. This example further underlines the importance of seeking sustainable alternatives for both the industry and the environment.

2.2.5 Steel

Steel has also found its place in the construction of violin instruments. While traditionally associated with the use of gut strings, the incorporation of steel components in violins has introduced new possibilities for instrument makers and musicians. The introduction of steel strings revolutionised the sound of stringed instruments. Steel strings offer enhanced durability, projection and a brighter tone compared to traditional gut strings.[83] The use of steel in the tailpiece and other parts of the instruments, like fine tuners, is also common, providing stability and adjustability to the instrument.[84] While the use of steel brings numerous benefits, we can also consider the sustainability and environmental impact of its production. Steel is derived from iron ore, which requires extensive mining and energy-intensive processing. The extraction and processing of raw materials for steel production can contribute to deforestation, habitat destruction and carbon emissions. The acquisition of these metals raises significant environmental and social concerns. Known as conflict minerals, their extraction has been documented to contribute to hazardous working conditions, pollution and societal instability. Both large-scale industrial operations and artisanal mines controlled by local militias have been implicated in these issues. Workers in mines face unsafe conditions, with minerals processed by hand and inadequate safety measures. The smuggling of these minerals to foreign producers further exacerbates the risks for workers and the environment.[85] The EU has banned the import of conflict minerals as of 2017, as well as smelters and refiners in the EU and globally from using conflict minerals. There are also regulations in place for securing the rights of mine workers.[86] In a global market, there can however, be challenges in ensuring the traceability, as well as in trading and importing musical instruments outside of the EU.

2.2.6 A broad challenge beyond specific species—and musical instruments

The illegal trade of wood has, as we have explored, far-reaching consequences for the environment, the music industry and local communities. While ebony is the most widely problematic species in the violin family of instruments, they are not the only ones impacted by illegal trade. The pressure on certain species has led to the emergence of alternatives with their own ecological and social implications. Finding alternatives for specific species of wood can seem like a good solution, and may even be necessary with certain types of wood, such as ebony. This chapter delves into the case of Swietenia macrophylla, a highly sought-after species that became regulated under CITES due to an unsustainable demand. This made it illegal to trade.

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[83] Bucur, V. (2016). Strings for Musical Instruments of the Baroque and Romantic Periods. In *Handbook of Materials for String Musical Instruments*. Springer, Cham. https://doi.org/10.1007/978-3-319-32080-9_10

[84] Bucur, V. (2016). Pieces for String Fitting. In *Handbook of Materials for String Musical Instruments*. Springer, Cham. https://doi.org/10.1007/978-3-319-32080-9_12

[85] Allen 2023 (unpublished), p. 24-25

[86] European Commission. (2023.). *Conflict Minerals Regulation. The European Commission's trade department*. Retrieved 5th of June from https://policy.trade.ec.europa.eu/development-and-sustainability/conflict-minerals-regulation_en

As a result, Fiji Pure Mahogany emerged as a substitute, which was cultivated extensively in the Fiji mountains. However, this development has raised questions about the beneficiaries of these plantations and their impact on local indigenous forests. Who these plantations benefitted and how the plantation affected local indigenous forests is a question José E. Martínez-Reyes analyses in this paper Timber to Timbre. He analyses the global commodity chains and infrastructures linked to the production, focusing on how Honduran mahogany has impacted Fijian landowners' perceptions of forests, sustainability and justice. It also examines the power dynamics and ontological politics involving various actors, species and objects. The section of the thesis highlights the connection between musicians' aesthetic preferences for particular timbres and the broader historical context of colonialism and capitalism.

Mahogany was introduced to Fiji by British colonialists, who sought to turn the region into a source of profit. Fijian mahogany, the same species as Honduran mahogany (Swietenia macrophylla), became a significant part of the global supply chain for the production of Les Paul guitars since the mid-1990s. This has led to a range of social and environmental issues in Fiji, such as political and ethnic conflicts, health impacts and environmental degradation. Martínez-Reyes highlights how the history of mahogany in Fiji is connected to the broader context of extractive global capitalism and British colonialism. These plantations began in the 1950s and 1960s, and the Fijian Department of Forestry documented their progress in annual reports. One of the main sites for early plantation experiments was the Colo-i-Suva forest in southeastern Viti Levu. The growth of mahogany was found to be impressive, and the trees were largely free of pests and diseases. The colonial authorities saw the potential monetary value of mahogany and began to clear native forests to make way for the new plantings. Indigenous trees, including hardwoods suitable for various purposes, were poisoned and removed to make space for the mahogany plantations. Mahogany, once planted, competed well with local species and eventually became successful in natural regeneration. The colonial authorities saw the potential monetary value of mahogany and began to clear native forests to make way for the new plantings. Mahogany competed well with local species and eventually became successful in natural regeneration. The transformation of the Fijian landscape due to the growth of mahogany plantations came at the cost of sacrificing numerous indigenous trees, including hardwoods.[87]

In this examination of Swietenia macrophylla and the emergence of Fiji Pure Mahogany as a substitute, we can see that it is important to consider the broader implications of using alternative wood species in the production. While it may seem like a good solution for reducing the pressure on endangered species, the introduction and cultivation of alternatives can have significant consequences on local ecosystems, native species and the communities that rely on these natural resources. The historical context of timber-driven colonialism and plantation capitalism also provides insight into the complex relationship between the aesthetic preferences of musicians and the exploitation of natural resources. This connection underlines the importance of understanding the implications of our choices and responsibility when sourcing materials for musical instruments.

While the discussion on the materials and construction of musical instruments is indeed significant, it is important to see that this aspect represents only a small part of the broader issues in the music industry. The industry's environmental, social, and cultural impacts extend beyond the manufacturing and use of musical instruments. The production, distribution, and consumption of music in both physical and digital formats

[87] Pardo and Martínez-Reyes, p. 148–155

have considerable ecological implications. For instance, the energy consumption and carbon emissions associated with data centres, servers and streaming services contribute to the overall environmental footprint of the industry. Similarly, the production of physical formats such as CDs and vinyl records involves resource extraction, manufacturing processes, and transportation, all of which have environmental costs. The social and economic aspects are also essential to consider. Issues such as fair compensation for artists, equitable access to music, and the impact of major record labels on independent musicians should be acknowledged and addressed—these are also a part of the broader field of sustainability. Live music performances and large-scale events, such as music festivals and concerts, also contribute to the industry's environmental and social footprint. The consumption of resources, waste generation, and transportation-related emissions are all relevant factors that need to be considered in the context of sustainable event management. While the materials and construction of musical instruments are important aspects to examine, the broader scope of the music industry encompasses many environmental, social and cultural dimensions. A comprehensive analysis of the industry's impact requires considering all these interconnected elements and working towards more sustainable and equitable practices in every aspect of music production, distribution and consumption. Hence, the depth and complexity of the subject matter present many research questions for expanding our understanding of the topic.

2.2.6 Research on new materials

While replacing materials with more sustainable substitutes in some cases carries with it its own issues, moving forward, research in this field is essential for the emergence of alternatives that can replace endangered wood. There has been some research in this area, with materials being explored as substitutes. However, the quality and characteristics of these materials are not yet fully comparable to those of ebony. Hence, further research and development of more sustainable substitutes that can match the unique properties and characteristics are necessary to ensure the long-term sustainability of the musical instrument industry—cultural sustainability—while also protecting endangered species. By investing in such research, we can also help reduce the pressure on populations of ebony trees in certain areas and promote a more sustainable future for both the culture and the environment. This also promotes competency development for all stakeholders in the fields. In the following chapter, we will explore some of the challenges and opportunities associated with the adoption of new materials in the industry. It is important that we continue to examine the ecological and social impact of materials used in musical instrument production, as well as the potential cultural implications of using substitute materials. Ultimately, by considering both ecological and cultural sustainability, we can work towards a more harmonious and fair future for both the music industry and the environment.

An instinctive thought may be to use locally produced species. This not only contributes to a reduced carbon footprint due to less transportation but also supports local economies. Many studies have tried to investigate this. One such study was carried out by Martina Meincken, Gerhard Roux and Thomas Niesler. They examined the physical and mechanical properties of wood species indigenous to southern Africa in order to evaluate their suitability for building violins. Of the local species included in the stud, they identified yellowwood and sapele as the most fitting choices among the assessed species. Using these woods, a skilled luthier built an 'African' violin, which underwent

sound quality evaluation through live performances and spectral analysis of recorded audio. The resulting data revealed a distinct acoustic profile for the indigenous wood violin yet similar to instruments made from traditional wood species, showing that yellowwood and sapele are viable tonewood alternatives that produce a unique sonic character. High-quality violins are traditionally crafted from imported spruce and maple wood, which can be expensive in South Africa. However, the growth conditions of many southern African wood species suggest their potential as viable tonewoods. The research demonstrated that several of these species could indeed serve as suitable tonewoods and that violins made from them produce a unique, albeit somewhat different, high-quality sound.[88] By incorporating these materials into instrument manufacturing, it is possible to create instruments that are not only sustainable but also have a unique sound profile. This does hence not only within the environmental pillar of sustainability but also social, as it makes musical instruments more available and affordable. Culturally it also provides a new dimension to the world of string instruments and luthier craftsmanship.

The African example is one of many. Innovative luthiers and startups have begun exploring alternative materials for the construction of musical instruments, addressing sustainability concerns while maintaining performance and quality. Joseph Curtin, a renowned luthier, has experimented with Sonowood—a compressed spruce species—as a substitute for carbon fibre in reinforcing instrument necks. According to Curtin, Sonowood offers several advantages, including increased stability under fluctuating humidity, improved wear resistance, reduced acoustic dampening, and enhanced stiffness. However, the material's high density can result in heavier components, making it necessary to make design adjustments to balance the added weight. Another player in the field is a Finnish startup founded in 2018 by Armin Seebass, a bow maker with a background in forestry, and Kristiina Aatsinki, who oversees sales and administration. The company is developing a range of sustainably sourced wood composites, which are intended to provide violin makers with alternatives to ebony and ivory. Seebass claims that tailpieces, pegs and fingerboards can all be manufactured using these composites, which are derived from natural plant fibres obtained from agricultural and forestry sources.[89] There are also other examples, such as Corene, developed in Switzerland, which is also made out of a composite and claims to be indistinguishable from ebony.[90]

Furthermore, players using alternative materials for instruments, such as carbon-fibre bows or entire instruments made out of carbon fibre, may not necessarily be more sustainable if the carbon is derived from nonrenewable petroleum. Trees, as renewable resources, could be a better option if managed responsibly. The aesthetic aspect of using traditional materials like pernambuco bows is important for musicians, but there may be a misalignment between aesthetics and environmental impact, requiring a change in aesthetics to support sustainability. Aesthetics is furthermore not only about what looks or sounds nice—it is a philosophy of the senses that connect with culture and ethics. When people value certain sounds, they support the musical cultures that produce those sounds. However, this becomes complicated when the valued sounds cause economic and social injustice or environmental harm. Aesthetics is an essential entry point for music and sound studies in the context of sustainability, as it highlights the connections between aesthetics and ethics and their relevance to sustainability

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[88] Meincken, M., Roux, G., & Niesler, T. (2021). An African violin – The feasibility of using indigenous wood from southern Africa as tonewood. South African Journal of Science, 117(11/12). https://doi.org/10.17159/sajs.2021/11175

[89] Wise 2022

[90] Fingerboard No Ebony. (n.d.). *Corene*. Retrieved June 9th, 2023, from https://www.mycorene.com

frameworks.[91]

These examples and examples made by comments such as Chanana earlier in the thesis, show how competency development and new research is important across all stakeholders in the field. By investing in research and development of sustainable substitutes and promoting responsible forest management, we can reduce the pressure on endangered tree populations and promote a more sustainable future for both culture and the environment. For instance, educating suppliers in choosing and/or cultivating the correct types of wood instead of cutting them down and abandoning them on the forest floor due to improper management. Competency development in the field also promotes innovation. As startups and luthiers experiment with alternative materials, such as Sonowood or sustainably-sourced wood composites, they help address sustainability concerns while maintaining performance and quality. It can also encourage a shift in the aesthetic perception of musical instruments, aligning aesthetics with environmental impact and ethical considerations. As the connections between aesthetics, ethics and sustainability frameworks become stronger, this can help raise awareness of the potential social and environmental consequences of valuing certain sounds, materials and traditions. Furthermore, research promoting using locally-produced species not only reduces the carbon footprint due to less transportation but also supports local economies. Research, for instance, such as that by Meincken, Roux and Niesler, has shown that local species like yellowwood and sapele can be good alternatives to traditional tonewoods, producing a unique sonic character while also making musical instruments more available and affordable. This contributes to the social pillar of sustainability.

2.3 Craftsmanship, lifespan and cultural value

In this chapter, we explore the significance of the manufacturer, examining the potential environmental implications that stem from the varying lifespans of instruments made by different makers. Specifically, we will discuss the distinction between instruments crafted by luthiers, which often possess lifespans of decades or centuries, and factory-made student instruments, which may only last for a few years. By investigating these differences, we aim to shed light on the role that craftsmanship plays in instrument longevity and its subsequent impact on the environment and sustainability in the music industry. This topic also plays a role in our previous discussion of cultural values. The craftsmanship that luthiers bring to the creation of their instruments often results in a high-quality product that carries a unique artistic and cultural significance. These instruments not only produce exceptional sound and performance but also have the potential to become pieces of history passed down through generations of musicians. On the opposite side, factory-made instruments may lack the same level of cultural and performative value due to their shorter lifespans and standardised production methods.

This question furthermore raises some concerns as to how we objectively can measure the quality of an instrument. There have been some studies aimed at discovering parameters for this. One such study was performed by Heinrich Duennwald. In his paper *Deduction of objective quality parameters on old and new violins,* Duennwald measured around 700 violins of various types, specifically old Italian violins, violins made by old masters, violins made by hobby makers and factory-made violins. As you might suspect, Duennwald found that the "best" violins do not have many individual sounds that are nasal or harsh. To do this, Duennwald used a machine to apply a steady

[91] Allen 2019, p. 51-53

vibration to the violin's bridge, and measured the sound it produced with a microphone. They then analysed the sound spectrum of each note, and calculated its "loudness" in different frequency ranges using a method called "Lautheit" (loudness). They also look for patterns in the sound spectrum that indicate "nasal", "harsh" or "clear" and compare the percentage of notes that fall into each quality category to determine the overall quality of the violin.[92] Other researchers have however found instances where no difference was found when examining different 'classes' of instruments. George Bissinger examined 17 violins of varying quality to identify any trends related to their acoustic properties. The study found that all violins showed no apparent quality trends for mode frequencies or total damping. Comparisons between "bad" and "excellent" violins for a wide range of properties generally showed no significant differences. They did, however, find that 'excellent violins' were more even across the sonic range and showed strength in the lowest range.[93] It is worth noting that these studies used different methods of measurement. We will not be examining the topic any further in this thesis, but it could be a topic worth detailing in future research.

Sound is not the only measurement of value we can use on instruments. Cultural value, quality of work (lifespan) and craftsmanship are also important factors. As Duennwald mentions:[94]

> *The reason for these results seems to be special knowledge among the old Italian violin makers. This knowledge was transferred to some other violin makers in Europe during that period, so that more instruments made before 1800 in other locations are very good in sound.*

It is hence important to note that handmade and factory-made instruments are made with different approaches, priorities and markets in mind. While a luthier cannot compete with the factory on price, the factory cannot match the luthier's level of attention to detail, care and judgement in their work. As a result, the choice between handmade and factory-made instruments often comes down to the preferences and priorities of the musician. For those who value the unique craftsmanship, personalised touch and the potential for a deeper connection with the instrument, a handmade instrument crafted by a skilled luthier may be the preferred choice. These instruments often possess a distinct character and superior tonal qualities, reflecting the artistry and skill of their maker. On the other hand, factory-made instruments cater to a broader market, offering a more affordable and accessible option for musicians at various skill levels. The standardised production process ensures consistent quality and availability, making these instruments an attractive choice for those who seek reliability and value for money. However, the mass-production approach may lead to a compromise in some aspects of the instrument's individuality and tonal character.

It is also worth noting that consumer choices can be influenced by the presence of myths, cultural narratives and glorification surrounding certain types of instruments or their origins. These narratives may create a perception of prestige or superior quality for traditional materials, which can, in turn, impact the purchasing decisions of musicians. It is important to separate fact from fiction and objectively evaluate the true qualities and

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[92] Dünnwald, H. (1991). Deduction of objective quality parameters on old and new violins. *Catgut Acoust. Soc. J.,* p. 1-5

[93] Bissinger, G. (2008). *Structural acoustics of good and bad violins. The Journal of the Acoustical Society of America, 124*(3), 1764–1773. https://doi.org/10.1121/1.2956478

[94] Dünnwald 1991, p. 5

characteristics of an instrument. While certain myths and stories may have historical or cultural significance, they should not be the sole determining factor when selecting an instrument. Instead, musicians should base their choices on evidence-based criteria, such as tonal quality, playability, durability and compatibility with their playing style and preferences.

In an article in the luthier magazine *The strad* they talk about "Overcoming our addiction to tropical hardwoods". The article is based on research made by Tom Stewart and explores some of the current alternatives. Tom Stewart's research and the article in The Strad shed light on the challenges faced by luthiers and the music industry in moving away from the use of tropical hardwoods. Finding alternatives to these woods is a complex process, as it requires balancing the technical and tonal requirements of musical instruments with environmental considerations. The article also highlights the power each small luthier workshop holds:[95]

> *People are used to cheap ebony, but unless they switch to a sustainable alternative they will have blood on their hands. We might all be happy and comfortable working with densified wood or compressed paper in my workshop, but each workshop is a world in miniature. It's incumbent on us, now, to go out and show people just how good these materials are.*

The issue of sustainability in the musical instrument industry is not just a scientific problem to be solved. It is a topic that people in the industry seem to be genuinely concerned about–yet, empirically, the awareness is limited, and the implementation of sustainable practices is often challenging for the consumers involved. Despite the genuine concern among industry professionals, the implementation of sustainable practices has been relatively limited. We have established that musicians, luthiers and music lovers alike have a deep emotional connection to their instruments and the natural materials used to make them. The idea of contributing to the destruction of forests and endangered species can be difficult for those who appreciate the beauty and complexity of the natural world. We can presume that consumers can play a role in promoting sustainable practices by being more conscious of the products they purchase. By choosing items made from certified sustainable wood, customers can encourage manufacturers and suppliers to adopt more environmentally friendly methods.

2.3.1 Allocation of resources

It is also important to consider the impact of craftsmanship and production methods on the longevity of musical instruments. In this context, the distinction between instruments crafted by luthiers and factory-made instruments can have significant sustainable implications. However, when it comes to resource allocation within the musical instrument industry, there has been relatively little—or any—research done on how to find a harmony between ecological sustainability and cultural preservation.

Luthier-crafted instruments often have longer lifespans, sometimes lasting for decades or even centuries, and factory-made instruments may only last for a few years—maybe more if you are lucky. This issue is of particular relevance to the music industry, as the unique artistic and cultural significance of luthier-crafted instruments

[95] The Strad. (2022). Overcoming our addiction to tropical hardwoods: the latest alternatives. Rertieved 11.05.2023 from https://www.thestrad.com/lutherie/overcoming-our-addiction-to-tropical-hardwoods-the-latest-alternatives/9090.article

cannot be overlooked. The measurement of instrument quality is a complex and multifaceted task, as it is, by nature, artistic and cultural. It is not solely determined by acoustic properties. Cultural value, craftsmanship and lifespan are equally important factors to consider when evaluating the sustainability of a musical instrument. For instance, ebony is, as we have detailed, an endangered species, and its harvest is tightly regulated to prevent overuse. By allocating such materials to luthiers who specialise in crafting high-quality instruments, we can ensure that they are used in a sustainable and responsible manner. In contrast, factories may use ebony in lower-quality instruments that have a shorter lifespan, contributing to the over-exploitation of this valuable resource. Handmade instruments, on the other hand, benefit from the luthier's attention to detail and ability to customise individual components for the natural variability of wood materials. As a result, they may also be easier to repair and maintain due to the use of traditional materials and techniques.

The allocation of endangered resources also carries with it significant financial, logistical, cultural and ethical considerations. While it is important to prioritise conservation, allocating resources solely on the basis of threatened species listings may not be the most cost-effective or sustainable approach. The focus on endangered species alone may overlook important species that play key ecological or cultural roles. Additionally, the limited availability of specific species needed for musical instrument production highlights the need for more sustainable and responsible forestry practices.

The production of factory-made instruments is often geared towards affordability and mass production, enabling them to reach a broader market. However, this often comes at the cost of the personalised touch and precision that a skilled luthier can provide. Factory-produced instruments may not account for the subtle nuances in wood materials and their unique properties, which can impact the overall quality and sound of the final product. Hence, the importance of luthier craftsmanship in producing high-quality and culturally significant instruments cannot be overlooked.

Debating who gets access to what and when involves complex questions that touch on power structures and social inequalities. The sustainable allocation of resources needs to consider not only the ecological impact of production but also the social and cultural values of the industry. The recognition of the role of luthiers in producing high-quality and culturally significant instruments underscores the importance of fair distribution of resources. Allocation of endangered materials to skilled luthiers who specialise in producing long-lasting instruments is not only a sustainable approach but also promotes traditional craftsmanship and cultural preservation. This should hence be considered when developing policies and regulations that impact the industry.

3 A framework example

In the following chapters, I will present an example of the framework for sustainable assessment of musical instruments presented earlier in the thesis, specifically focusing on instruments in the violin family. The framework will consider the materials used in the production of these instruments, the craftsmanship involved in their creation and the social and cultural dimensions of the industry. This framework is intended to provide a holistic approach to sustainability assessment focusing specifically on the impact of deforestation in the production of string instruments rather than doing a full life-cycle assessment—a methodology suggested by, for instance, Aaron Allen and Kevin Devine, as we detailed earlier.

Table 4, as presented earlier in the thesis, provides a list of indicators that will form the basis of the framework for assessing sustainability in the production of musical instruments in the violin family. These indicators cover various aspects, including the source of materials, deforestation impact, biodiversity impact, as well as the social and cultural impact. To ensure the sustainability of musical instrument production, a variety of factors need to be considered. These include the source of materials, such as whether they are sustainably sourced and certified from responsible forestry programs, as well as the impact of unused wood left on the forest floor. Another important factor is the impact of deforestation associated with the harvesting of woods used in instrument production, including the loss of natural habitats and endangered species. Social and cultural impact is also crucial, including fair labour practices within the supply chain and engagement with local communities—and the impact of the other factors on the ecosystem services of the area in question. This forms a holistic evaluation of sustainability, focusing specifically on the impact of deforestation—which is relevant for this particular group of musical instruments, and forms a framework to build and expand upon the field of ecoorganology. It should be noted that, due to the inability to acquire the required data from ebony providers, no assumptions will be made in presenting the framework example. This is to ensure the credibility and accuracy of the framework presented and to not create any bias for future use. By considering these indicators and implementing the framework, we can achieve a more sustainable approach to musical instrument production, one that takes into account both environmental and social impacts. By identifying the specific factors that contribute to sustainability and evaluating each aspect, we can create a more comprehensive understanding of the industry and its impact. Furthermore, the framework can serve as a guide for manufacturers and suppliers in the industry, encouraging them to consider sustainability in their practices and to move towards more responsible and ethical sourcing of materials. This is not only important for the longevity of the industry but also for the preservation of our natural resources and the cultures surrounding traditional craftsmanship. The framework can serve as a tool for promoting a more sustainable future for the violin family of musical instruments so that they can continue to be there for future generations. Marking something as sustainable or not sustainable would make use of our sustainability criteria presented in chapter 1.1.2, which included the wood used not being listed in Appendix I or Appendix II of CITES, not listed in the ‘Threatened’ category of classifications in the IUCN Red List of Threatened Species, measures being made to limit the material waste from the production process as well as to not cause the loss of ecosystem services.

3.1 Source and type of materials

The source and type of materials is an important aspects to consider in the sustainability of a musical instrument production. The use of wood from sustainably managed forests is essential to maintain the ecological balance and ensure the long-term availability of these valuable resources—and for the ecosystem services, they provide and live as a part of. The percentage of sustainably sourced woods, the use of certified woods from responsible forestry programs, and minimising unused wood left on the forest floor are all important factors to consider in the overall sustainability of the instrument production. Therefore, it is necessary to evaluate the source and type of materials used in the production of musical instruments, with a focus on ensuring sustainable practices and responsible sourcing. In chapter 2.2.1 a list of some of the most common types of ebony used in such production was presented. The endangerment status for some of these types of ebony was higher than others. Consequently, we must consider the specific type of wood being used. A higher endangerment status, such as the one for Madagascar Ebony (*Diospyros celebica*), which has exports banned, would equal to a less sustainable practice for the production process. Using Gaboon Ebony (*Diospyros crassiflora*), which is marked as 'Endangered' would be better—but as it is classified under an Endangered category, such use would not be considered sustainable under our criteria presented in chapter 1.1.2.

A more comprehensive assessment of this factor would make use of data for how much and to what extent the species are harvested. This would require a detailed analysis of the extent of harvesting for each species used in the production. It is also important to consider the minimisation of unused wood left on the forest floor and other practices in the production process, as this can have a significant impact on the overall sustainability. However, this method would have limited accuracy and a lack of context about the specific practices associated. Furthermore, acquiring such data can be challenging and have little meaning. At scale, it could also be challenging to assess such factors. Hence it would be more beneficial to incorporate multiple evaluation methods and consider a broader range of sustainability indicators.

Another way to assess this factor is the use of responsible forestry programs or other certifications based on the type of material, such as the Congo Basin Institute Ebony Project, which aims to ensure access to nutritious food and opportunities for economic growth, [...] effective conservation [...] and ensure that the tropical hardwood ebony is available for generations to come. They wish to "ensure that the tropical hardwood ebony is available for business, communities, and researchers to work together to protect a valuable timber species, reforest degraded land, address local food security issues, and improve rural livelihoods generations to come».[96] Such certifications or projects can make it easier for researchers to obtain data on the sustainability of the production. Forest certification programs have set standards for sustainable forest management that include ecological, social and economic criteria. These certifications provide a set of guidelines for forest management, ensuring that forest operations are carried out in a sustainable manner. By using wood sourced from certified sources, it becomes easier to ensure that the source of materials used in instrument production aligns with sustainable practices. A certification can set a baseline for what researchers should expect, but not necessarily remove the need for acquiring data entirely. We can assume that certification programs are not immune to misuse and fraudulent claims of sustainability. Hence, it is important to conduct thorough research and verification of the

[96] Congo Basin Institute. (2022). *Ebony Project*. Retrieved June 11th, 2023, from https://www.cbi.ucla.edu/ebony-project

certifications. This will ensure the credibility and accuracy of the data used in the assessment and avoid promoting unsustainable practices that could have negative impacts on the environment and local communities. We can also assume that the vendors responsible for harvesting would not always be credible in their reports. Due to the complex and often unclear supply chains, it can be difficult to trace the origin of wood used in the production of musical instruments. Vendors may not always be transparent about their sourcing practices—which empirically was an issue in preparing this framework—and even if they do provide information, it may not be reliable. In some cases, there may be an intentional misrepresentation or lack of awareness of unsustainable harvesting practices. Hence, it is important to conduct thorough research and verification of the sustainability claims made by vendors to ensure the credibility and accuracy of the data used in the assessment. This will help to avoid promoting unsustainable practices that could have negative impacts on the environment and local communities. This approach also takes into account that forests are not just made up of trees, but also include other vegetation, wildlife and, more importantly, ecosystem services, which are all important factors to consider in assessing sustainability.

Interdisciplinarity

Using an interdisciplinary approach when dealing with this factor can greatly better the assessment of the source of materials. Collaboration among researchers from various fields, such as ecology, can provide a more complex and encompassing understanding of the environmental aspects involved. The calculations involved may appear straightforward, but it is important to acknowledge that even simple calculations can be prone to errors or misinterpretation, especially when performed by individuals without the necessary expertise or training. For example, determining the percentage of sustainably sourced woods requires accurate data on the number of sustainably acquired trees or the area of sustainably managed forests in relation to the total number of trees or forest area. These calculations need reliable and comprehensive data, which may not always be available or easily obtained. Errors in data collection, incomplete information, or a false understanding of the results can lead to inaccurate calculations and misleading end results. Furthermore, only calculating a percentage without considering the broader ecological contexts can result in oversimplified conclusions. Furthermore, the involvement of social scientists could assist in analysing the impact of different sourcing practices on local communities, contributing to a broader understanding of sustainability that goes beyond environmental concerns. An interdisciplinary approach can greatly benefit the assessment of waste minimisation and resource efficiency. For example, conservation biologists and ecologists could also contribute by offering guidance on how to minimise the environmental impact of waste. Moreover, collaborations with designers and musicians could lead to the creation of innovative instrument designs that use less material or make better use of offcuts.

3.2 Deforestation impact

Deforestation is a major environmental issue that has gained significant attention in recent years. It has a direct impact on the health of ecosystems, as well as the well-being of local communities that rely on the resources provided by forests. In the context of musical instrument production, the harvesting of wood for use in the violin family can contribute to deforestation, especially if unsustainable practices are used. This section of the thesis will focus on assessing the deforestation impact associated with the harvesting of wood used in instrument production. The main factors that will be assessed are the rate of deforestation associated with the harvesting of woods and the area of natural habitats impacted or lost due to deforestation. By evaluating these factors, we can gain a better understanding of the impact of instrument production on deforestation and the environment as a whole. For this we will explain two possible approaches for assessing these factors: one which uses a mathematical model for detailed analyses and one more generalised method.

There are many ways of calculating deforestation rates, but the one we will be using in this thesis was presented by Jean-Philippe Puyravaud in his article *Standardising the calculation of the annual rate of deforestation*.[97] As most musicologists are not expert mathematicians, this will be presented in a simple and explained manner. Typically, this is also an example of where an interdisciplinary approach would be beneficial—not just for the mathematical calculations, which some might be able to do, but also for acquiring the required data, verifying the results and analysing the implications of the results. It is also important to note that other factors than the ones presented here in most cases will be present and important to include in assessments. This is presented only as an example of the logic behind an approach making use of statistics so that we can better understand and with an interdisciplinary approach, apply it in our evaluation of the impact on deforestation rates.

$$r = \frac{1}{t2 - t1} In(\frac{A2}{A1})$$

$$r = (1 \,/\, year\ 2 \ - \ year\ 1\,) \ \cdot \ In\,(A2/A1)$$

The formula described by Puyravaud can be used to calculate the annual rate of deforestation associated with the harvesting of wood and the area of natural habitats that are impacted or lost due to deforestation. The formula is derived from the Compound Interest Law—a term from economics that describes interest on top of interest, which is used to calculate interest over time. It takes into account the initial forest area (A1) and the final forest area (A2), as well as the time period between the measurements (t2 - t1). t2 is the most recent year and t1 is the one furthest away.

[97] Puyravaud, J.-P. (2003). Standardizing the calculation of the annual rate of deforestation. Forest Ecology and Management, 177(1), 593–596. https://doi.org/10.1016/S0378-1127(02)00335-3

The formula indicates that you divide the natural logarithm[98] of the ratio of the final forest area to the initial forest area by the time period between the measurements. The resulting rate (r) is the annual rate of deforestation between the two times.

If we want to calculate the rate of deforestation in a forest area between 2000 and 2020. We would measure the forest area in 2000 (A1) and in 2020 (A2). Let's say the forest area in 2000 was 100 km^2, and in 2020 it was 80 km^2. Please note that this is only an example and not actual data. We would then use the formula like this:

$$r = \frac{1}{2020 - 2000} \cdot In(\frac{80}{100})$$

Because 2020-2000 is 20, we have:

$$r = \frac{1}{20} \cdot In(\frac{80}{100})$$

Using a calculator, you can simply input "ln(80/100)" and get the result.

ln(80/100) is about -0.2231, so we get:

$$r = \frac{1}{20} \cdot -0.2231$$

$$r = -0.011157$$

is -0.011157, which means that the rate of deforestation in this forest area is -1.11% per year between 2000 and 2020. You get the percentage rate of deforestation from -0.011157 by multiplying by 100, as follows: -0.0112 · 100 = -1.11

It is also important to consider reforestation. If there was an increase in forest area due to reforestation, future or current, then A2 would be greater than A1. In this scenario, the value of ln(A2 / A1) would be less negative or, in some cases, positive—indicating a gain in forest cover. Make careful consideration in addressing reforestation, preferably with an interdisciplinary approach. By calculating the rate of change of forest cover using this formula, it will be possible to better understand and compare the impact of deforestation. It is important to clearly indicate the forest area and time of measurements when making such calculations to ensure accurate comparisons.

As mentioned, this is presented only as an example of the logic behind an approach making use of statistics. Deforestation rates are influenced by many complex factors. Additionally, while the Puyravaud formula allows us to quantify deforestation, it cannot fully capture the ecological impact of deforestation. Therefore, it is important to complement quantitative methods such as Puyravaud with qualitative analysis—or use other methods when these quantitative methods are not readily accessible, which is presented next. In this part of the assessment, we must also note that the music industry is not the only industry that uses ebony. Harvesting of ebony and other woods for musical instrument production is just one of many industries that rely on these resources. A provider may supply wood to multiple industries, and the impact of

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[98] — *A **logarithm** is a way of expressing a very large or very small number in a way that is easier to work with. A **natural logarithm** is a type of logarithm that uses the number e (approximately 2.718) as its base. It is used to describe things that grow or get smaller, as in our case with forests. It is often written as "ln", which you can see in the formula, or as "log_e". ln(x) is the number you use as an exponent in e, in order to get the result. E.g. $x = e^{ln(x)}$. (reference: Matematikk.org. (2023). Den naturlige logaritmen. Retrived May 7th, 2023, from https://www.matematikk.org/artikkel.html?tid=193847)*

deforestation needs to be considered from a broader perspective. Even if ebony is not sold to luthiers, it could still be sold to other industries that require it. Therefore, it is important to assess the sustainability of the forestry practices in the region as a whole rather than just focusing on the impact of the music industry. An unsustainable result would still form a conclusion that can be used in our sustainability assessment of musical instruments and in the context of ecoorganology.

A second approach, knowing that the first approach may be too comprehensive, can lead to misinterpretations of the results or not be accessible as a method, is to consider which sustainability indicators we should expect from the suppliers providing the necessary materials. By defining clear expectations, we can establish specific criteria that suppliers must meet. For example, suppliers should demonstrate transparency in their supply chains, providing information on the origin of the materials, traceability and compliance with legal requirements. Another example could be that they should have robust systems in place to verify the legality and sustainability of their products, ensuring that the materials used in instrument production come from well-managed and legally harvested sources. This was, as indicated, a point that proved to be difficult to acquire adequate information on when collecting data from suppliers for the thesis. Based on the research goal and instrument in question, these expectations can vary. There are many frameworks to assess the traceability of a product. One such method involves the use of Environmental Product Declarations (EPD). EPDs is a demonstration of a manufacturer's commitment to transparently measuring and reducing environmental impacts, providing verified data for objective evaluation of their products and services. The indicators of EPDs are different depending on the sector.[99] No EPD was found for musical instruments specifically, so in our example, we will use suggested indicators for furniture. In her article, *Miljødatabase og miljødeklarasjoner for møbler*—Environmental database and environmental declarations for furniture—Annik Magerholm Fet suggests that in accordance with the ISO standards 14025 (ISO, 2004), the following indicators for traceability should be expected from this industry. This list has below been translated from Norwegian.[100]

- Manufacturer, company or wholesaler and their environmental work
- The production process of
- the item's (product's) content
- Material and energy flow in the products
- Maintenance and recycling
- Other information of interest to the manufacturer or company

Based on the traceability results we can form criteria tailored to the specific musical instrument or research goal in question. In our example with instruments from the violin family of instruments, such criteria can be based on the notes from the certifications criteria or local and international laws for ebony trade. This may involve assessing whether the ebony was sourced from sustainably managed forests, whether it was harvested and traded in accordance with international conventions and local laws, and whether the supplier can provide proper documentation and certification to support the

[99] ISO. (2006). Environmental labels and declarations - Type III environmental declarations - Principles and procedures. Retrieved May 15th,.2023, from https://www.iso.org/obp/ui/#iso:std:iso:14025:ed-1:v1:en.

[100] Fet, Skaar, Riddervold, & Norges teknisk-naturvitenskapelige universitet, Fakultet for ingeniørvitenskap og teknologi, *Program for industriell økologi*. (2006). Miljødatabase og miljødeklarasjoner for møbler. *Program for industriell økologi*. http://hdl.handle.net/11250/242695, p.12

legality and sustainability of the material. This approach promotes transparency, responsible sourcing and the preservation of natural resources, contributing to the overall goal of achieving a more sustainable and ethical approach to instrument-making within the violin family.

One potential limitation is the difficulty in acquiring adequate information from suppliers. The lack of transparency in some supply chains and the complex nature of the musical instrument industry—as with any other global industry—can make it difficult to verify the sustainability claims made by suppliers. This can make it hard to create a reliable assessment of traceability and sustainability. As musical instruments and furniture are equally diverse in their use of materials, no adaptation in the factors suggested by has been made in this thesis, apart from removing the factor "The product's potential environmental impact", which is a part of the research goal and does not need to be indicated in this context. This can, however, be a future research point worth delving further into. Defining clear indicators and criteria helps establish accountability and transparency. Using EDPs is considerably easier for musicologists to use as a tool without adequate interdisciplinary knowledge and can be a better alternative in many cases in order to create more uniform results.

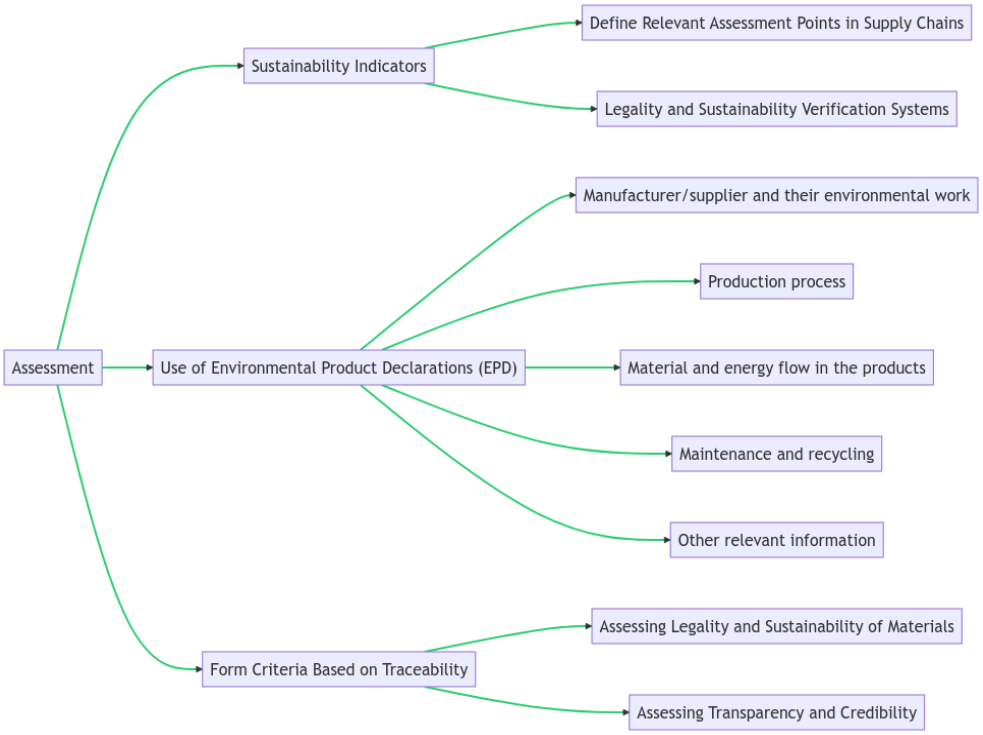

Figure 4: The above diagram shows the suggested indicators/factors found in the second approach that can be used in this part of the assessment.[101]

[101] — *This and other diagrams not cited were created by the thesis author.*

Interdisciplinarity

Puyravauds suggests that "forest loss can be measured using satellite imagery and spatial analyses. The annual rate of change is calculated by comparing the area under forest cover in the same region at two different times".[102] Analysing satellite imagery and spatial analyses should not be done without proper training. An interdisciplinary approach would be beneficial and recommended in this step of the assessment. Analysing satellite imagery and spatial analyses requires specialised knowledge and training. While ecomusicologists/ecoorganologists may not have this expertise, they can work with experts from these fields to ensure that the data they are using is accurate and that the analysis is done correctly. This interdisciplinary approach can help to avoid mistakes and misinterpretation of data, leading to a more accurate and reliable sustainability assessment. A trained expert would also be able to utilise other methods of measuring forest loss, providing numbers we can use in the formula by other means. Interpreting the results is also an important step of the process, which may require an interdisciplinary approach—it can be difficult to know what a 1.11% deforestation rate means in practical terms. Another approach can be to use already established data when available and make informed assumptions, but this may be substantially more prone to errors or misassumptions. Environmental scientists, ecologists and biologists can provide invaluable insights into the ecological impact of deforestation, while social scientists can help understand the social and economic drivers and consequences of deforestation. Together, an interdisciplinary approach can provide a more holistic understanding of the impact on deforestation rates and guide the development of more sustainable practices.

In traceability and sustainability, the interdisciplinary collaboration also facilitates the development and utilisation of tools such as EPDs. EPDs can serve as a valuable tool for them to make informed choices based on verified data and objective evaluation. In order to create EPDs specific to musical instruments, collaboration between various disciplines is essential. Experts from fields such as musicology, environmental science, materials engineering and supply chain management can contribute their knowledge and expertise to develop robust methodologies for assessing the environmental footprint of musical instruments. This interdisciplinary approach ensures that the EPDs encompass a comprehensive set of indicators and criteria that are relevant to the unique characteristics of musical instruments.

3.3 Ecosystem services impact

Ecosystem services are the benefits that humans derive from the natural environment, including goods such as timber, water and food, as well as services such as air and water purification, carbon sequestration and pollination. The production of musical instruments from the violin family relies heavily on the natural environment, including the forests that provide the materials for the instruments. Hence, the sustainability of the production of these instruments must take into account the impact on the ecosystem services of the forests and surrounding ecosystems. In this chapter, we will consider the impact of unsustainable practices on the natural environment and the potential benefits of sustainable practices in promoting the continued provision of ecosystem services for future generations.

Assessing ecosystem services is a complex task that requires a comprehensive understanding of the interactions between various components of an ecosystem. It would be necessary to collect and analyse large quantities of data in order to determine

[102] Puyravaud 2003

the impact of activities on ecosystem services. However, the scope of this thesis and the available resources may not permit a detailed evaluation of all associated ecosystem services or their impacts on them. Therefore, in this thesis, we will make generalisations about the impact on ecosystem services based on available literature and data. These generalisations will provide an overview of the major impacts of musical instrument production on ecosystem services and serve as a starting point for future, more comprehensive research in this area.

In order to get a generalised assessment, we will make some assumptions. In the research used and found for this thesis, there was no specific percentage rate indicated at which deforestation becomes unsustainable. We can assume that it depends on various factors such as the location, type of forest and the reasons for deforestation. The rate of deforestation should, of course, ideally be zero or close to zero in order to maintain healthy forest ecosystems and the ecosystem services they provide. However, some studies suggest that a rate of more than 0.5% per year is considered a 'high deforestation rate country' and used this as a criterion for grouping countries with high and low deforestation:[103]

- High deforestation countries with a deforestation rate of 0.5% per year or more.
- Low deforestation countries with a deforestation rate of less than 0.5% per year.
- Stable or increased forest areas have a deforestation rate of 0 or negative.

Based on the metrics provided by Simula, we can assume that a deforestation rate greater than this, assessed in our last step, will, in the short or long term, have negative consequences on the ecosystem services in a given area.

Deforestation can take many forms, and some are more harmful to the environment than others. One such example is what is known as 'clear-cutting', which involves the removal of all or almost all trees in an area at once. Clear-cutting can have significant impacts on ecosystem services. Removing all or most of the trees in a particular area can cause increased soil erosion and nutrient loss, leading to reduced water quality and decreased soil fertility. It can also result in an increased release of CO_2 and negatively impact the habitat of many wildlife species.[104] Because clear-cutting has such a rapid and negative effect on local environments—and communities that might live in these forests—such practices can be assumed to contribute to the loss of ecosystem services. Clear-cutting can also have an impact on the cultural and recreational value of the area. The visual appeal and natural beauty of a forest can be significantly reduced with clear-cutting, impacting tourism and other recreational activities that rely on a natural environment. In addition, some communities rely on forests for cultural and spiritual practices, such as traditional medicine or religious ceremonies. Clear-cutting can disrupt these cultural practices and negatively impact the social and economic well-being of these communities.

We must also look at mining operations in connection with the steel and/or other metals used. This has, in both small and greater forms of operations, impacts on a local area. While this is significant, this has been included in the cultural sustainability part of the assessment due to its—even more—broad aspects. Here things such as working

[103] Simula, Markku. (2009). REDD Finance Mechanisms – TFD Background Paper, Draft for discussion. *United Nations Framework Convention on Climate Change*, p. 25
[104] Larsen, Øyvind Stranna. (2022). flatehogst. *Store norske leksikon*. Retrived May 8th, 2023, from http://snl.no/flatehogst

conditions and social implications come into play, which in that context can be more concrete to take into account.

Tourism is another important aspect to consider, as it is directly linked to ecosystem services. Many tourists are attracted to natural areas due to their inherent beauty, diverse wildlife and recreational opportunities such as hiking, bird-watching or photography. The degradation of these natural areas due to unsustainable practices in musical instrument production can thus have significant impacts on tourism, which can in turn have economic repercussions, particularly for communities that rely heavily on tourism for their livelihoods.

Note that while we have not been able to provide a detailed evaluation of all associated ecosystem services or their impacts, we have made assumptions based on generalised information. Based on these two points, we can assume that deforestation rates greater than 0.5% per year can have negative consequences on the ecosystem services in a given area and that clear-cutting independently of this can also have a negative impact on ecosystem services in a local area. Furthermore, any form of mining operation would make the area in which this operation takes place inaccessible so that it would be unable to provide any ecosystem services until recovery takes place—if it can recover at all. This reduction or loss of ecosystem services can have severe consequences on the environment and local communities that rely on these services for their livelihood.

Interdisciplinarity

It is also important to remember that this assessment is not a full one, and that further interdisciplinary research is needed to understand the complexity fully. By collaborating with experts in fields such as ecology, forestry and environmental science, we can gain a more nuanced and comprehensive understanding of the impacts of musical instrument production on ecosystems and local communities. Such interdisciplinary approaches can help us form a more solid assessment and identify more sustainable practices for the production of musical instruments, thus contributing to the larger goal of achieving a more sustainable future. Ecosystems and their assessment methods can, as we have seen, be very complex, and a consideration of what is most relevant to the context of the area in question or the focus point of the assessment in total can be beneficial.

3.4 Social and cultural impact

In addition to the environmental impact of the production process, it is also important to consider the social and cultural sustainability of the industry. This includes factors such as working conditions and fair labour practices in the supply chain, as well as engagement with local communities and their involvement in decision-making processes related to resource management. Cultural sustainability is not always a straightforward issue, as it often involves weighing the preservation of one cultural practice against the potential harm caused to another. In the UNESCO report *Intangible Cultural Heritage and Sustainable Development* discusses the importance of cultural heritage and inclusive social development. Cultural sustainability is typically divided into groups of material and immaterial sustainability. Material, or in other words intangible, cultural sustainability are aspects of culture that are not physical, such as language, knowledge and traditions.

Material cultural sustainability can include everything from old monuments to objects,[105] but in our example, forests might hold a spiritual or cultural value themselves which goes beyond only being a service for residents within and in surrounding areas. When it comes to musical instruments, there is a tension between the desire to maintain the authenticity and sound quality of certain instruments and the need to preserve natural resources and indigenous communities. Many traditional instruments, such as instruments in the violin family, as with our case, require hardwoods such as ebony and rosewood for their construction. By taking a holistic approach to sustainability that considers not only the environmental impact but also the social and cultural aspects, the harvest process can become. The immaterial cultural sustainability has many similarities to social issues such as human rights and social justice, as outlined by Axelsson et al.[106] In their article, they try to establish criteria that go beyond the traditional focus on material and cultural heritage, using both material and immaterial aspects. The aspects can be quite complex to encompass in our assessment. A generalised assessment of social and cultural sustainability would involve examining various aspects related to the social and cultural impact. It would involve analysing the consequences for local communities, indigenous populations and marginalised groups. Factors such as livelihoods, health, education and equity can be considered to assess the broader social implications. Axelsson et al. also point out that social and cultural criteria have been described in detail before, but the integration in political decisions has been small, revealing a significant gap between awareness and action. Cultural sustainability, encompassing values, traditions, and practices, plays a vital role in shaping societies, yet its incorporation into comprehensive policies are still limited.

By using these indicators to a lesser or greater extent, we may be able to form a general idea of the cultural sustainability of the industry. For instance, in the engagement of local communities in the decision-making processes related to resource management, this involvement can ensure that the communities are able to protect and preserve their cultural heritage and practices while also benefiting from the economic opportunities provided by the industry. In addition, the use of sustainably sourced materials, such as legally harvested ebony, can also indicate cultural sustainability. This is because the use of these materials supports the preservation of the traditional practices of harvesting and using these resources, which sometimes can be deeply related to local cultures and histories. However, it is important to note that these indicators may not be applicable in all contexts and that a more comprehensive assessment of cultural sustainability would require more specific and nuanced data—as with the other factors, but to a greater extent. In an article discussing *Cultural sustainability as a strategy for the survival of museums and libraries,* Kirsten Loach points out the importance of seeing the complexity in the cultural systems at place:[107]

[105] UNESCO. (n.d.). *What is Intangible Cultural Heritage?.* Retrieved June 4th, 2023, from https://ich.unesco.org/en/what-is-intangible-heritage-00003

[106] Axelsson, R., Angelstam, P., Degerman, E., Teitelbaum, S., Andersson, K., Elbakidze, M., & Drotz, M. K. (2013). Social and Cultural Sustainability: Criteria, Indicators, Verifier Variables for Measurement and Maps for Visualization to Support Planning. *Ambio, 4*2(2), 215-228. https://doi.org/10.1007/s13280-012-0376-0

[107] Loach, K., Rowley, J.,; Griffiths, J. (2016). Cultural sustainability as a strategy for the survival of museums and libraries. *International Journal of Cultural Policy, 23*(2), 186–198. https://doi.org/10.1080/10286632.2016.1184657

> *Just as an acute awareness of complex ecosystems and the careful management of ecological resources underpins environmental sustainability, so there would seem to be an increasing recognition that a similar approach is required for our cultural systems in order for cultural sustainability to be possible. If culture is as fundamental to enabling a sustainable society as has been suggested, then more strategic methods of encouraging cultural vitality and managing our cultural heritage, as key components of the fourth pillar, would certainly seem necessary.*

In looking at the impact on cultural sustainability practises in the industry, we can hence look at it as a contribution to finding ways of assessing this fourth pillar of sustainability. While environmental, social, and economic pillars have traditionally dominated sustainability discussions, as we detailed earlier, the inclusion of cultural sustainability as a fourth pillar recognizes the vital role of culture in shaping sustainable communities. By developing robust indicators and methodologies for assessing cultural sustainability, we better the understanding of the complex interplay between culture, music and sustainability. This makes it possible to identify areas for improvement, drive positive change and develop strategies that prioritise preserving cultural practices.

We briefly looked at one example of the assessment of cultural sustainability earlier in the thesis through the study conducted by Rebecca Dircksen. She spent many years living and studying in Haiti and maintains a residence there with Haitian family and friends. This long-term engagement with the local context provides a deep understanding of the cultural, environmental and dynamics affecting the tanbou and the trees used in their construction. The research was followed by an exhibition at the Mathers Museum of World Cultures featuring the Haitian drums made by Charles Charlesine, a master drum maker from the Artibonite region of Haiti. The participants also had the opportunity to engage with the exhibition *Sacred Drums, Sacred Trees: Haiti's Changing Climate,* which featured photography by Haitian filmmaker Kendy Vérilus and was curated by Dirksen.[108] These methods reflect an interdisciplinary approach that combines ethnographic fieldwork, immersive cultural experiences and exhibition practices to explore the meeting points of environmental change, cultural heritage and spirituality. While not comprehensive to the full extent suggested in this framework, it stands as an example of the incorporation of cultural sustainability. Dricksen highlights the spiritual values of the forests used to create the equally culturally valuable tanbou drums. Her exploration of the sacred nature of the forests, and their role in crafting the tanbou drums, illustrates the deep cultural and spiritual significance that these resources hold. The threat that deforestation and climate change pose to these forests is hence not only an environmental issue but also a matter of cultural survival. The sustainable management of forests becomes an important not only for ecological matters but also for the preservation of the Haitian cultural heritage embodied in the tanbou drums. In this context, the concept of cultural sustainability extends beyond the conservation of a cultural artefact – the tanbou drum – to the preservation of cultural practice—and, more broadly, a way of life.

[108] Keck, Mary. (2019). Vodou drums symbolize clash between climate change and the sacred in Haiti. *News.Iu.Edu*. Retrieved June 9th, 2023, from https://news.iu.edu/live/news/26054-vodou-drums-symbolize-clash-between-climate-change

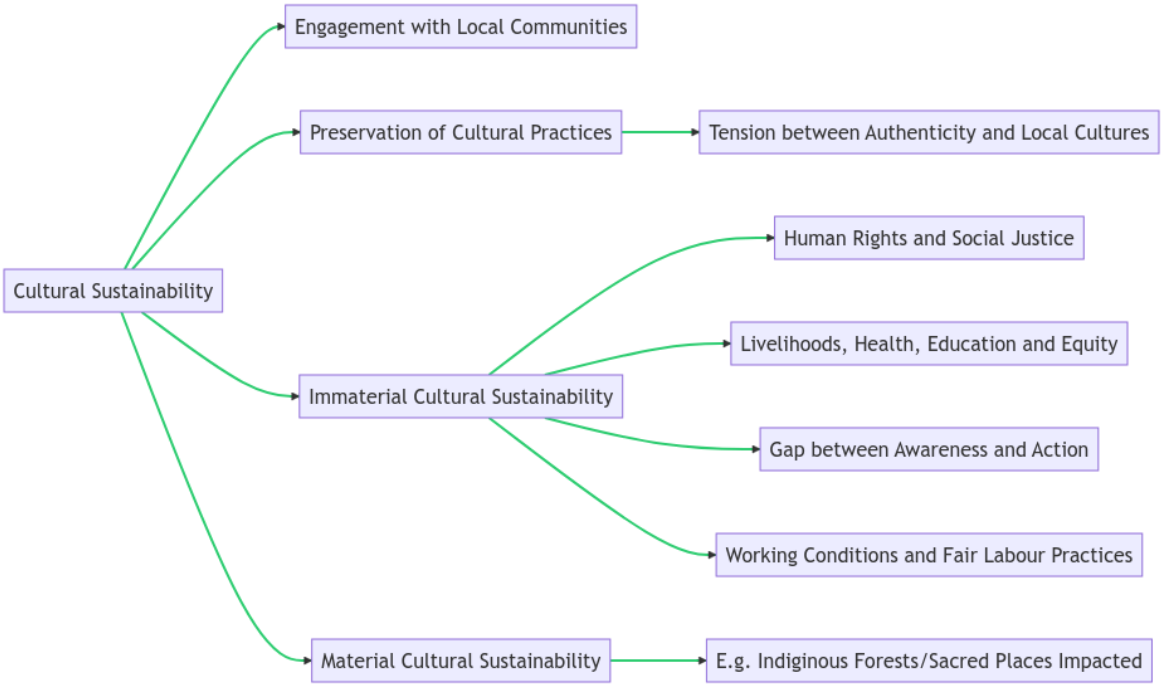

Figure 5: The following diagram shows the suggested indicators/factors we can look at when assessing cultural sustainability. Please note that the examples of immaterial and material sustainability are only that—examples. Furthermore, it is important to remember that the tension between authenticity and local cultures can be especially relevant for musical instruments, depending on which instrument is being assessed, as both cultures independently want to be persevered—this should be looked at on a broader scale when working on other indicators/factors.

Working conditions are also an aspect worth assessing when looking at the cultural aspects. For this, we can take the mining operations used for acquiring steel and/or other materials for strings and other metal parts as an example. Mining operations can have severe environmental consequences, including deforestation, soil erosion, water pollution and habitat destruction. Additionally, the extraction of metals often involves hazardous working conditions, labour exploitation and human rights violations.[109] These impacts cannot be overlooked when considering the sustainability of steel and other metals used in musical instruments. It is important to ensure responsible mining practices, ethical sourcing and fair trade in the supply chain of these materials. While these issues are not exclusive to the music industry, it should not be neglected or overlooked. By addressing the social and environmental aspects of mining operations, the music industry can contribute to a more sustainable and socially responsible supply chain in all sectors. This requires transparency, accountability and a commitment to continuous improvement in the sourcing and production of musical instruments.

As we can see, considerations need to be made. While it may seem necessary to examine every aspect of social and cultural issues, it is more beneficial to focus on the

[109] Allen 2023, p. 24-25

specific areas that have the greatest impact on the cultural sustainability of musical instruments. By identifying the specific social and cultural aspects that have the most significant impact on the cultural sustainability of the violin family of instruments, we can direct research towards the areas that truly matter. This targeted approach allows for a deeper understanding of the critical challenges within the industry, making it easier to promote the development of effective strategies for sustainable practices. Cultural preservation and the maintenance of traditional craftsmanship are inherent to the music industry's identity and heritage. Balancing the need for sustainability with the preservation of cultural practices requires thoughtful and sensitive approaches. We must recognize and respect the cultural significance attached to musical instruments and the impact that changes in production practices may have on cultural expressions and artistic traditions.

Interdisciplinarity

Assessing cultural sustainability in a generalised—or even in a detailed—manner can be a challenging task, especially without fieldwork and with the knowledge that this is a field still in development. We must acknowledge that this assessment is not definitive and that further non-interdisciplinary and interdisciplinary research is needed to fully understand the complex interplay between musical instrument production, cultural sustainability and environmental impacts. As the assessment and implementation of cultural sustainability are still in its beginning stages, working with researchers in related fields can help to form a more solid assessment and identify more sustainable practices for the production of musical instruments. This would be the part of our sustainability assessment that musicologists are best equipped to handle within their field of knowledge. Still, working with other fields equipped for assessing the indicators will be beneficial, such as anthropology or other humanities aimed at researching interplay in cultures and societies. These fields bring expertise in understanding the intricate dynamics of cultural practices, identities and social interactions. By working together, musicologists can gain valuable insights into the broader cultural implications of instrument production, ensuring a more comprehensive assessment that encompasses the social, economic and political dimensions.

It is worth noting that this is a factor where generalising too much can lead to unreliable results. For example, using indexes such as the Labour Rights Index can give you an idea of how markets in your specific country or area compare with others.[110] This does, however, may not apply to specific suppliers. Hence, in order to obtain an accurate assessment of the working conditions and fair labour practices within the supply chain for the production of musical instruments, it is important to conduct research on individual suppliers. A more comprehensive and interdisciplinary approach can include interviews with employees and suppliers, as well as site visits to assess the working conditions and labour practices in person. A less comprehensive approach can base assumptions on certifications targeted at such factors. It is also important to consider the different stages of the supply chain, from harvesting to manufacturing, as each stage may have different labour practices and working conditions.

[110] WageIndicator Foundation & Centre for Labour Research. (2022). Labour Rights Index: Labour Law for 135 Countries Covered in One Global Index. *WageIndicator*. Retrieved May 9th, 2023, from https://labourrightsindex.org/

4 Discussion—implications, challenges and recommendations

It has become apparent that a comprehensive approach is necessary to address the diverse types of issues involved. Hence, we must focus on the practical steps that can be taken to promote sustainable material sourcing, develop robust certification processes, raise awareness and education, promote collaboration and interdisciplinary research, as well as influencing policy and regulation. In this chapter, we will look at the practical implications that the research findings from the framework in this thesis can create so that we can translate the theoretical framework into actionable steps towards a more sustainable future for musical instrument production. Building upon the knowledge gained throughout the research, we will look closer at the measures that can be taken by industry stakeholders, policymakers, musicians and consumers to create environmental and cultural sustainability within the manufacturing of musical instruments.

4.1 Breaking traditional barriers

Before we look at how the suggested framework and sustainable practices can be used, we should first question why such measures have not yet been established or even research to a greater extent. Despite growing awareness of environmental and social concerns, it is evident that progress towards sustainable practices in music production has been slow and limited. This would be a discussion natural to include in assessing the gap between awareness and action, as indicated in the previous chapter.

In general terms, 'culture' and 'tradition' are important keywords in this context. As we have explored earlier, such as in the article on the Italian forest of violins Val di Fiemme, myths can be a significant contributor to resistance towards change. The weight of tradition, whether in the form of a legendary Stradivarius violin or an iconic vintage recording studio, can act as a substantial roadblock to the adoption of more sustainable practices. Based on the literature we have reviewed in this thesis, we can break this down into a few key points:

1. Music, like many other art forms, is steeped in tradition and culture. In many cases, these traditions are closely linked to specific materials or processes, some of which may not be environmentally friendly. The mythology surrounding certain practices can make it difficult to introduce changes. A Stradivarius violin, made from wood from the Val di Fiemme, is often considered the pinnacle of violin craftsmanship,[111] but can have harmful implications on the local forest. Myth-based beliefs can lead to resistance to change and the adoption of more sustainable practices.
2. Despite growing awareness of environmental issues, there is still a significant gap in understanding how these issues intersect with music production. Many musicians and producers may not be aware of the environmental impact of their practices or know about more sustainable alternatives. We can theorise that this may have contributed to the focus point of most sustainability research within musicology until recently has been on how music acts as a tool for promotion rather than being a part of the issue, as indicated by Vinge et al.[112]

[111] Alle 2012, p. 311
[112] Vinge et al., p. 248

3. Economic factors may also play a role. Empirically, sustainable practices can sometimes—but not in all cases—be more expensive in the short term, making them less appealing in an industry that often operates on tight budgets. We can also theorise that out of necessity, local cultures which make a living of exporting materials that are considered as endangered may also find it difficult to find other incomes.

A common theme in all barriers is resistance to change, which is a well-documented psychological phenomenon. This can hinder the success of any change process. A study by Pardo et al. examines various sources of resistance to change and their impact on evolutionary and strategic changes. The research identifies that 'deeply rooted values" are a powerful source of resistance. They suggest that change leaders—as in the ones who drive change—should address these sources of resistance. While this particular study was aimed at work and organisational culture, it can also be carried over to other areas.[113] The issue of resistance towards change is, as you can see, not unique to the music industry and can be applied to almost any other. A very recent example historically is the change from fossil fuel cars to electric. Such changes have been met with significant resistance due to a variety of reasons. Much like in the music industry, people are often comfortable with what is familiar and resistant to change. Despite the benefits, many people were hesitant to make the switch due to uncertainty or unfamiliarity with the technology. Many people also had concerns about the driving range of electric vehicles, fearing they would not be able to travel as far on a single charge as they could with a tank of gasoline. Similarly, just as the sound of the Stradivarius violin is often romanticised in the music industry, the performance and 'feel' of a gasoline-powered car are sometimes perceived as being better than electric vehicles. Some individuals believe that electric vehicles cannot provide the same power, speed, or driving experience as traditional cars. The factors have been suggested to be mostly cultural. In research, language similar to what is being used to describe 'authentic' instruments are also being applied to vehicles, such as 'soul and character'.[114] However, with the emergence of new technology that disproved many of these concerns, the resistance to change gradually slowed down. In the same way, research in new materials, in our case example for instruments in the violin family, has been shown to alleviate many of the mentioned concerns. The main point of interest can hence be seen in turning the information available—or alternatively, the information derived for the sustainability assessment—into actionable steps.

The journey towards sustainability in any industry, including music, has many complexities that range from cultural and traditional barriers to economic factors and lack of awareness. But it is also a journey marked by immense potential for positive change. The knowledge and insights gained from this research can serve as a way to navigate our way. By understanding and addressing the obstacles that stand in the way, we can begin to shift from resistance to acceptance and action. The next steps involve translating this understanding into measures that can effectively bridge the gap between awareness and action in music production.

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[113] Pardo del Val, M., & Martínez Fuentes, C. (2003). Resistance to change: A literature review and empirical study. *Management Decision*, *41*(2), 148–155. https://doi.org/10.1108/00251740310457597

[114] Krishna, G. (2021). Understanding and identifying barriers to electric vehicle adoption through thematic analysis. *Transportation Research Interdisciplinary Perspectives*, *10*, 100364. https://doi.org/10.1016/j.trip.2021.100364.

4.2 Counterarguments and framework challenges

Implementing a sustainability framework in any industry can pose many challenges, particularly in industries where sustainability practices have not traditionally been researched to a greater extent. The music industry, including musical instrument production, is one such industry where the integration of sustainability measures has been relatively limited until recently. This chapter will try to outline potential challenges and implications of the framework presented, both in performing the assessments and in using the findings derived from it.

4.2.1 In research and teaching

Although the framework asserts that interdisciplinarity can be beneficial—and sometimes necessary—in order to form a solid assessment, it can still be a weak point. The framework encompasses many dimensions, including environmental impact, social sustainability, cultural sustainability and economic considerations. While this comprehensive approach may be desirable, it may also introduce complexity and require significant effort to gather relevant data and assess each individual aspect thoroughly. As indicated, data availability can also be a challenging point. Assessing sustainability requires reliable and up-to-date data from various sources, such as suppliers, manufacturers and certification programs. A potential challenge is the lack of transparency and availability of such data, particularly in complex and global supply chains. Acquiring accurate data may prove challenging, which can bring to light incomplete or inaccurate assessments.

The framework acknowledges the need for interdisciplinary collaboration. It underscores the importance of bringing different fields of study to generate comprehensive solutions. However, it also emphasises the difficulties that may arise in the process of creating effective collaborative efforts and communication between diverse disciplines. Therefore, bridging these gaps and initiating productive interdisciplinary dialogue can often demand some effort. This is especially true when the collaboration attempts to bring together the humanities and STEM (Science, Technology, Engineering and Mathematics) fields—two areas that have historically different sets of methodologies and perspectives. In the realm of education, an emerging trend is the integration of STEM within the humanities. However, this concept often faces resistance from some educators within the humanities. Their resistance can be rooted in a perceived incompatibility of the sciences with the humanities or a fear that the integration of STEM disciplines into their curriculum could dilute the importance of humanistic studies. However, with STEM education receiving substantial funding and support, humanities teachers are prompted to reflect on their role in response to the promotion of STEM programs.[115] Looking back to our beginning chapters, where Allen talked about some of the same approaches, we can retrace the aspects that should be considered when incorporating sustainability—and with that, we can include STEM: 1) embracing the change-oriented meaning of sustainability, 2) recognizing the foundational role of the environment, 3) viewing sustainability as a framework or lens and 4) incorporating aesthetics into sustainability discussions. Having similar aspects to go by in research can help alleviate many of these issues.[116] The integration of STEM or 'scientific

[115] Gleason, D. W. (2018). The humanities meet STEM: Five approaches for humanists. *Arts and Humanities in Higher Education, 19*(2), 186–206. https://doi.org/10.1177/1474022218806730
[116] Allen 2019

fields' in musicology is not a new thought. In their article *Coupling Scientific and Humanistic Approaches to Address Wicked Environmental Problems of the Twenty-first Century: Collaborating in an Acoustic Community Nexus* the article authors Jennifer C. Post and Bryan C. Pijanowski discusses the integration of soundscape ecology and sound studies in ethnomusicology, combining the strengths, tools and fresh perspectives from both fields. They recognize that planning and implementing collaborative scientific and humanistic work is challenging due to differing methods, conflicting values related to the roles researchers play and different analytical techniques and platforms. In order to overcome this, they propose—in their own example of acoustic community—finding common grounds and creating new disciplines. The authors aim to make use of the collective strengths, innovative tools and fresh perspectives from both fields. This fusion intends to create a new model that can effectively address emerging environmental problems. The first part of their solution is finding common ground, which involves discovering shared objectives, methodologies, or questions that both fields of study can align with. This would pave the way for effective communication, shared understanding, and, eventually, productive collaboration. The second part, creating new disciplines, is an ambitious but necessary step. It involves the formulation of academic areas that naturally merge different fields, thereby reducing the friction that can result from attempting to force different academic cultures, terminologies, and methodologies to work together. By applying this two-pronged strategy, the authors believe that it's possible to foster successful interdisciplinary collaboration between the scientific and humanistic fields.[117]

Awareness and education play important roles in any form of change. Increasing awareness among musicians, consumers and the general public about the environmental and cultural impact of instrument production is essential. Empirically, when promoting and debating the research with other musicians and institute of music members, few have thought about the consequences in the music industry. By highlighting the consequences of unsustainable practices, individuals can make more informed choices. Education is an important part of making musicians and consumers prioritise sustainability. By educating about the importance of selecting sustainably produced instruments, we can recognize the long-term benefits for both the environment and cultural heritage. This education can encompass information about responsible sourcing, certification programs and the significance of supporting luthiers who prioritise sustainable practices. Making use of frameworks in creating educational materials can help to structure and deliver content. Additionally, partnerships with environmental organisations and experts can provide valuable resources and expertise to further enhance educational initiatives. Through increased awareness and education, the music industry can create a commitment to sustainability, driving positive change and creating a more sustainable future for instrument production.

[117] Post, J. C., Pijanowski, B. C. (2019). Coupling Scientific and Humanistic Approaches to Address Wicked Environmental Problems of the Twenty-first Century: Collaborating in an Acoustic Community Nexus. *MUSICultures*, *45*(1-2). p. 71-73.

4.2.2 In practice

Implementing measures in the music industry, particularly among instrument manufacturers and suppliers, may face resistance due to traditional practices, cost implications and a focus on traditional craftsmanship. This also applies to the customers of the industry, who also need to overcome a resistance to change. Musical instruments are not just functional objects—they also possess cultural and artistic significance. Balancing the sustainability goals of material sourcing, manufacturing processes, and environmental impact with artistic considerations, such as sound quality and traditional craftsmanship, can present challenges. Finding sustainable alternatives without compromising the artistic integrity of instruments may require innovative solutions and ongoing research. When evaluating the results of the framework, we must also explore the cultural and traditional barriers that may hinder change and the reluctance of some stakeholders to adopt sustainable practices. Address the concerns or scepticism that may arise regarding the feasibility, cost or perceived impact on the culture of music.

While implementing measures at the level of instrument manufacturers and suppliers is important, it may face obstacles due to resistance to change and concerns about the impact on traditional craftsmanship and cultural significance. Instead, targeting regulatory frameworks and industry-wide standards can provide a more comprehensive and effective approach to promoting sustainability. By establishing clear guidelines and requirements for material sourcing, manufacturing processes and environmental impact, regulatory measures can create a level playing field and encourage industry-wide adoption of sustainable practices. Additionally, addressing cultural and traditional barriers to change can help overcome resistance and create a shared commitment to sustainable development. Such ways have been proven to be effective in other industries, such as in our example of the change from fossil fuel cars to electric. This can be seen as an inspiration for the music industry to follow. By implementing regulatory measures, similar to those that have successfully driven the transition to electric vehicles, the music industry can accelerate its progress towards sustainability. These measures can include establishing mandatory environmental standards for instrument production, promoting responsible sourcing of materials and incentivizing the adoption of sustainable practices through tax benefits or subsidies. By learning from the successes and challenges faced by other sectors, the music industry can leverage the power of collective action to create a more sustainable future.

But—while regulatory measures can be effective in driving sustainability in the music industry, it is important to recognize the need to preserve cultural heritage and artistic traditions. The music industry is not just a commercial enterprise; it encompasses rich cultural practices, diverse musical genres and centuries-old traditions. We can assume that it would be beneficial to strike a balance between environmental goals and the preservation of culture. This could involve musicians, instrument makers and other stakeholders in the regulatory process to ensure that sustainability measures do not undermine the cultural significance and artistic quality of musical instruments. By addressing the concerns of preserving cultural heritage alongside sustainability, regulatory measures can effectively support the long-term sustainability of the music industry while honouring its rich traditions and artistic expression.

4.2.3 Counter-arguments

There are not many counterarguments to promote more sustainable practices in the music industry. One such argument could be that it makes it harder to preserve cultures and traditions that have been built around the use of specific materials or techniques in instrument production. Many traditional methods have been passed down through generations, and changing them could be seen as a loss of cultural heritage—such as in the case with the traditional drums Dircksen investigated or even Western instruments in the violin family. These are rooted in centuries-old customs and practices. Altering these could potentially disrupt the transmission of such artisanal knowledge and the preservation of these traditions. Another counter-argument might be related to the perceived quality and performance of the instruments. Musicians and instrument makers often hold strong beliefs about the superior acoustic properties of certain materials. Changing these materials could potentially affect the sound quality, playability, and longevity of the instruments, aspects highly valued by musicians. There may also be scepticism about the actual impact of the music industry on global environmental issues. Some might argue that the music industry, specifically in terms of instrument manufacturing, represents such a small fraction of overall global wood consumption and greenhouse gas emissions that efforts to improve sustainability within this industry might have a negligible effect on the overall problem.

However, these counter-arguments should not deter efforts to promote more sustainable practices in the music industry. While preserving cultural heritage and maintaining high-quality musical instruments is undoubtedly important, these goals must be balanced with the need to protect our environment and ensure the sustainability of resources for future generations. As for the argument of scale, every industry and sector contributes to global environmental issues—and every effort towards sustainability counts. The music industry, given its global reach and influence, has the potential to set a powerful example for others to follow. Sustainability efforts in this sector can also contribute to broader societal shifts towards responsible consumption and environmental awareness.

4.2.4 Finding the focal point

When considering the actionable steps derived from the sustainability framework, it can be beneficial to determine the ultimate goal we seek to achieve. Is our aim primarily focused on preserving the forest, protecting endangered species and local cultures, or do we strive to establish a more sustainable musical instrument industry as a whole? Both objectives are significant, but they may require different approaches and initiatives. By clarifying our goals and implementing the appropriate measures, whether through regulatory changes or industry-driven initiatives, we can make significant strides towards preserving forests, protecting endangered species, and building a more sustainable future for the musical instrument industry.

If our primary concern is the preservation of forests and the conservation of endangered species, regulatory changes and restrictions can be seen as more impactful, as they target the source issue and all manufacturers. It also acknowledges that materials may also be used in other industries, such as we have seen in the example of ebony. This might involve creating stricter legislation on the sourcing and trade of certain wood species, establishing protected areas for endangered species and strengthening enforcement mechanisms to combat illegal logging of CITES species—or species by other

measures concerned as endangered.[118] These regulatory measures aim to address the root causes of environmental degradation and biodiversity loss, providing a legal framework to safeguard valuable ecosystems and species. Additionally, as we discussed in the chapter on the allocation of resources, prioritising luthiers who create instruments with a larger lifespan—as opposed to factory manufacturers—in the allocation of endangered resources can contribute to an overall sustainable use of the available materials.

On the other hand, if the focus is on creating a more sustainable musical instrument industry, the responsibility lies with luthiers and instrument sellers. It creates the need for a shift in their practices and business models—which includes incentivising a change in how customers perceive it, as in our example from the vehicle industry. Luthiers should adopt sustainable sourcing strategies, such as using certified wood from responsibly managed forests, promoting ethical and transparent supply chains and exploring alternative materials with lower environmental impacts. They can also prioritise craftsmanship techniques that maximise the lifespan and durability of instruments, reducing the need for frequent replacements. Additionally, raising awareness among musicians, customers and industry stakeholders about the importance of sustainability can drive demand for instruments, either from a selling or consumer viewpoint.

While researchers play a role in providing information and insights, it is important to recognize that our responsibility lies primarily in generating knowledge and informing decision-making processes. Researchers can contribute to the understanding of complex issues, identify challenges and propose potential solutions. However, the actual implementation of change and the adoption of sustainable practices ultimately lies with relevant stakeholders, such as luthiers, large manufacturers, policymakers and consumers. Researchers can serve as contributors to change by showing their findings, advocating for informed decisions and policies and promoting collaboration among different stakeholders.

4.3 Awareness and education

Awareness and education play important roles in the change. Increasing awareness among musicians, consumers and the general public about the environmental and cultural impact of instrument production is essential. Empirically, when promoting and debating the research with other musicians and institute of music members, few have thought about the consequences in the music industry. No studies have been found that address this. By highlighting the consequences of unsustainable practices, individuals can make more informed choices. Education is an important part of making musicians and consumers prioritise sustainability. By educating about the importance of selecting sustainably produced instruments, we can recognize the long-term benefits for both the environment and cultural heritage. This education can encompass information about responsible sourcing, certification programs and the significance of supporting luthiers who prioritise sustainable practices. Making use of frameworks in creating educational materials can help to structure and deliver content. Additionally, partnerships with environmental organisations and experts can provide valuable resources and expertise to further enhance educational initiatives. Through increased awareness and education, the music industry can create a commitment to sustainability, driving positive change and

[118] — 'by other measures' indicates, for example, red lists internal for a specific country, as with our example of East Indian ebony (Diospyros melanoxylon), red-listed in The National Red List 2012 of Sri Lanka, in chapter 2.2.1

creating a more sustainable future for instrument production. A good example of an initiative that aims to promote awareness is the exhibition curated by Rebecca Dircksen, as we explored earlier. In an interview, Dircksson highlights the positive outcomes of such initiatives:[119]

> "My greatest hopes are that visitors to the exhibition will come away with enhanced appreciation for the sacred interactions between people and their environment," Dirksen said. "My aim is to help demystify Haiti as a place and Vodou as a metaphysical worldview, and to help people see the beauty of these drums – in terms of Charlesine's exquisite craftsmanship, but also in that these instruments are made from materials from the natural world and are used to bring about communion with the spiritual forces."

In promoting knowledge, there is even more room for interdisciplinary strategies. These projects, like the one showcased in Dircksen's case, create a platform for exploration and expression. Traditional learning methods can play a role in educational settings, but there is also value in including artistic projects that engage individuals on a different level. By integrating art, music and other creative mediums into sustainability education, we can engage audiences in a more emotive and immersive way, encouraging them to reflect on the interconnectedness of environmental, social and cultural dimensions. This is especially relevant in our case, as these mediums are a part of what we are trying to preserve and promote. These interdisciplinary strategies allow us to tap into different learning styles and perspectives, reaching a wider range of individuals and fostering a deeper connection to the subject matter. Artistic projects also offer a unique avenue for self-expression and storytelling, which makes participants able to explore complex sustainability issues in a personal and meaningful way. In light of the specific preferences for woods originating from particular locations, such as the Italian forests exemplified by Allen[120] or the French trees mentioned by Pickett[121], it is also crucial to promote awareness among the practitioners of the music cultures themselves so that we can further explore those preferences often based on tradition, anecdotal evidence or undocumented claims, rather than on scientific research or empirical data. This poses a challenge for both researchers and practitioners in the field, as it highlights the need for more robust studies that can accurately assess the acoustic properties of different woods and the potential alternatives that could be used in instrument production.

[119] Keck 2019
[120] Allen 2012, p. 30
[121] Pickett, p. 527

4.4 Acknowledging the broad nature of the issue

The sustainability challenges that the music industry is facing are not isolated but rather part of a broader issue that extends beyond the boundaries we have explored in this thesis. While the music industry may appear as a small piece in the larger puzzle, it is important to recognize its interconnectedness with other industries and the collective impact they have on the environment. As in our example of ebony wood, we may presume that unsold wood will be used for other industries, such as the furniture industry. We can draw lessons from successful sustainability initiatives in other industries, such as the example from vehicles, recognizing that the best practices can be applied to the music industry—and vice versa. We also consider the policy and regulatory landscape that shapes sustainability practices, highlighting the importance of policies and regulations that carry across multiple sectors in order to create change.

In creating the suggested sustainability framework, this was addressed. Looking at the assessments as a contribution to our understanding of the broader sustainability challenges, we acknowledge that the issues facing the music industry are not solely within the music industry's control. The production and distribution of musical instruments involve complex supply chains that span across multiple sectors, including forestry, manufacturing, transportation and retail. Each sector contributes to the environmental impact, social aspects and economic dimensions of instrument production—and our framework only assessed the forestry impact of that production.

Therefore, we must acknowledge the broader nature of the issue and recognize that addressing sustainability in the music industry requires collaboration and cooperation among various stakeholders. We could also argue that the music industry, due to its cultural significance and global reach, is in a unique position to influence attitudes and behaviours towards sustainability.

Additionally, while this thesis has mainly focused on the use of wood in the manufacturing of traditional musical instruments in the violin family, we must recognize that other materials and components used in the production process also have environmental implications. Metals, plastics and various chemical substances used in finishes and adhesives also contribute to the ecological footprint. This can be especially relevant for modern instruments, where these materials are increasingly utilised. These alternative materials may offer potential advantages, such as durability, affordability and a different aesthetic and/or cultural appeal. However, their extraction, processing and disposal also present a range of environmental challenges that need to be comprehensively reevaluated. Beyond the material considerations, there are also sustainability implications in the transportation and distribution of musical instruments. From the transportation of raw materials to manufacturers, through to the distribution of finished instruments to retailers and consumers, each stage of the process has associated carbon emissions. Innovations in packaging, logistics and retailing could help to reduce these impacts. Studies such as the one by Meincken et al. on a locally produced African violin is a good example of such studies.

5 Conclusions

While the thesis has focused mainly on the use of wood in the production of musical instruments in the violin family, it is important to consider the broader sustainability implications associated with the use of other materials, modern manufacturing technologies, distribution practices and end-of-life management. By taking a holistic approach to sustainability in the music industry, we can work towards solutions that balance the needs of musicians, the environment and future generations. In analysing the current state of sustainability within the music industry, particularly within the realm of violin family instruments, we have seen the complex interplay of ecological, social and economic factors. Addressing these interconnected challenges requires a multi-faceted approach and a commitment from various stakeholders. This includes manufacturers, suppliers, musicians, consumers and policymakers—each of whom has a vital role to play. One of the key findings of this research is the need for more transparency and better data collection within the supply chains of musical instrument manufacturing. This will allow for more accurate assessments of environmental impacts and help identify areas where sustainability improvements can be made. It is clear that without such transparency, meaningful progress will be difficult to achieve. This thesis has also highlighted the need for continued research and innovation in identifying and testing sustainable alternatives for traditional materials used in instrument production. Not only should these alternatives meet environmental criteria, but they must also satisfy the quality and performance standards expected by musicians. Education and awareness is also crucial in driving change within the industry. Musicians, as end consumers, can have a considerable influence on market demand. By providing them with information about the environmental impacts of their purchasing decisions, we can contribute to choosing more sustainable options. At the same time, in line with the broad nature of the supply chains, the policy and regulatory landscape also play a significant role in shaping industry practices. Advocacy for policies that promote sustainable wood sourcing, responsible manufacturing practices and recycling or repurposing of old instruments—the latter of which is already a part of the instrument culture—can help drive systemic change within the industry.

The framework proposed in this thesis serves as a guide and a tool to understand, assess and improve sustainability in the music industry, particularly with respect to musical instruments in the violin family. It provides a structure for systematically analysing the various stages of instrument production—with a focus on sourcing of materials—and identifying opportunities for sustainability improvements. One of the strengths of this framework is its flexibility. It can be adapted and refined based on new information or changing circumstances—and may also be extended to other groups of instruments. As sustainability is a dynamic field with continuous advancements in research and technology, this adaptability will allow the framework to remain relevant and effective over time. The framework also encourages an interdisciplinary approach, recognizing that sustainability encompasses not just environmental considerations but also social and economic aspects. This holistic view is crucial for developing solutions that are not only ecologically sound but also socially equitable and economically viable. Additionally, the framework highlights the importance of stakeholder involvement and collaboration. Achieving sustainability in the music industry is a shared responsibility that requires the active engagement of all parties involved, from wood suppliers and instrument manufacturers to musicians and policy-makers. By providing a common structure for understanding and addressing sustainability issues, the framework can facilitate communication and cooperation among these diverse stakeholders.

One distinguishing aspect of this thesis is its interdisciplinary perspective. By integrating knowledge and methodologies from different fields, such as biology, ecology, social science, economics—and musicology, a more comprehensive understanding of sustainability in the music industry can be achieved. This interdisciplinary approach is essential for addressing the many challenges and identifying effective strategies for sustainable practices.

Despite its strengths, the proposed framework is not without its limitations. One critique may be that the framework, while comprehensive, may be complex for practical application among musicologists. Stakeholders with limited resources or knowledge may also find it challenging to implement the suggested actions or may struggle to interpret and apply the various sustainability criteria. Another potential limitation is the framework's heavy reliance on transparent and reliable data. As highlighted earlier in this thesis, there are significant gaps in data availability, especially when it comes to supply chains and the environmental impacts of different production stages. Without this data, the utility of the framework could be limited. The framework also assumes a high level of cooperation and willingness among stakeholders to commit to sustainability efforts. However, in reality, there may be resistance due to economic constraints, cultural preferences or a lack of awareness about the importance of sustainability. Overcoming these barriers will require considerable effort and persistence. The framework, while adaptable, may also not account for all possible future trends and developments, such as new manufacturing technologies or materials—such as carbon fibre, which is already in use—changes in market demand or emerging environmental issues. A practical implementation may furthermore pose challenges for stakeholders with limited resources or expertise. Additionally, the reliance on transparent and reliable data presents a significant challenge. Overcoming these limitations requires continued research, awareness and commitment from all parties involved. Another critique could be that economic structures always pave the way and that expecting more would not be realistic. This is, however, exactly where our structural changes need to be taken into action. Kyle Devine talks about this in a published interview titled *Sustainability, Solutionism, and the Problem of Music*, where he talks about his two publications *Decomposed* (2019) and *Audible Infrastructures* (2021)—which we have touched upon earlier in the thesis. In the interview, Devine discusses the transformation of the music industry in response to the climate crisis. He critiques the "solutionism" that focuses on economic solutions within capitalism, and argues that these approaches may not lead to the radical and structural changes needed to address the root issues. Devine emphasises the importance of unlearning common sense and questioning the material conditions through which the music industry operates. The interview also touches upon the lack of attention given to the negative aspects of popular music industries, such as pollution, waste and labour issues, within academic disciplines like Cultural, Media, or Popular Music Studies. Devine challenges the notion that these issues are separate from popular music, asserting that they are intrinsic to its existence and should be addressed by those who are passionate about the genre. He notes the current efforts in the music world to address climate issues, such as sustainability campaigns and carbon calculations, but suggests that these initiatives alone may not be sufficient. He calls for a more comprehensive examination of the industry's cultural formation and the building of something better.[122]

[122] Devine, K.,; Christoph, J. (2022). Sustainability, Solutionism, and the Problem of Music. *Transformational POP: Transitions, Breaks, and Crises in Popular Music (Studies)*, *2*(1).

Devine also critiques our lack of action, and that the actions taken should dramatically change our ways of living—a transformation of the transformation:[123]

> *Knowing what we know about music's exploitation of human and environmental resources, and knowing something about that world's current efforts to address such issues, what do I see as the crucial transformation? Simple: the transformation of the transformation. [...] Real advances will emerge from this formation of imagination and action. But so long as "solutions" such as sustainability are saturated with a particular idea of economic growth, [...] then they ultimately will only ever be marketing tools that try to fight fire with fire. In other words, if the musical world seeks to transform itself only along the lines of sustainability, then the sustainability of this world cannot really be addressed. Sustainability is, on some level, precisely that which is not sustainable.*

Devine's critique emphasizes the need for a transformation that goes beyond surface-level solutions, and addresses the fundamental structures in the music industry's relationship with human and environmental resources. He argues that the current efforts to address sustainability issues within the music world, while important, are often limited by a narrow understanding of sustainability that is intertwined with the pursuit of economic growth. To truly make meaningful progress, Devine suggests a transformation of the transformation itself. This involves a reimagining and restructuring of the systems and values that govern the music industry. Instead, a radical shift is required—one that challenges the foundations of our current ways of living and producing music. Devine's perspective aligns with the notion that sustainability is not just about environmental considerations but encompasses social, economic and cultural dimensions as well. By transcending the boundaries of sustainability as it is conventionally understood, we can envision a more holistic and transformative approach that addresses the inherent contradictions and limitations of our current systems.

In addition—expanding upon Aaron Allen's earlier remarks on a change-oriented sustainability within music[124]—we must also not fail to recognize the significance of aesthetics. Scholars and researchers in ecomusicology have a unique opportunity to bridge the gap between ethics and aesthetics. By exploring these connections, we can gain insight into the ethical implications of the values we uphold within musical contexts. The observations made highlights a crucial point: when our values and actions in music contribute to environmental destruction and harm to other individuals, we are faced with a heartfelt challenge. Sustainability, in its essence, demands that we address this challenge, even if it appears paradoxical at times. It is important that we do not ignore this ethical dilemma, as doing so would be damaging.

Within the field of ecomusicology and ecoorganology, there is a responsibility to engage with these ethical considerations and critically examine the environmental impact of musical practices. By doing so, we can contribute to a more sustainable and responsible approach to music-making and consumption. Through research, education and advocacy, ecomusicologists can raise awareness about the ecological consequences of our cultural actions and encourage meaningful change. While fully resolving the tension between aesthetics and sustainability may be a complex task, acknowledging and confronting this challenge is, at least, the first step we can take. By integrating ethics and aesthetics in our scholarship and practice, we can foster a deeper understanding of the values we assign to sounds and cultural expressions, and work towards aligning these values with environmental and social responsibility. Ignoring the

[123] Devine 2022, p. 88-90
[124] Allen 2019, p. 46-48

ethical dimension of sustainability in music would be a missed opportunity to address the challenges we face in creating a more sustainable and harmonious relationship between music, culture and the natural world.

The framework proposed in this thesis can be a valuable tool for driving sustainability in the music industry, whether that be in future research or as a contribution to the overall focus on sustainable practices in the industry. It should be viewed as a starting point, a guide that can be adapted and built upon as we continue to learn and evolve in our journey towards sustainability. It is our collective responsibility to take up this challenge and strive for continuous improvement in our quest for a more sustainable music industry. The necessity of incorporating interdisciplinarity in assessing the impact cannot be overstated. Biologists, ecologists, social scientists, economists—and musicologists all have a role to play. In placing this thesis within the landscape of ecomusicological literature, it is evident that sustainability in the music industry is a topic of growing importance. While previous research has primarily focused on the environmental impact of music events and performances or music as a role in the promotion of sustainability, this thesis contributes to the field by examining the sustainability of instrument production—ecoorganology. By addressing the ecological and social dimensions of instrument production, the thesis expands the understanding of sustainability in the music industry. The theoretical contributions of this thesis lie in its interdisciplinary approach and its emphasis on the interconnectedness of environmental, social and economic factors. It highlights the need for collaboration among musicians, instrument manufacturers, policymakers and researchers to achieve sustainable practices while acknowledging the challenges and limitations faced in implementing sustainable solutions. To the field of ecomusicology and ecoorganology, this thesis serves as a call for deeper engagement with the sustainability issues in instrument production. It invites scholars to further explore the ecological and social impacts of materials, manufacturing processes and end-of-life management in the music industry. By incorporating interdisciplinary perspectives and engaging with stakeholders, ecomusicologists can contribute to the development of innovative and sustainable practices in instrument production.

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