Fachhochschule Köln
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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA
PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES
AND
COLOGNE UNIVERSITY OF APPLIED SCIENCES
INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

THE USE OF PAU-BRASIL (*CAESALPINIA ECHINATA* LAM.) FOR MAKING VIOLIN BOWS: A SOCIAL-ECOLOGICAL SYSTEM'S ANALYSIS LINKING ENVIRONMENT AND ART

THESIS TO OBTAIN THE DEGREE OF
MAESTRÍA EN CIENCIAS AMBIENTALES
DEGREE AWARDED BY
UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
AND
MASTER OF SCIENCE
TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS
IN THE SPECIALIZATION: RESOURCES MANAGEMENT
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SAN LUIS POTOSÍ, MÉXICO August 2015

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ACRONYMS AND ABBREVIATIONS

APNE	Association of Plants from the Northeast (Associação Plantas do Nordeste)
APP	Areas of permanent preservation (Áreas de Preservação Permanente)
CEPLAC	Executive Committee of the Plan of Cocoa Farming (Comissão Executiva do Plano da Lavoura Cacaueira)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COMURNAT	Confederation of Crafts and User of Nature Resources (Confédération des Métiers et des Utilisateurs des Resources de la Nature)
FUNBRASIL	National Foundation of Pau-Brasil (Fundação Nacional do Pau-Brasil)
IFV	Institute of the Living Forest (Instituto Floresta Viva)
IPCI	International Pernambuco Conservation Initiative
NCPPB	National Conservation Programme of Pau-brasil ('Programa Nacional de Conservação do Pau Brasil' - NCPPB)
RL	Legal Reserve area (Reserva legal)
RPPN	Private Reserve of Natural Heritage (Reserva Particular de Patrimonio Natural)

ABSTRACT

The wood of pau-brasil, *Caesalpinia echinata* Lam., is the worldwide used raw material to build high quality violin bows. Today there is no alternative wood accepted for being as good as pau-brasil for the construction of modern violin bows for professional musicians. Due to the historical and current overexploitation of pau-brasil in the Atlantic Forest of Brazil, this species is highly endangered. The dependence of traditional manufacturing of bows for stringed instruments on pau-brasil on one side and the fact of using a threatened species on the other side as well as an increasing mass production of bows have resulted in a conflict characterized by a raw material scarcity, unequal access to the raw material and different legislative regulations on the local, regional and global scales. This situation has led to cross-arching challenges in the biophysical (decline of natural populations of *C. echinata* and socioeconomic dimensions (conservation, management, socio-political organization associated with an increasing market of pau-brasil wood) and thus represents a complex problem on local, regional and global scales. Therefore, the analysis of this problem requires a comprehensive framework of a complex system, in a social-ecological system's (SES) context.

In the case of a continuous use of pau-brasil in the production of bows for stringed instruments, it is pertinent to identify and analyse the role of key actors and factors that contribute to the dynamics of this particular SES, to identify both possible system states and their resilience and scenarios that put pau-brasil and its use in bow making potentially at risk on the long-term. Hence, the current study will include an analysis of the socioeconomic, political and legislative backgrounds and drivers as well as an analysis of the ecological distribution, and the biophysical conditions of species plantations, which together will allow me to understand the complexity of the problem more precisely.

Keywords: pau-brasil, *Caesalpinia echinata*, social-ecological system, bows for stringed instruments

RESUMEN

La madera de *Caesalpinia echinata* Lam. es la materia prima en el nivel mundial para la construcción de los arcos de mayor calidad para tocar violines. Hoy en día es inexistente una madera alternativa para la construcción de un arco de violín moderno para los músicos profesionales. Por el aprovechamiento histórico y actual de *C. echinata* en la Mata Atlántica de Brasil, esta especie se encuentra en peligro de extinción, lo que representa un problema complejo de alcances locales, regionales y globales con repercusiones emergentes entre diversas instituciones, organizaciones, personas y poblaciones naturales de la especie. Por ello, el análisis de esta problemática requiere un marco integral de un sistema complejo, con un enfoque socio-ecológico. El análisis de un sistema complejo se realiza con el fin de comprender los efectos de los factores internos y externos que influyen en la dinámica de un sistema y cómo este sistema puede mantener su estructura y función bajo múltiples presiones sin perder su identidad, es decir su resiliencia. Además, este análisis se enfoca en identificar diferentes estados estables del mismo sistema y los potenciales umbrales socio-ecológicos, los cuales una vez cruzados podrían inducir una transformación del sistema hacia estados indeseables. Por ende se buscan estrategias para mantener el sistema en una amplitud de estados deseables y sustentables. En el caso del uso ilimitado de *C. echinata* en la laudería, es pertinente identificar y analizar el papel de los actores y factores clave que interactúan dentro del sistema socio-ecológico, para conocer cuáles contribuyen potencialmente a poner en riesgo a la especie y sus usos en la laudería. Al mismo tiempo, se requiere un análisis de los antecedentes socioeconómicos, bióticos y abióticos que explican la dinámica y situación actual y permiten entender con mayor precisión la problemática compleja y posibles soluciones a largo plazo.

Palabras clave: *Caesalpinia echinata*, Palo de Brasil, Sistema socio-ecológico, arcos para instrumentos de cuerda

INTRODUCTION

ART AND ENVIRONMENT - BOW MAKING AND PAU-BRASIL

The concept and understanding of art has undergone several transformations and its most recent "definite" denotation dates back to the eighteenth century; however, during the epochs of Classic, Medieval and Renaissance similar understandings of art were widely spread (Kristeller 1952). "Art" is often associated only with the visual arts, even though a broader usage of this term is common. Art is defined as "the expression or application of human creative skill and imagination" for the production of works which are mainly appreciated for their beauty or for their emotional power (Oxford Advanced Learner's Dictionary 2015). Most philosophers who have been writing about aesthetics, dating back to Kant and until today, have defined art as an area formed by the five major arts - painting, sculpture, architecture, music and poetry (Kristeller 1952). Therefore, the inherent characteristics of art can evidently be separated from those of crafts, the sciences and other human creations or activities (Kristeller 1952). Doing arts underlies a different approach than other areas, as doing arts often includes taking controlled risk to allow creativity and innovation while science, for example, tries to reduce the risk of mistakes (Scheffer et al. 2015). In a recent study (Scheffer et al. 2015) on dual thinking for scientists, it is shown that science and art could complement each other in an inspiring and creative way.

For a wide variety of artworks nature and the environment was the source of inspiration: in paintings it especially influenced the impressionists, e.g. Claude Monet or Vincent van Gogh; in architecture Antoni Gaudi or Friedensreich Hundertwasser; in poetry, e.g. Johann Wolfgang von Goethe and in music several compositions such as "Die Moldau" by B. Smetana, "Four Seasons" by Antonio Vivaldi and "Imaginary Landscape" by John Cage.

Expression of art requires different types of materials, and it is often natural material that is used for the creation of art. These can range from paper to pigments or dyes to wood and exotic natural materials, such as ivory or tortoiseshell.

The traditional construction of most musical instruments has always been based on natural materials, mainly special woods with particular quality characteristics, which evolved in specific conditions of natural ecosystems and environments. Hence, making musical instruments, which by itself is a form of art, represents a bridge between nature and music. It is the process of transforming a natural raw material into an object of art and for art. For me constructing musical instruments is a mixture between craft and sculpture in the service of producing sound and music.

Most musical instruments are traditionally made of template or tropical woods or contain parts of animal origin, some of the woods and almost all of the parts with animal origin are from endangered species, as for example ivory from the African elephant (*Loxodonta africana)*, tortoiseshell (*Eretmochelys imbricate)*, mother of pearl from several species of arthropods, ebony (*Diospyros spp.)* and pau-brasil (*Caesalpinia echinata*) (U.S. Fish & Wildlife Service 2010). The ecological and conservation status of these species is tightly linked to and interconnected with the demand for the construction of musical instruments and in consequence with the development and expression of music itself.

Violin making is a specialization of the construction of instruments, Shigo & Roy (1983) describe the profession as one of the most highly developed forms or technologies of art that man has ever developed. Hundreds of years of tradition have brought every step and detail to perfection, so that the process of constructing a violin is considered extremely detailed and highly demanding. This description can also be applied to the specialized profession of bow making.

The highly complex interaction of string and bow is guided by the musician to create a desired sound, in order to fulfil its function in this interplay quality bows must meet

certain material requirements (Wegst 2006). Neither the interaction of string and bow nor the required material characteristics are fully understood (Wegst 2006). Although great scientific effort has been made to understand all the properties of universally accepted perfect instruments and their reproduction, the true guarantee of high quality instruments is the knowledge and experience of highly skilled instrument makers that is passed on from generation to generation (Wegst 2006).

Ever since the early 1800s, when F.X. Tourte introduced the use of pau-brasil in the manufacturing of bows for stringed instruments, this wood has been the best raw material for the production of high quality bows (Aguiar & Pinho 2007).

David Garrett gives a meaningful statement in the documentary "The music tree" ("A Árvore da Música") about the importance of the bow for the musician (Juliano & Ferraz 2009):

"There is a wonderful saying in French, it's called: "L'archet est le violon[1]"– the bow is the violin. Basically it just states that the bow has such a big importance on sound, on performances and on the quality. A great bow can get another 30 - 40 % out of a good violin. A lot of experiments have been made with different wood, carbon fibres and like steal even. Jean Baptiste Vuillaume tried almost every possible wood, in the end it comes down to the Brazilian wood is without a doubt the one which works the best for the sound, which is the most comfortable while you play even like technical stuff, for instance Paganini - we all know Paganini - he had a wonderful collection of Francois Peccattes and Francois Tourtes and Vuillaume bows and they were all made from this wonderful and incredible wood. So if you play something like that [playing a part of a Paganini composition] you can need something which works with it and it's impossible with any other wood."

[1] Original phrase: "Le violon, c'est l'archet" by Giovianni Battista Viotti (1755-1824)

Pau-brasil (*Caesalpinia echinata*) is one of the endemic and endangered tree species of the Atlantic Forest of Brazil (Rocha 2010). The Atlantic Coastal Rainforest or Mata Atlântica of Brazil is one of the most diverse ecosystems on Earth, despite of suffering enormous ecological devastation in the recent centuries (Ribeiro et al. 2009). It is considered one of the global biodiversity hotspots with the highest number of endemic species and the fourth most threatened biome and region in the world (Myers et al. 2000). The excessive exploitation of the Atlantic Forest started in the early 16th century with the discovery of Brazil by the Portuguese and the exploitation of pau-brasil because of its red pigment, known as brazilin, which was used as dye for textiles (Aguiar & Pinho 2007). Since pau-brasil gained increasing economic importance for the Portuguese, they named their country Brazil, referring to the place where they found the tree pau-brasil (Aguiar & Pinho 2007). Hence, pau-brasil (*C. echinata*) today represents the national tree of Brazil (Aguiar & Pinho 2007).

For centuries, high quality violin bows have been made of the precious wood of pau-brasil. This species, however, is now listed as highly endangered (IBAMA 1992; Varty 1998; CITES 2007). While rarely perceived as an interrelated issue, this is an example where environment and art get tightly linked. The global demand for pau-brasil wood is emerging as a far-reaching complex problem, potentially affecting the art of playing the violin. The proposal of this thesis urges that upholding the high standards of excellence in classical violin music should be closely associated with a sustainable production of the raw material instruments are made of. Thus, the future of bow making and high standards of playing classical music basically depend on the conservation of the species *C. echinata* and on novel efforts and strategies to ensure its sustainable use. A social-ecological system's (SES) approach will be applied as it offers a suitable framework to examine key factors, drivers, processes and variables that have been shaping the complex interactions between pau-brasil extraction from the natural ecosystems and the tradition of bow making in an increasingly globalized world.

THEORETICAL FRAMEWORK

A SOCIAL-ECOLOGICAL SYSTEM'S (SES) APPROACH

Ostrom (2007) highlights the need to recognize the complexity of ecological problems when linked to human activities. It is important to acknowledge that ecological problems seldom have one single cause. Complexity has one key characteristic, which is unpredictability or uncertainty; according to Holling (2001), complexity always has to be analysed as complex as necessary but as simple as possible. According to Folke et al. (2010) the missing recognition of the linkage between ecosystems and social systems is responsible for recurring problems in natural resources use and management. Potential solutions for specific problems can only be found by working in an interdisciplinary way on complex SESs (Ostrom 2007).

A SES is integrative considering ecosystems and human society, e.g. biotic, abiotic and socioeconomic components, and is characterized by interactions and interrelatedness among these different subsystems in space and time; with a particular focus on the „humans-in-nature" perspective manifested on different scales (Chapin et al. 2009; Folke et al. 2010). At the same time complex systems are adaptive; this means they consist of a large number of components, which are changing in time in a non-linear unpredictable fashion, they are interacting in ways that cause the system to adjust in response to changes in internal and external factors (Chapin et al. 2009). The analysis of complex adaptive systems requires the identification of critical internal and external factors and to scrutinize their effects on the dynamics of a SES and how this system can maintain its structure and function under multiple pressures without losing its resilience (Chapin et al. 2009).

RESILIENCE

In the 1970s, the ecologist Holling (1973) introduced the concept of ecological resilience described as the capacity of ecosystems to persist and to absorb changes and disturbances by maintaining similar relations among populations or state variables. Later the term has also been used in a more technical context known as engineering resilience, referring to the buffer capacity of an ecosystem to maintain the main functions and a certain state of equilibrium after a perturbation event (Holling 1996). The buffer capacity of engineering resilience also refers to the time needed for recovery from a disturbance or perturbation (Mittelbach et al. 1995; Pimm 1991; Adger 2000).

In contrast to the ecological resilience, social resilience refers to the ability of groups or communities to deal with external stresses and disturbances which result from social, political and/or environmental change (Adger 2000). Social and ecological resilience are directly linked especially when social groups or communities are dependent on a single natural resource (Adger 2000).

In the context of SESs, resilience refers to the capacity of a SES to absorb a spectrum of perturbations and to sustain and develop its fundamental functions, structures and identities as a result of the reorganization or regeneration of the biophysical and/or human subsystem in a new context (Carpenter et al. 2001; Walker et al. 2004; Chapin et al. 2009).

According to Walker et al. (2004) resilience has four key aspects: the latitude, the resistance, precariousness and panarchy. The latitude refers to the possible number of changes of a system before it loses its ability to recover or before a threshold gets crossed and recovery is made difficult or impossible. Resistance means the amount of force required (ease or difficulty) to disturb or change a system and should not be mixed up with engineering resilience (Walker et al. 2004). Precariousness describes how close the actual state of a SES is in that moment to a limit or threshold and finally, panarchy refers

to the dependence on cross-scale interactions, which are the states and dynamics of systems on scales above and below of the focal scale.

Carpenter et al. (2001) and Folke et al. (2010) point out that in every analysis of a SES and its resilience it is important to clarify the question of "resilience of what and to what?". In contrast to sustainability, a resilient state of a SES can be desirable or undesirable and it does not automatically mean that a resilient state is desirable by different stakeholders (Carpenter et al. 2001).

Based on the assumption that dynamical systems such as ecosystems, societies and SES usually do not reach a stable or equilibrium state where they stay, it is presumed that they pass through the process of an adaptive cycle (Carpenter et al. 2001).

ADAPTIVE CYCLE

According to Carpenter et al. (2001); Folke (2006); Holling (2001) and Walker et al. (2004) a dynamical system passes through four phases of an adaptive cycle and can be divided into a forward loop and a backward loop as shown in Figure 1. The slow and cumulative forward loop encompasses the growth and exploitation phase (*r*), which passes on to the conservation phase (*K*) and represents a phase of the system where the dynamics are relatively predictable. The lasting *K* phase results in resource scarcity - this happens when the system becomes less flexible and more responsive to external shocks. When staying for too long in the *K* phase the system may suffer from chaotic collapse. From there the system enters the unpredictable backward loop with the release phase (Ω) from which it moves rapidly to the phase of reorganization (α). This is the phase where innovation (social and ecological) and new opportunities are possible. From the α phase the cycle leads again to the *r* phase, which can be similar to the previous r phase or considerably different.

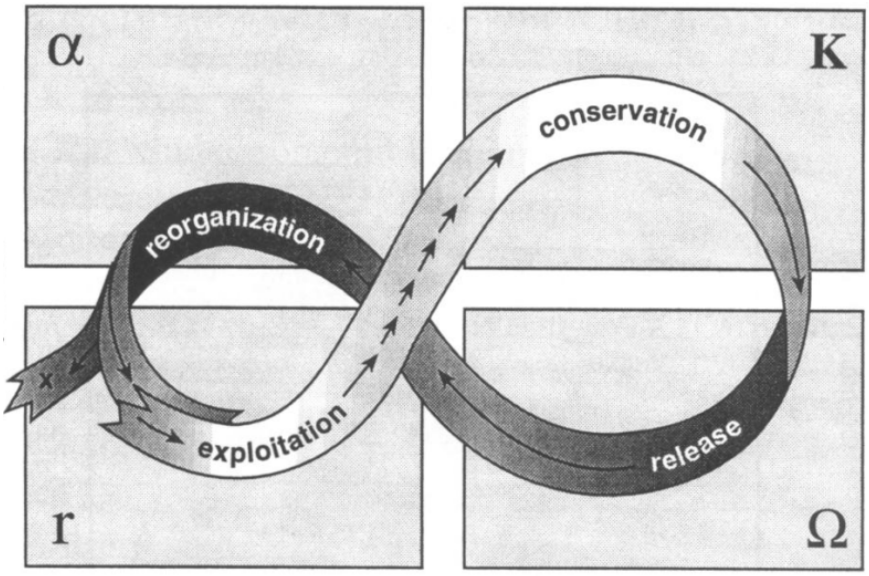

Figure 1: The adaptive cycle[2] (Holling 2001)

The response to a disturbance of a system can either be the regeneration to a similar system state or the transformation to a new system state (Walker et al. 2004). These two possible responses implicate the adaptability and the transformability of a SES. According to Walker et al. (2004) "adaptability is the capacity of actors in a system to influence resilience. In a SES, this amounts to the capacity of humans to manage resilience" and the transformability, is the "capacity to create a fundamentally new system when the existing ecological, economic and social conditions make the existing system untenable". The transformation to a new system state can be induced by a regime shift which is the "abrupt large-scale transition to a new state or stability domain characterized by very different structure and feedbacks"(Chapin et al. 2009). According to Folke et al. (2004) ecological systems and the services they provide are often transformed by human action

[2] **The adaptive cycle with its four different phases (r, K, Ω, α), the speed of the flow is indicated by the arrows. Slow changes are marked with short and closely spaced arrows and rapid changes with long arrows.**

into less desired states - this happens when thresholds are passed. Therefore the threshold is the critical level of one or more drivers or state variables before a regime shift is induced (Chapin et al. 2009).

Adaptive cycles of a focal system interact with adaptive cycles of systems on multiple scales, this is described as panarchy (Gunderson & Holling 2002). Holling (2001) describes panarchy as the concept that combines adaptive cycles and space/time hierarchies. Figure 2 shows two critical connections between three different hierarchical scales in regard to the creation and sustainment of the adaptive capability in the context of panarchy and adapted cycles (Holling 2001). The first critical connection is the "revolt" connection and implies that a critical change in one cycle can affect up to a vulnerable stage in a larger and slower cycle. The second one is the "remember" connection; here the renewal is facilitated by drawing on the accumulated and stored potential in a larger, slower cycle. In this case study, for example the sequence from small and fast through larger and slower and thence to largest and slowest, could be on the ecological part of the Atlantic forest which includes the trunk of pau-brasil, the species pau-brasil and the natural populations of pau-brasil - and for the social part the individual bow maker, the association of bow makers and the association of musical instrument makers.

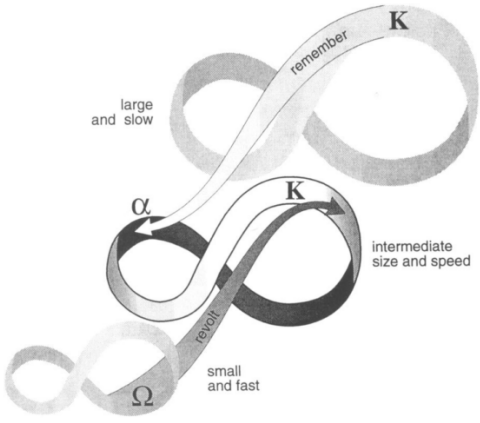

Figure 2: Panarchical connections (Holling 2001)

KEY ELEMENTS OF A SES

SESs react to a variety of controls that operate across a range of temporal and spatial scales, these controls can be grouped in slow variables, fast variables and exogenous control (also called external drivers) (Chapin et al. 2009). Usually the fast variables (e.g. soil nitrate, fire event, community income, population density, etc.) are of primary concern to ecosystem users, but the dynamics of the fast variables are strongly influenced and shaped by other system variables, which change in a slower manner – the slow variables (e.g. soil organic matter, cultural ties, etc.) – and influence the way how fast variables react to the variation or change of an external driver (Walker et al., 2012). The internal system variables control the dynamics of other variables of the system, the so-called feedbacks; there are no feedbacks of complex systems to external drivers (Walker et al., 2012). External drivers are variables that do not form part of the system within the scale of the analysis and they are not affected by what occurs inside the system - there is no feedback effect (Walker et al., 2012). System change is always provoked by internal relationships (slow and fast variables) and the effects of external drivers or drivers from a higher scale on internal variables (Walker et al., 2012).

According to Walker et al. (2006) the interactions of a few key slow variables determine the resilience of a desirable state of a system and they are of high interest for the management of the system as they influence general system dynamics. The overall dynamics of an interdependent SES are determined by the feedback loops among components of ecosystems and social systems (Folke et al. 2010).

RESEARCH QUESTIONS AND CORE OBJECTIVES

RESEARCH QUESTIONS

What is the historical background that led to the actual situation of *C. echinata* and bow making?

What are the internal and external drivers that led to the evolution and shaped the historical development of the SES *C. echinata* and bow making?

Who are the main actors in this complex system and how do they contribute to the current situation of *C. echinata?*

What is the actual natural distribution of *C. echinata* and what are the main threats to the species?

What efforts have been made for both conserving *C. echinata* and satisfying the need of high quality raw material for bow making?

GENERAL OBJECTIVE

Elaboration of a conceptual model of the complex SES of *C. echinata* – bow making, which allows or stimulates a sustainable use of *C. echinata* in the manufacture of bows for stringed instruments.

SPECIFIC OBJECTIVE

Analyse the dynamic of the complex SES *C. echinata* – bow making in its historical and current context considering biophysical and socioeconomic drivers and processes on global, regional and local scales to understand how the ecological situation is connected to the use of *C. echinata* in bow making on the different scales.

METHODS

The focus of this study is on the analysis of the key factors, processes and actors contributing to the dynamics of the SES *C. echinata* – bow making in the historical and current context. A dynamic and prescriptive analysis from the history until today helps to connect the different aspects of the system (Holling 2001). As there are several relevant processes for the SES operating on different scales, there are also stakeholders present on different scales, thus it is important to analyse the situation on several scales simultaneously with a multi-scale analysis (Scholes et al. 2013). The initial stakeholder identification shows which actors form part of the current SES on the global, regional and local scale, furthermore this identification serves as complementary background information for the spatiotemporal analysis.

SPATIOTEMPORAL ANALYSIS

The spatiotemporal analysis of the SES is the base for the identification of the drivers and processes of the SES and shows the whole development of *C. echinata* and bow making. This helps to put the current situation into the adequate socio-political, socioeconomic, socio-cultural and environmental context. Four main elements formed part of the analysis: (1) politics and legislation, (2) environmental exploitation and land degradation, (3) the tradition of violin and bow making and (4) the development of classical music. The information for this analysis was obtained through literature review and empirical observations.

LITERATURE REVIEW

The analysis of environmental exploitation and degradation was based on historical reports about the exploitation and the ecological background of the Atlantic Forest. Literature about the current conservation status of pau-brasil complemented this analysis. The analysis of the historical background of political events and legislation was based on

literature about the history of the Atlantic Forest and was complemented with an analysis of the current political and legislative drivers relevant for pau-brasil and bow making, which was based on the review of statutory laws as well as on local, regional and international policies. In order to connect the ecological situation with the tradition of bow making historical reports on the production of bow making in Europe delivered information of the extracted quantities of pau-brasil in the Atlantic Forest for the purpose of making bows. Specialized literature on violin and bow making complemented the analysis of violin and bow making. Additionally, an analysis of the current demand for pau-brasil in bow making was considered by analysing the actual trade situation. Therefore, the database of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was consulted and provided data about the legal trade on the global scale, while the Brazilian Institute of Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA) provided recent data on the legal trade of pau-brazil as well as on uncovered illegal trade on the local scale. This information was complemented with empirical data from a conducted online survey. For the analysis of classical music musicological literature was consulted.

EMPIRICAL METHODS

The perception of the situation of the species of *C. echinata* from key actors was determined through a conducted online survey on the global scale. The online survey (see Appendix I) was internationally applied to bow makers, violin makers and dealers of musical instruments and accessories. The realization of the survey was based on the 'Strad directory', a global collection of directions of violin makers, bow makers, tone wood dealers, string producers and dealers of musical instruments and accessories, which includes the majority of the directions on the international level (The Strad 2014). The elaborated survey encompasses questions about the perception of the ecological situation

of pau-brasil and the Atlantic Forest, about current production volumes and sales volumes of pau-brasil bows, but also questions about the awareness of trade regulations in regard to pau-brasil. Hence, it encompassed the global scale and included qualitative and selected quantitative questions. The survey was applied in six different languages (English, French, German, Italian, Portuguese, and Spanish) and sent to 1882 companies, bow makers and violin makers which are registered in the 'Strad directory'. The results of the survey were used to complement and connect the obtained data from the literature review and the measurements with perceptions, observations and production numbers of the participating stakeholders.

Selected semi-structured expert interviews formed part of the methods during the field work and were applied to different actors. In this way scientists specialized on pau-brasil, officers from IBAMA and bow makers gave additional and complement information, on the perception of the problem, about statutory laws and illegal trade and on the use of *C. echinata* in the manufacturing of bows on the regional and local scale.

The analysis of the current status of pau-brasil plantations was based on internal information of the involved organisations and plantation owners as well as on the measurement of the plantations. The design of the undertaken measurements focused on basic parameters relevant for a future use in bow making. The following parameters had been determined: the morphotype of pau-brasil, the diameter at breast height, the height of the first branches, the tree height, and the description of the tree appearance, characterized in three categories. In each plantation plots - if possible several ones - were established at a size that included minimum 20 - 25 trees. When the plot measurements were repeated in the same plantation, the same plot size was used. As several types of plantations (monocultures, agroforestry systems and mixed plantations) were measured, the plot sizes differed between the different plantations. It was strived to establish 3 to 5 plots per plantation, distributed over the plantation. Additionally every plot and each tree was registered with a GPS device. The internal information of the organizations and the

plantation owners complemented the measurements with information about the year of planting, the number of planted trees, the size of the planted area and the treatment which was given in what periods to the plantation (use of fertilizer, irrigation, water capturing methods and pruning[3]).

THE FIELD WORK

In order to obtain the information in the field, specific study sites in the Atlantic Forest region were selected. The main criteria for the selection were: (1) that the visited institutions were of importance for the current scientific researches going on in regard to pau-brasil, (2) that the visited institutions had been or were involved in conservation or plantation projects of pau-brasil, (3) that the individual persons were committed to the conservation and plantation of pau-brasil, (4) that the individual persons were involved in the manufacturing of bows for stringed instruments, or (5) that the experts could provide special information about the statutory laws in regard to pau-brasil. Hence, the following institutions, persons and places were visited in the Atlantic Forest:

- The Botanical Garden of Rio de Janeiro to meet scientific experts on genetics and wood anatomy of *C. echinata.*
- The Forest Institute (Instituto Florestal) and the University of in São Paulo to meet a scientific expert on wood anatomy and alternative woods for violin bows, as well as a scientific expert on the geographical distribution and the historical exploitation of pau-brasil.
- The Federal University of Espirito Santo (Universidade Federal de Espirito Santo) to meet a scientific expert on physiology of pau-brasil in Vitoria.

[3] It is meant the selective removal of branches to increase the wood quantity and quality for commercial uses

- Officers of IBAMA with special knowledge of the statutory laws in regard to pau-brasil in Espirito Santo, Paraíba and Rio Grande do Norte.
- The Instituto Floresta Viva (IFV) in Ilhéus and the Executive Committee of the Plan of Cocoa Farming (Comissão Executiva do Plano da Lavoura Cacaueira – CEPLAC) in Itabuna (Southern Bahia) were visited to get to know some of the existing conservation and plantation projects. Some of the pau-brasil plantations were measured in the described way.
- The Association of Plants from the Northeast (Associação Plantas do Nordeste - APNE) to get to know the current conservation and plantation projects in the Northeast of Brazil (Rio Grande do Norte, Paraiba and Pernambuco)
- The National Foundation of Pau-Brasil (Fundação Nacional do Pau-Brasil – FUNBRASIL) to get to know the pau-brasil museum and the plantation and education efforts of the NGO.
- Different bow making companies in Espirito Santo such as Horst John & Cia. Ltd. and Bögen Schaefer in Guaraná, Renato Casara in Joao Neiva and Marco Raposo in Domingos Martins to get to know their companies and the production of bows as well as to get to know their pau-brasil plantations which also were measured in the described way.

The participation in the II Workshop Pau-brasil in João Pessoa in Paraíba provided additional information about current conservation efforts, the importance of new scientific findings on the topic and the involvement of bow makers and violin makers from around the world on the local scale.

This multi-scale approach allowed a cross-scale analysis of key SES processes and variables and external and internal drivers, their interactions and feedbacks (Scholes et al. 2013).

RESULTS

The analysis encompasses three scales – the global, regional and local scale. The hierarchical top scale of the SES is the global scale. The regional scale is Europe, where the tradition of bow making arose, while the local scale centres on the Atlantic Forest, where the endemic species of pau-brasil occurs. The focal system of this SES analysis consists of the regional scale and the local scale, with a focus on pau-brasil and bow making as shown in Figure 3.

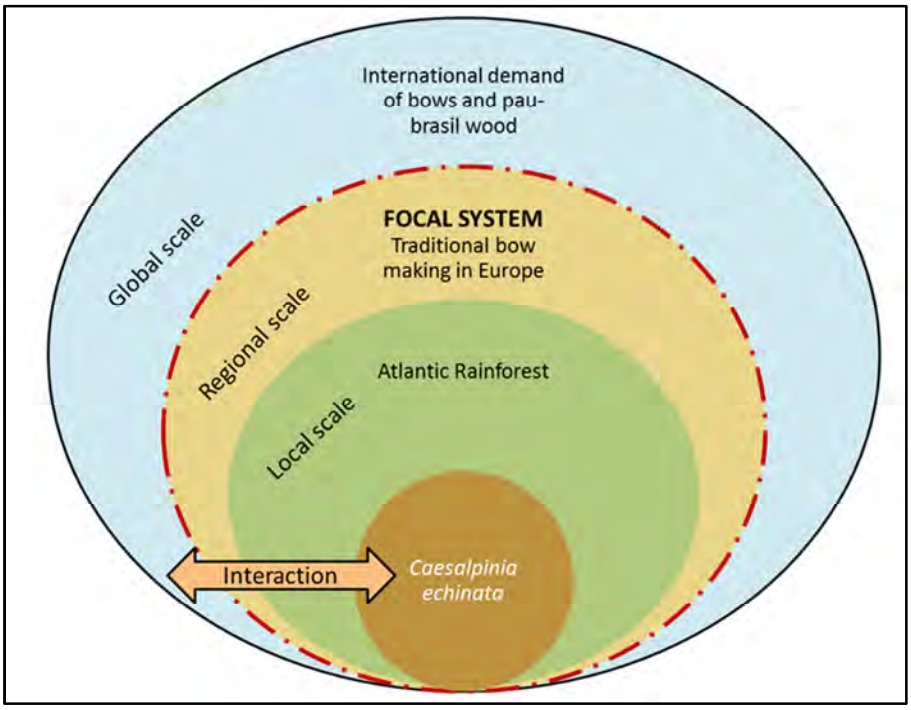

Figure 3: SES with the focal system of this analysis

THE PAU-BRASIL TREE

Caesalpinia echianta Lam. is a species of the family of *Fabacea* and of the subfamily of *Caesalpinioideae* (Cronquist 1981), and is also known under the synonymous *Guilandina echinata* (Lam.) Spreng.

Popular names of *C. echinata* are pau-brasil, ibirapitanga, pau-vermelho, ibirapiranga, arabutã, brasileto, araboretam, pau-de-pernambuco and pernambuco tree (Cronquist 1981).

Figure 4: Pau-brasil tree

The species is known to be a climax species of slow growth (Cronquist 1981) and occurs in low altitudes with a density of four trees per hectare along the Brazilian coast line from Rio Grande do Norte to Rio de Janeiro (Dean 1996). The tree (see Figure 4) may reach up to 30 m and its diameter varies between 40 and 60 cm under natural conditions (Aguiar & Pinho 1996). The ideal diameter for cutting is said to be at approximately half a meter (Dean 1996). Cultivated trees can, according to Marques et al. (2012), be cut after 30 years for being used in the construction of bows.

Figure 5: Trunk of a pau-brasil tree

The trunk (see Figure 5) of *C. echinata* is circular and usually almost straight, with a brown to grey bark. The bark (see Figure 6) is characterized by many thorns that decrease significantly with the age of the tree (Aguiar & Pinho 2007). The colour of the heartwood is reddish-brown (see Figure 7), and forms the source for the dye as well as for the construction of bows, and the sapwood is of a bright colour (Aguiar & Pinho 2007). The wood has a density between 855 kg m^{-3} to 1197 kg m^3 (Schimleck et al. 2009) and is very heavy and resistant (Aguiar & Pinho 2007). In a recent study it was proven that *C.*

Figure 6: Bark of the pau-brasil tree with

Figure 7: Cross section of a pau-brasil trunk

echinata forms annual rings, mainly depending on the climatic factor and on the precipitation (Macedo 2015).

The leaves (see Figure 8) of *C. echinata* are pinnate; each consists of between 9 and 19 leaflets - they are of small oval shape, have a shiny dark green colour and a leathery appearance (Aguiar & Pinho 2007). The tree is hallmarked by dense foliage. *C. echinata* develops three different morphotypes, known as *arruda* (small), *café* (medium) and *laranja* (big), which can be distinguished due to the leaflet size and shape and due to the wood colour (Macedo 2015).

Figure 8: leaves of pau-brasil

The inflorescence (see Figure 9) is also branched and each bunch consists of 15 to 40 flowers, the petals of the flowers are of yellow-golden colour with a red-purple coloured blotch at the top centre petal (Aguiar & Pinho 2007). This provides the flowers very ornamental character. The flowers are transmitting a mildly sweet aroma and become a great attraction for bees, which probably are the main pollinators of *C. echinata* (Aguiar & Pinho 2007).

Figure 9: Pau-brasil flower

The fruit (see Figure 10) is spiny and can be described as a dehiscent legume which opens when it is ripe and releases the seeds (Aguiar & Pinho 2007). The maturation of the fruits of pau-brasil occurs around 50 days after the peak of the flowering time, when there is a change of colour from green to dark brown (Aguiar 2001).

Figure 10: Fruit of pau-brasil

The seeds (see Figure 11) of pau-brasil are flat and elliptical and of a brown colour, their size varies in diameter between 1 to 1.5 cm and they have a thickness of 0.3 cm - usually there are 2 - 4 seeds per fruit (Aguiar & Pinho 2007).

Figure 11: Seeds of pau-brasil

In the past, pau-brasil was used in the past as a dye for textiles and for construction and fencing posts. Since 1800 until nowadays it has been used for the construction of violin bows (see Figure 12). Some studies analysed the medicinal effects of pau-brasil against cancer (Aguiar & Pinho 2007; Zanin et al. 2012; Prod et al. 2014).

Figure 12: Phases of bows in construction and made from pau-brasil

STAKEHOLDER IDENTIFICATION

The actors of this SES can be divided into four groups: The actors who are of importance at institutional and political levels, actors who are actively involved in the conservation of the species, actors who are highly resource-dependent and actors who are interested in agricultural extension also on areas of the Atlantic Forest. The identification is based on local interviews and conversations with actors who form part of the SES.

GLOBAL ACTORS

On institutional and political level the **CITES** convention wants to ensure that the trade of specimens does not threaten the survival of wild animals and plants.

At the level of environmental conservation the non-profit organisation **International Pernambuco Conservation Initiative** (IPCI) is the leading consortium of stakeholders that unifies bow makers, violin makers and musicians. The organisation has an interest in the conservation of pau-brasil and the implementation of commercial plantations of pau-brasil for future use for making bows, and most of the members are highly dependent on pau-brasil. IPCI is composed of the conjunction of independent offices in the USA, Canada, Germany and France and works together with local NGOs in Brazil. Apart from the ecological support, IPCI supports a small musical project and orchestra for children and youth in Ibirapitanga in Southern Bahia.

A rather unorganized stakeholder group that highly depends on pau-brasil, consists of the **musicians**, who travel a lot giving concerts internationally.

REGIONAL ACTORS

On the regional scale, the institutional and political levels are represented by the **Council regulations of the European Union**, which regulates the trade of protected species of Wild Fauna and Flora.

In regard to actors active in the protection and conservation of the species pau-brasil, there are regional institutions of IPCI – **IPCI Germany** and the **Confederation of Crafts and User of Nature Resources** (Confédération des Métiers et des Utilisateurs des Resources de la Nature COMURNAT) in France - which are at the same time highly dependent on the species pau-brasil.

As unorganized groups on a regional level we can find **bow makers and musicians** who highly depend on pau-brasil as well as violin makers who are involved in the selling of bows made of pau-brasil wood.

LOCAL ACTORS

On the local scale, we can find the **Brazilian Government** as a stakeholder on the institutional and political level that, in form of laws, regulates and influences the protection and trading of pau-brasil.

There are two stakeholders, who are interested in the extension of their agricultural areas at a large scale including areas of the Altantic Forest, the natural habitat of pau-brasil - the **paper and pulp industry** and the **sugar cane industry**.

Another stakeholder group consists of **some local bow makers** who contribute to the species reduction due to illegal selective cutting of pau-brasil. They contract local people for the illegal cutting process or buy illegally cut wood. In this way the wood also enters

the international market illegally, because of high international demand - bow makers are highly dependent on pau-brasil.

Several stakeholders were identified who are locally involved in the protection efforts of pau-brasil:

The **National Conservation Programme of Pau-brasil** ('Programa Nacional de Conservação do Pau Brasil' - NCPPB) was created in September 2012 and in theory wants to promote and support strategic activities for the protection of the natural habitat of pau-brasil (Ministerio do Meio Ambiente 2012). At the time of analysis there were practically no activities of the programme going on. In the future the state programme '**Programa Arboretum'**, a programme with the goal of conservation, restauration and valorisation of the diversity of the Atlantic Forest might be important for the protection of pau-brasil. This programme is under the umbrella of the Ministry of Environment of Brazil and in the future wants to involve pau-brasil as one of the species of its programme. At the moment of this research study the programme was located in Southern Bahia and concentrated its efforts on native tree species such as juçara *(Euterpe edulis)*, Brazilian Rosewood *(Dalbergia nigra)*, Araticum cortiça *(Annona crassiflora)* and Jequitibá (several species of the family of Lecythidaceae).

The **National Foundation of Pau-Brasil** (Fundação Nacional do Pau-Brasil – FUNBRASIL) was the first non-profit organization for the protection and the cultural value and educational importance of pau-brasil, founded in 1988 by Profesor Roldão de Siqueira Fontes. The actual president of the organization is his daughter Ana Cristina Roldão and the organization is located in the state of Pernambuco. This organization implemented some of the first existing pau-brasil plantations in Brazil. In the recent past FUNBRASIL was supported by IPCI. At the moment of visit the activities of this organization were relatively limited due to missing financial support. Usually the organization has as its goal the production and distribution of more than 150,000 seedlings per year.

The local non-profit organisation **Association of Plants from the Northeast** (Associação Plantas do Nordeste - APNE) is located in Pernambuco and Paraiba and promotes the reintroduction of pau-brasil trees in areas of former natural occurrence or existing natural populations and the plantation of pau-brasil trees for a future commercial use in the Northeast of Brazil. In the past APNE has also analysed the status of the natural populations in Rio Grande do Norte, Paraiba and Pernambuco. The organisation is financially supported by IPCI.

The **Institute of the Living Forest** (Instituto Floresta Viva-IFV) is a non-profit agroforestry organisation in Southern Bahia and promotes the introduction of native tree species into agroforestry systems. Usually IFV works together with rural, mainly small landowners in Bahia. With the financial support of IPCI the organization wants to strengthen and increase the promotion and work with pau-brasil. The support of IPCI for IFV is relatively recent and there are not any project results to be record yet.

The **Green Brazil Project** or **Green Brazil Institute** (Instituto Verde Brasil) is a non-profit organization located in Domingos Martins in Espirito Santo. According to the online information of the organization, its foundation was in 2002. The president of the organization is the owner of a bow making company and was visited during field work. Due to time scarcity this program was not examined in detail, therefore there is no information available on how many of the planted trees survived, how the actual situation of this organization is and which activities are realized. Based on the online information this organization works together with the big paper company Aracruz.

Private initiatives or single private persons have planted pau-brasil in the past and have contributed to the conservation of the species with some of the oldest plantations of pau-brasil within the country. These actors mainly were bow makers themselves who have started to replant pau-brasil. These plantations are partly located in APPs or Legal Reserves and most of them will not be available for future commercial purposes.

The stakeholder identification can be summarized as shown in Figure 13; this graphic also includes, apart from the main actors, the ecological context, other influences and the less known parts (illegal trade and the Chinese market) of the SES.

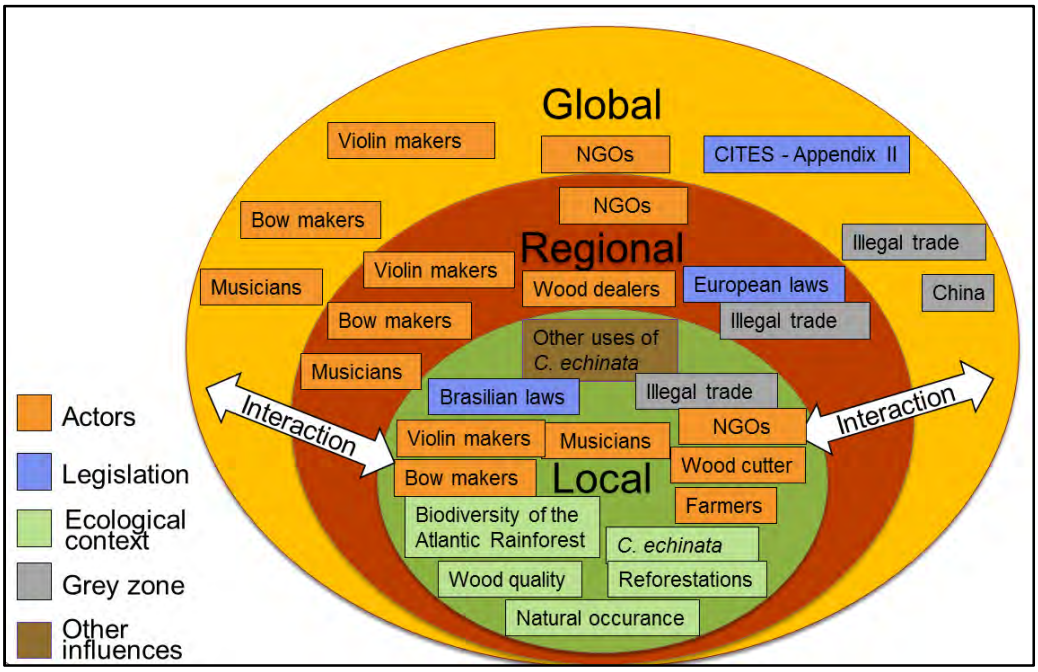

Figure 13: Relevant actors for the SES on the three scales of analysis

SPATIOTEMPORAL ANALYSIS

The spatiotemporal analysis involves results from the online survey in an integrative way in the different chapters. From the 1,882 persons who received the online survey 453 persons started to answer the survey and 340 persons completed the whole survey. The answers of the 340 participants (n = 340) were considered for the analysis and correspond to a return of 18.1 %. The survey was designed in a flexible way depending on the type of respondents; therefore not all participants had to answer all the questions. 67.6 % of them were violin makers, 40.9 % were dealers of stringed instruments and accessories, 25.3 % were bow makers and 9.1 % others.

At the end of each of the four main chapters of the spatiotemporal analysis there will be one graphic which concludes the chapter and captures, the most important events and periods; these graphics are merged in the chapter of the dynamics of the SES of *C. echinata* and bow making.

ENVIRONMENTAL EXPLOITATION OF *C. ECHINATA* AND LAND DEGRADATION

Globally, the history of environmental exploitation and land degradation is reflected at the Earth system scale and temporally it can be divided into pre-industrial revolution (before mid-18th century), post-industrial revolution or anthropocene (after mid-18th century) and the great acceleration (second half of 20th century) (Huber-Sannwald et al. 2012).

Europe, the regional scale, was heavily involved in the exploitation of the Atlantic Forest and is highly responsible for the environmental degradation of the Atlantic Forest. The original interest of Portugal and Europe in Brazil was the pau-brasil wood and its red dye, brazilin, which eventually led to an extreme exploitation of pau-brasil and the Atlantic Forest. Pau-brasil replaced the dye of *Caesalpinia sappam* L. from Asia and represented the most valued natural resource of Brazil after its conquest. The influence of pau-brasil reached such importance that in 1530 the name of the country was changed from the previous name Terra do Santa Cruz to Brazil (Rocha 2004). The history of exploitation of pau-brasil had/has continuous and direct impacts on the Atlantic Forest. According to Dean (1996), the Portuguese exported around 1,200 tons/year of pau-brasil during the first years of exploitation. Later, around 1550, when the French started exploiting pau-brasil as well, approximately 12,000 tons/year of wood were exported. It was in 1607 when wood export was limited to 600 tons/year because of the drastic decline of the species (Dean 1996). A rough calculation of the approximate number of extracted trees suggests that about two million trees were cut during the first century of exploitation (Dean 1996). Even though the main exploitation of pau-brasil occurred in the first century after the discovery, this tree remained the dominant trading good for the Portuguese

Crown and its exploitation continued until the end of the 18th century (Dean 1996). At the beginning of the 19th century until 1822, the quantity of pau-brasil smuggled, confiscated or discharged in foreign harbours was higher than the legally sold quantity of wood (Dean 1996). In total, about 91,243 tons of pau-brasil were logged between the 16th and the 21st century, which corresponds to about 527,182 trees, considering only legally reported trade (Rocha 2004). Table 1 shows an overview of the amounts of logged pau-brasil in every century.

Table 1: Overview of the logged pau-brasil in history (ROCHA 2004)

Century	Quantity in tons[4] per century	Number of logs[5] per century	Number of trees[6] per century
16th	8,412.4	560,827	48,605
17th	16,555.3	1,103,687	95,653
18th	55,775.8	3,718,387	322,260
19th	8,606.6	573,773	49,727
20th/21st	1,892.9	126,193	10,937
Total	**91,243.0**	**6,082,867**	**527,182**

These numbers show how much export numbers dropped in the 19th century; this was the time when aniline colours were discovered and replaced the from pau-brasil extracted brazilin. By the end of the nineteenth century practically all natural dyes had systematically been replaced in the colour industry (Michaelson 1993). This trend removed the pressure on the exploitation of pau-brasil.

The development of the Atlantic Forest can be divided into so-called exploitation cycles: the sugar cane cycle, the gold cycle and the coffee cycle (Nehren et al. 2013). According to Rocha (2004) prior to the sugar cane cycle one can refer to the pau-brasil cycle.

[4] In tons (1 t= 1,000 kg), based on: 1 quintal = 4 arrobas ~ 58.8 kg; 1 tora = 15 kg.
[5] One log has 1.3 m length and 15 kg.
[6] One cut tree with a useful trunk of 15 m length.

The pau-brasil cycle took place in the years from 1500 onwards. Until 1530 pau-brasil represented almost 90 % of the exported products from Brazil (Couto 1997). Although the trade of pau-brasil was of high importance, the percentage of the total revenue for the Portuguese Crown was only 2.5 % in 1558 (Boris Fausto 2001). A map of Brazil (see Figure 14) from 1519, illustrates what was happening in that period. It is also one of the earliest evidences demonstrating how close science and art were connected at that time, as the map depicts scientific cartographic information along the coastline and colourful artistic paintings of the interior of the country.

Figure 14: "Terra Brasilis" by Pedro Reinel and Lopo Homem, Miller Atlas, 1519, French National Library in Paris (obtained from Rocha 2004)

The sugar cane cycle began with the planting of sugar cane in 1535 (Hobbs 2004). Around 1600 sugar cane substituted the importance of pau-brasil for the Portuguese economy and later even overtook its economic importance (Couto 1997). But during the sugar cane cycle the exploitation of pau-brasil continued even though it was no longer the main economic export good (Rocha 2004). In general, it can be said that the exploitation of pau-brasil during the 17th century was realized through particular licences. These licences were given to the Company of the Jesuits (Companhia de Jesus) and the Trade Company (Companhia do Comércio) (Mauro 1997) for the exploitation of pau-brasil and harvests of sugar cane. Independently from these licences, the transport and trade of pau-brasil were monopolies of the Portuguese Crown or of the contracted persons for this purpose (Mauro 1997). In the 1700s gold was found in today's state of Minas Gerais, which forms part of the Atlantic Forest, this marked the beginning of the gold cycle (Hobbs 2004). The construction of roads and the immigration into the region led to further destructions of the Atlantic Forest in that area. After the introduction of coffee to Brazil, by the Brazilian Francisco de Mello Palheta from French Guiana, mainly to the Atlantic Forest region, in 1726, the coffee production increased and expanded and around 1800 coffee became the most important export good, this was the time when the coffee cycle began (Hobbs 2004). After that paper and cellulose production, together with modern infrastructure, agriculture and urban development enhanced the degradation and loss of the Atlantic forest after that (Kröger 2012; Rocha 2010).

From 1800 onwards pau-brasil was used for making violin bows (Baines 1961; Longui et al. 2010) and must have contributed as well to the selective cutting of pau-brasil in the Atlantic Forest. It is not known how much the share of pau-brasil wood for bow making was during the transition time when pau-brasil was still used as a dye and pau-brasil bows were already constructed. But in 1872/73 there was a demand of 3.5 - 4 tons of pau-brasil wood in Markneukirchen (Germany) according to Chamber of Commerce (Handels- und Gewerbekammer 1874).

According to Rocha (2004) the history of exploitation and decline of pau-brasil populations began with the discovery of Brazil and can be divided into three periods regarding: the economic period, the period of extinction and the period of regeneration. The economic period of pau-brasil was shaped by the extensive exploitation of the species for the production of the red dye brazilin. The impact on the species was very high and culminated in the period of extinction, when pau-brasil was thought to have been extinct. The period of recovery is signed by the national and international protection efforts. A study conducted by the Botanical Garden of Rio de Janeiro as part of the 'Pau-brasil Project' shows that the populations of pau-brasil in the 'Bosque Estacional Semideciduo' in the diversity centre of Cabo Frio are naturally regenerating (CITES 2007).

As a result of the historical exploitation and land degradation the current area of the Atlantic Forest is highly fragmented (Figure 15). Studies about the remaining areas of the Atlantic Forest come to very different results. A relatively recent study by Ribeiro et al. (2009) concluded that the remaining extent of the entire Atlantic Forest biome possibly ranges between 11.4 % to 16 % of its original expansion, which is about twice as much as reported by other sources estimating the remaining vegetation covering between 7 % to 8 % of its original area (Myers et al. 2000; Galindo-Leal & Cámara 2005; CITES 2007). An updated study by Sloan et al. (2014) used improved measurements in their analysis and came to the conclusion that the natural intact vegetation of the Atlantic Forest is only about 3.5 %. Figure 15 depicts remnant fragments and the original extent of the Atlantic Forest as well as the original and current distributions of *C. echinata*.

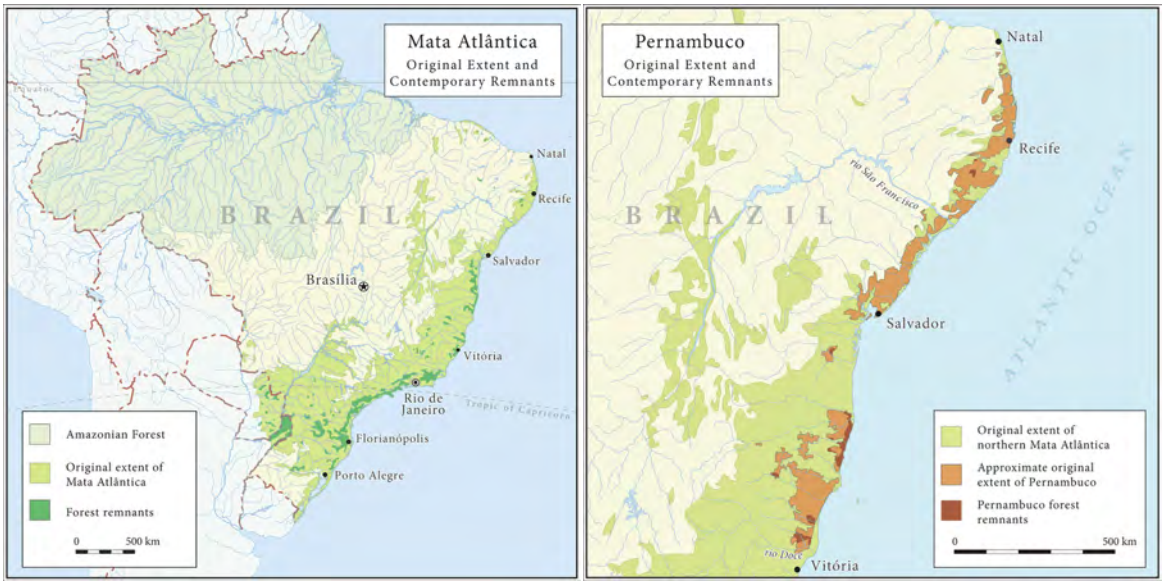

Figure 15: Left side map of Atlantic Forest, its original area and the fragmented parts of today, right side map of the original distribution of pau-brasil (*Caesalpinia echinata*) and the left fragments of distribution today (IPCI Canada 2015)

Regarding the geographical distribution of *C. echinata* Rocha (2010) confirmed in 2003 during his field work in the states of Sergipe, Alagoas, Pernambuco, Paraíba and Rio Grande do Norte the existence of 14 spots with native populations of pau-brasil. The majority of the natural populations are in protected areas. For the whole Atlantic Forest Region there are 19 conservation areas where pau-brasil can naturally be found, only the states of Espirito Santo and Sergipe do not have any conservation area with natural occurrence of pau-brasil (Rocha 2004). According to the studies of Cardoso et al. (1998, 2005) one natural population exists in Aracruz, Espirito Santo, as it formed part of their genetic analysis of natural populations in 1998 and 2005. Macedo (2015) mentioned some additional spots of natural populations of pau-brasil in Bahia and Rio de Janeiro. Based on that analysis there might actually be around 38 known locations where natural populations of pau-brasil can be found; a listing and summary of the states and

municipalities where these populations are found is demonstrated in Table 2 - some of the listed areas were visited during the field work for this study.

Table 2: Summary of remnants of natural populations of pau-brasil

State	Municipality	Instituition/Property	Source
Rio Grande do Norte	Baia Formosa	RPPN Mata da Estrella	Rocha 2010
	Tibau do Sul	Mata da Fazenda Galhada	
	Pamamirim	Mata do Catre, Base Aérea do Natal	
	Natal	Trilha da Geología , Parque Estadual das Dunas	
	Extremoz	Parque ecológico Agua das Dunas	
Paraiba	Mamanguape	Mata Palmeira, Reserva Biológica Guaribas	
		Estação Ecológica do pau-brasil	
		Mata Alagamar/Sucupira, Usina Monte Alegre	
		BR.101.km 38	
Pernambuco	São Lourenço da Mata	Estação Ecológica do Tapacurá	
Alagoas	Coruripe	Sitio pau-brasil	
		Mata da Grota da Anta	
		Mata da Fazenda Capiatã	
		Mata das Fazendas Poção e Carito	
Sergipe	-	-	
State	**Municipality**		**Source**
Bahia	Eunápolis, Porto Seguro, Monte Pascoal, Caraíva, Ponta de Carumbau, Prado		Rocha 2004
	Itamaraju, Barrolândia, Jussari, Ipiaú, Caraíva, Camacã, Pau-brasil, Ubaitaba, Taper		Macedo, 2015
Espirito Santo	Aracruz		Cardoso et al. 2005; Cardoso et al. 1998; Macedo 2015
Rio de Janeiro	Cabo Frio, Saquarema, Guaratiba, Bùzios		Rocha 2004
	São Pedro da Aldeia, Araruama, Rio de Janeiro and Niterói		Macedo, 2015

The alarming situation of pau-brasil led to an inventory of the existing number of trees within the 'Pau-Brasil Programme' conducted by the Executive Committee of the Plan of Cocoa Farming (Comissão Executiva do Plano da Lavoura Cacaueira – CEPLAC). During that inventory in the cacao producing region of South Bahia 1,754 individual trees had been

identified in 130 different locations, 1,669 of them were native from natural populations and 85 were cultivated (CITES 2007; CEPLAC 2008).

Apart from the natural populations pau-brasil trees can be found in several locations, where the species was planted *ex situ,* e.g. in Botanical Gardens, in parks and in front of institutional buildings. Rocha (2004) counted for example 3,544 pau-brasil trees only within the state of São Paulo in *ex situ* conservation unities of 27 institutions and 43 locations.

Another important aspect related to the ecological situation of pau-brasil is the genetic variation, which is essential for a long-term conservation of the species (Cardoso et al. 2005). Especially the effects of fragmentation are serious as an interrupted or decreased gene flow within a once-continuous population can provoke inbreeding and as a consequence decreasing levels of genetic variation. Therefore it is fundamental to consider the levels and patterns of genetic diversity for the elaboration of conservation strategies (Cardoso et al. 2005).

CONSERVATION STRATEGIES AND OPTIONS FOR PLANTATIONS

There are several conservation strategies for endangered species; in this chapter the ones which had been confirmed to be in practice for pau-brasil will be introduced.

Conservation strategies can be divided in *ex situ* and *in situ*. *In situ* conservation refers to the conservation and maintenance of species populations in their natural habitat, which comprises the conservation of ecosystems (Normah et al. 2013; Dawson et al. 2013). Nowadays *in situ* conservation receives often higher priority than *ex situ* conservation, mainly because of the increasing conscience about the importance of biodiversity (Normah et al. 2013). *Ex situ* conservation is the preservation of species outside their natural habitat, e.g. in seed storage, field trials, in field 'genebanks' and other 'exotic' locations (Dawson et al. 2013).

One *in situ* conservation strategy is the reintroduction of individuals of an endangered/extinct species into an area where the species occurred naturally but got extinct (Normah et al. 2013).

As the most common *ex situ* conservation strategies identified in the Atlantic Forest were individual plantings in parks and open public spaces, monoculture plantations and some mixed plantations that are mostly located in areas of APPs, RPPNs or Legal Reserves. In a certain degree agroforestry systems in Southern Bahia do also contribute to species conservation as native species form part of the system and also get replanted - within other native species also pau-brasil (Sambuichi et al. 2012).

A **monoculture** can be defined as "a uniform or homogeneous planting of a crop over a large area" (Capinera 2008). Most of the forestry plantations worldwide are monoculture tree plantations (West 2006).

Mixed tree plantations consist of two or more species in one planted area (West 2006). According to West (2006) these plantations have potential advantages: (a) in adequate tree combinations the growth and production of the mixed plantation can be higher than in monocultures, (b) the quality of the stem form and the individual growth of a species might be increasing, (c) the plantation can provide more than one product and possibly at different times (when mixed species have different rotation lengths), (d) damage risk due to pest and diseases declines, (e) degraded land might regenerate, (f) biodiversity gets improved due to a more diverse ecosystem and (g) the aesthetic appearance of the landscape might improve as well.

Agroforestry systems are agricultural systems with tree components, the species diversity and the high production of biomass contribute to environmental sustainability (Franke et al. 2000). A specific type of agroforestry is the *cabruca* system, a traditional agroforestry system in Southern Bahia, where cocoa (*Theobroma cacao* L.) is planted within the native forest in which the understory was cleared (Dawson et al. 2013; Sambuichi et al. 2012).

Significant numbers of pau-brasil trees from natural populations got conserved in this specific agroforestry system (Lobao & Valeri 2009). In existing agroforestry systems pau-brasil got replanted as shady species for the cacao plants (Sambuichi et al. 2012).

In Brazil plantations with commercial purposes are most commonly monoculture plantations, though in Southern Bahia, the most important area for cacao production, agroforestry systems and the *cabruca* system are widely spread. Some experiences were done in mixed plantations as well.

CURRENT CONSERVATION AND PLANTATION STATUS OF PAU-BRASIL

The conservation and plantation efforts can be divided into three major regions within the Atlantic Forest – the Northeast (with Rio Grande do Norte, Paraiba and Pernambuco), Southern Bahia and Espirito Santo.

In the **Northeast** of Brazil the NGOs APNE and FUNBRASIL are involved in conservation and plantation efforts.

According to the interview with Ana Cristina Roldão, the president of FUNBRASIL, the plantations realized by FUNBRASIL are among the oldest pau-brasil plantations in Brazil (from 1972 – 1987) and were all planted as monocultures. The plantations are not officially registered and principally are not thought for commercial use in the future, most of them are planted in protected areas. A lot of seedlings were distributed for educational purposes and planted in parks and public spaces. A special permission made it possible to remove sample trees from the oldest plantations to analyse the quality of plantation grown wood for scientific purposes.

For conservation purposes (reintroduction, APPs, RPPN or Reserva Legal) APNE planted 2,600 seedlings within the last two years (2014, 2015), and for commercial purposes the project of APNE planted 5,758 trees within the last three years (2013 - 2015) in 25 plantations. 1,631 trees were planted in agroforestry systems, 3,439 trees in homogenous

plantations (monocultures), 412 trees in an existing coconut plantation as an experiment of a mixed plantation, and 303 trees in an area of protection together with other native tree species in a mixed plantation.

For a future commercial use in the Northeast of Brazil there is currently only one officially registered plantation with 625 planted trees, but other plantations with a total number of 5,160 trees will be registered in the near future. APNE will give organizational support for the correct registration of the plantations with intentional future commercial use.

The actual situation in **Bahia** is very difficult to evaluate. How many trees of the 131,000 trees planted during the 'Programa Pau-brasil' between 2004 and 2008 have survived is unknown. From these 131,000 seedlings 21 % were directed to conservation, 14 % for public areas and 65 % to commercial plantations (CEPLAC 2008). According to the information I received in Bahia, there are only two of the agroforestry plantations of the same owner, where pau-brasil had been planted and registered at IBAMA for a future commercial use. But the registration is currently in the process of being adapted to the new requirements; the registrations in the official online register CAR are in process and after this process and based on the elaboration of a management plan the adaptations will conclude the full adaptation process. As all the areas for commercial use in Bahia are mainly agroforestry systems with a clear agricultural use it could be tried to achieve a delayed registration, especially as the registration in the CAR is presently in progress. Due to that fact as well as the missing monitoring of the planted trees the percentage of a possible future commercial use of these planted trees is not known.

In **Espirito Santo** most of the past and actual plantation efforts are realized by private persons that are all owners of bow making companies. Almost all of the plantations are monocultures - only the oldest of the plantations was a mixed plantation in the beginning, where pau-brasil together with other native species was planted with *Eucalyptus*. Due to the fast growth of the *Eucalyptus* trees they had been eliminated from that area some

years ago. Most of the planted areas are in APPs or in Legal Reserves, which means that it will not be possible to use them commercially. Some of the existing plantations are in areas which theoretically can commercially be used and had been registered at IBAMA, but were not yet registered in the CAR and also do not have a complete management plan yet.

During the field study nine plantation areas have been visited and measured, four in South Bahia and all five existing plantations in Espirito Santo. An overview of the plantations is shown in Table 3 (more details see Appendix II).

Table 3: Overview of the visited pau-brasil plantations

Localities	State	Latitude	Longitude	Altitude (m)	Plantation area (ha)	Year of the plantation	Density (ha)	Type of plantation	Planted morphotypes
Area CEPLAC	Bahia	S19° 37.393'	W40° 11.465'	41	1	2009	277	Agroforestry	All three morphotypes
Fazenda Maristela	Bahia	S14° 46.955'	W39° 03.031'	101	27.5	2005 (2008 replanted)	1111	Agroforesry	Mainly small
Fazenda Nova Aurora	Bahia	S14° 44.715'	W39° 06.340'	38	3.5	2005	1111	Agroforestry + Monoculture	One part only small other part all three
Fazenda Transval	Bahia	S14° 44.690'	W39° 16.998'	60	17	2005	120	Agroforestry	Mainly small
Fazenda Floriano Schaefer	Espirito Santo	S19° 40.750'	W40° 12.871'	37	2	1999 most probably	977	Monoculture	All three morphotypes
Terreno Renato Casara	Espirito Santo	S19° 45.695'	W40° 25.867'	210	1.1+0.7	1997 + 1999	3265	Monoculture	Mainly media
Terreno Jacy Sousa	Espirito Santo	S19° 40.686'	W40° 15.801'	25	1	Varying	1778	Mixed plantation	Mainly media
Fazenda Santa Rosa	Espirito Santo	S19° 54.455'	W40° 18.123'	7	-	Varying	-	Mixed plantation	Mainly media
Terreno Marco Raposo	Espirito Santo	S20° 22.577’	W40° 36.710’	535	1.2	1999	-	Monoculture	Mainly small

The actual conservation and plantation efforts are mainly forced and financed by the most affected stakeholders in case of an extinction of pau-brasil or a tightening of the restricting laws - bow makers, violin makers and musicians. The widespread concern of bow makers that wood from pau-brasil plantations probably would not have as good

characteristics as wood from trees of natural populations got recently dispelled when two scientific studies, one from Marques et al. (2012) and one from Taylor et al. (2013), showed that the wood from plantations is, referring to its quality, comparable to the wood obtained from trees of natural populations.

At the same time the demand for pau-brasil wood for bows of stringed instruments still generates illegal selective cutting in natural populations of pau-brasil. This was confirmed by several officers of IBAMA as well as by local NGOs.

The international online survey included some questions about the knowledge and the perception of the ecological situation of pau-brasil. According to the survey from 340 persons 97 % were aware of the origin of the pau-brasil tree and only 3 % did not know where the pau-brasil tree grows.

Concerning the question *"Do you consider the use of pernambuco[7] wood in bow making has a positive, negative influence or no relevance onto/for the natural forest populations of pernambuco trees?"* the answers of the 340 participants were very diverse; they are shown in Figure 16.

[7] In the survey the term Pernambuco wood was used as synonym for pau-brasil wood, as this is the common term used from violin and bow makers.

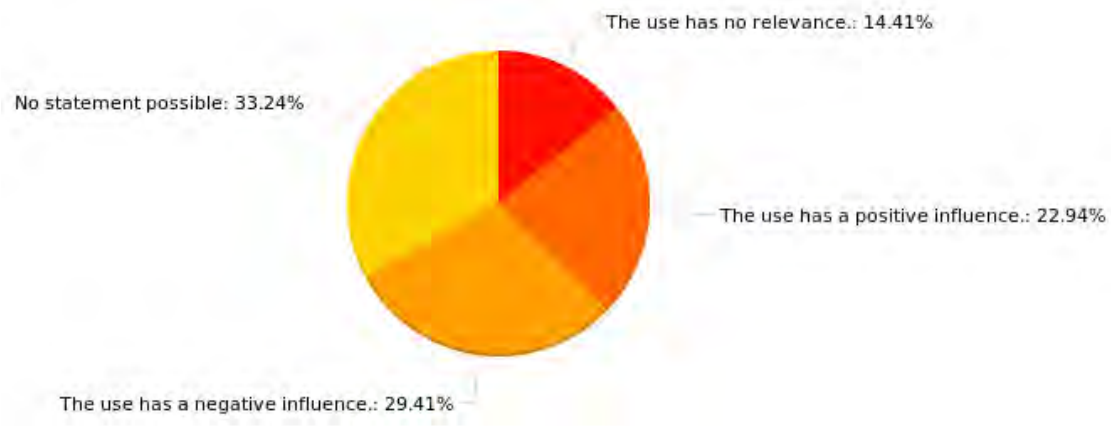

Figure 16: Question of the survey if the use of pau-brasil wood for bows does influence natural forest plantations of pau-brasil

With the following question the participants were asked "*Due to your opinion, why is it like that?*". This question was answered by 206 participants. The ones who answered that the use had no relevance mainly mentioned that the quantity of the used wood for bow making was very small and that the reason for the situation was the habitat loss due to agriculture and the historical use of the colorant made of pau-brasil. The participants who answered that the use for bows had a positive influence mainly mentioned as reason the protection initiatives of bow makers and the creation of awareness about the situation of pau-brasil. The participants who answered that the use had a negative impact mainly mentioned that the cutting of pau-brasil must have a bad influence on the ecological situation of pau-brasil.

An overview of the historical elements relevant to the context of the environmental exploitation and land degradation is shown in Figure 17.

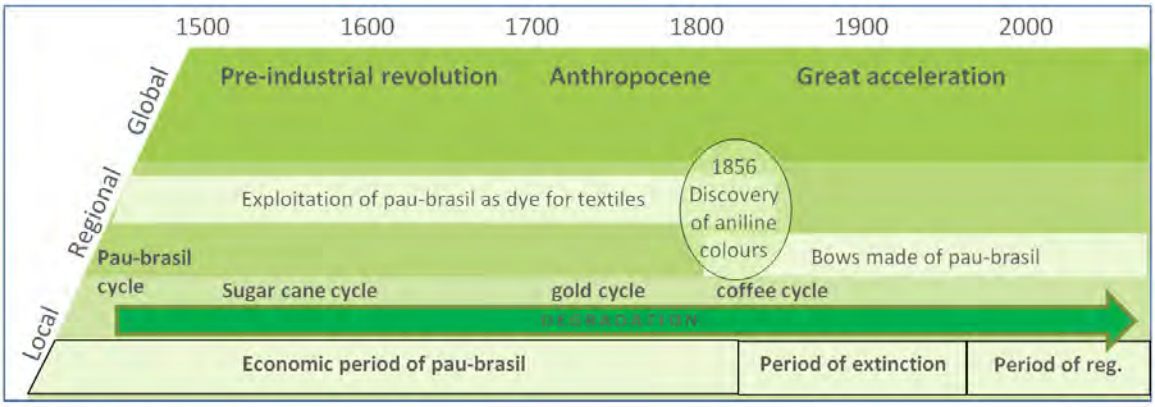

Figure 17: Overview of the environmental exploitation and land degradation of the Atlantic Forest in history

POLITICS AND LEGISLATION RELEVANT FOR PAU-BRASIL AND BOW MAKING

SHORT HISTORY OUTLINE

At the global scale the history can be divided into feudalism, capitalism and neoliberalism considering the global economic systems and the social order.

The European colonialization, in this context especially of South America, had important geopolitical consequences. In 1492 Christopher Columbus discovered America. During the colonial period of Brazil (1500 - 1822) the local history of Brazil and the Atlantic Forest was directly connected to Portugal and therefore to Europe and will be analysed together.

The most important historical events and political decisions in Brazil and Portugal about the Atlantic Forest are summarized in a timeline of the Portuguese-Brazilian history until the end of the Portuguese monopoly on pau-brasil.

Timeline of the Portuguese-Brazilian history with the focus on the Atlantic Forest

Before 1500 PRE-COLONIAL PERIOD	
	According to Galindo-Leal & Câmara (2003) indigenous communities had been living in some areas of the Atlantic Forest for at least 11,000 years and they had already practiced agriculture.
1500 - 1822 COLONIAL PERIOD	
	During the colonial period there were several intentions of the French to colonize Brazil; their main interest was the exportation and exploitation of pau-brasil (Rocha 2004). After several intentions the Portuguese could expulse the French from Brazil (Rocha 2004; Dean 1996).
Between 1498 and 1500	There is no consensus as to who discovered Brazil first (Rocha 2004). The literature mentions several Portuguese, French and Spanish expeditions that possibly passed through Brazil. The historical analysis by Rocha (2004) shows that the discovery of Brazil was between 1498 and 1500. From the early beginnings of the discovery of Brazil pau-brasil was brought to Portugal either by Gaspar Lemos after the discovery of Brazil in 1500 or by Gonçalo Coelho on his first expedition to Brazil (Dean 1996).
1530	The Portuguese changed the name of Terra Santa Cruz to Brazil due to the main export good – pau-brasil (Rocha 2004).
1549	With the beginning of the monopoly of the Portuguese Crown on pau-brasil the first slaves were brought to Brazil as labourers in sugar cane plantations (Rocha 2004).
1605	The Portuguese began regulating the exploitation of pau-brasil and put illegal logging under death penalty (Dean 1996).
1630 - 1655	The Dutch conquered the Northeast of Brazil and participated in the exploitation of pau-brasil (Rocha 2004).
1698	Laws for uncultivated land were created to limit deforestation in areas of wood reserves (Rocha 2004).
1822 – 1889 BRAZILIAN EMPIRE	
1822	Independency of the Brazilian Empire
1850	According to the Lei N° 601 Cutting of forest was considered a crime and punished with death penalty (Rocha 2004).
1859	End of monopoly of the Portuguese on pau-brasil (Dean 1996).

After the independence of Brazil the history continued as shown in the timeline of the independent Brazil.

Timeline of the independent Brazil with the focus on the Atlantic Forest

POPULISM AND DEVELOPMENT (1930 - 1964)	
1934	First Forest Code
MILITARY DICTATORSHIP (1964 – 1985)	
1965	Second Forest Code (LEI Nº 4.771)
1978	Declaration that pau-brasil is the National tree (LEI Nº 6.607)
1981	National Politics for the Environment (LEI Nº 6.938)
NEOLIBERALISM (1985 – PRESENT)	
1988	First free presidential elections
1992	United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro; in the same year pau-brasil got listed in the official list of Brazilian endangered species from IBAMA.
2006	Law of the Atlantic Forest (LEI Nº 11.428)

The first real important date for pau-brasil on the regional scale was the 1st World War (1914 – 1918) as the war led to an enormous reduction of the musical instrument sector and playing or even selecting a new musical instrument was not of concern during that period (Böscher 2008). The 2nd World War (1939 – 1945) had apart from the political and social impacts also big impacts for the production of musical instruments as their production was almost completely disrupted (Böscher 2008) in Germany and all over Europe - therefore the profession of bow making was directly affected.

POLITICAL DRIVERS

In 1998 *C. echinata* was listed as endangered (EN A1 acd[8]) on the red list of the International Union for Conservation of Nature (IUCN) due to the overexploitation and population decline of the species (Varty 1998).

Shortly after, in 2007, pau-brasil was listed on the Appendix II of CITES at the request of Brazil. CITES is an international organ to combat illegal trade, especially internationally, of endangered species and is based on an international agreement between governments. It is a convention and not an international law, every member is responsible for establishing the framework for national laws which implement the CITES regulations in their own countries. The convention created three different Appendices to classify the trade regulations, depending on the degree of threat for a species according to international trade (Appendix I = all species threatened with extinction which are or may be affected by trade, Appendix II = species which are not now necessarily threatened with extinction but which may become so, unless strict trade regulations are applied, Appendix III = species which any party identifies as being subject to regulation for prevention or restriction of exploitation when the cooperation from other parties is needed).

For the **export** from the country of origin every specimen requires a prior grant and an export permit. In case of pau-brasil, the only country where an export permit can be given is in Brazil as it is an endemic species of that country; in all other countries the export of pau-brasil from that country would be a re-export. Two conditions have to be fulfilled to receive an **export permit**. The first is that a scientific authority of the state has to prove that the export of the specimen does not affect the survival of the species – in Brazil these authorities are the Botanical Garden of Rio de Janeiro, the Institute Chico Mendes for the

[8] Categorization of IUCN – EN: endangered, A1: Reduction of population size ≥ 70% over the last 10 years, due to acd: a-direct observation, c-decline in the area of occupancy, extend or occurrence and/or quality habitat, d-actual or potential levels of exploitation

conservation of biodiversity (Instituto Chico Mendes de Conservação da Biodiversidade (*ICMBio*)) and the IBAMA. The second condition is that a management authority of the state has to prove that the specimen was not obtained in contravention to the protection laws for fauna and flora in its own country – in Brazil this institution is IBAMA. An export permit is valid for a period of 6 months and several other 'secondary' conditions have to be fulfilled to receive the permit. The **re-export permit** is issued by the management authority of the state. The permit has to specify the country of origin of the specimen (in the case of pau-brasil it basically always is Brazil), the number of the export permit of the country of origin and its date of issue. In the case that the specimen was already re-exported to the country it is necessary to include the country of the last re-export permit, the number of the re-export certificate of that country and its date of issue. The re-export permit is also valid during a period of 6 months. For trade within the European Union there is no re-export permit necessary as this is the territory of one costumes control.

In case of omission of this information the resolution on permits and certificates specifies that a justification has to be added to that. The inclusion of a **Pre-Convention certificate** might be considered as justification of the missing permits and certificates. The Pre-Convention certificate specifies that the specimens were obtained before the respective species got listed in CITES and includes the date of acquisition of the specimens. It is relatively easy to receive this certificate before the listing enters into force (90 days after enacting) during this transition period there is no burden of proof for owned specimens. In general there is **no import permit** needed unless the national law of the country of destination requires an import permit. All the described permits are not required as long as the specimens remain or are transited in the territory of one customs control. In the future, if pau-brasil wood from plantations gets available, it probably will be necessary to get a **phytosanitary certificate**, which certifies that the specimen had artificially been grown for the purpose of export from Brazil.

Pau-brasil is listed on the second highest level of protection (Appendix II) in the listing of the three CITES classifications. The listing includes a specified explanation what has to be understood as specimen of pau-brasil and forms part of the trade regulations: logs, sawn wood, veneer sheets, including unfinished wood articles used for the fabrication of bows for stringed musical instruments. The end product, the finished bow, was excluded from the listing. Due to that fact no special permits for international travels of musicians are required. This implies as well that the selling of finished bows on the international market, also from one bow maker to another or to a violin maker, does not require a CITES permit.

The exclusion of the finished bow is on one side a blessing as the travels of musicians do not get hindered, which is absolutely necessary for a continuous use of pau-brasil bows. On the other side this is one way how bows which are made with illegal cut wood can enter easier into the international market. It is also known that one way to get illegal wood into the market is selling a half finished bow as a finished bow to avoid the restrictions which are applied for processed wood. In general, it can be stated that CITES implies important consequences and influences to the local and regional scales.

On the regional scale in Europe the **Council Regulation** (EC) No 338/97 on the Protection of Species of Wild Fauna and Flora by Regulating Trade Therein (the Wildlife Trade Regulation) is responsible for the implementation of CITES. This regulation defines all aspects of export and import permissions and certificates of specimens from listed species. There are some stricter regulations than CITES provides, one relevant regulation in regard to pau-brasil is that it is required to get an import permit for specimens of the Annex B (most Appendix II species), applied for at the competent authorities in the Member State. The EC does categorize the threatened species in four Annexes A, B, C, D and includes also some species which are not listed in CITES. For the implementation on the country level each country has to nominate the responsible institutions. Three months prior to CITES was entering into force it was e.g. in Germany possible to register pau-brasil stocks (‘Altbesitz’) without the need to prove that the wood was obtained before CITES

listing in 2007 (BNatSchG § 49). In Germany there exists an obligation to keep books ('Buchführungspflicht') about wood listed in the CITES convention (§ 6 Bundesartenschutzverordnung – BartSchV); these books need to include also a note of every material and the amount which has already been used for the production of an end product. These books have to be kept in safe custody for five years and provide the information to reconstruct how much of the registered stock still exists and how much wood has already been used.

On 5th June 2015, the 'Musical Instrument Certificate' was introduced in Europe (Commission Regulation (EU) 2015/870) with retroactive effect from 5th February 2015. This is a document which can be obtained for musical instruments that hold parts of species under trade regulations (Appendix I, II, III or Annexes A, B, C, D). This certificate is already of importance for bows due to the fact that some parts of bows, other than the bow stick, are also of origin from species under trade regulation, such as ivory and tortoiseshell. These certificates can be issued if all these parts were legally obtained, even though in regard to ivory this instrument certificate is not accepted in the US, as there was a complete ivory-ban in February 2014 (DIRECTOR'S ORDER NO. 210). With regard to pau-brasil this only might become relevant in the future, if pau-brasil bows get included in Appendix II of CITES. This situation has already led to incredible extra work and has already resulted in the use of carbon fibre bows in order to bypass problems with confiscation in the US or other countries. It was due to the complete ivory-ban in the US that these restrictions resulted in the situation that in May 2014 musicians of the Bavarian Broadcasting Orchestra (Bayrische Rundfunkorchester), as well as in October 2014 musicians of the Berlin Philharmonic Orchestra had to play their concerts in the New York Carnegie Hall on cheap carbon fibre bows – in a concert where the tickets on the black market were sold for up to 3500 US$ (Richter 2014). According to the same newspaper article in spite of the use of cheap and low quality bows all the concerts were of big success and the audience was euphoric about the excellent music.

On the local scale, Brazil implemented the CITES restrictions and its trade regulations on 21st September 2000 when the DECRETO Nº 3.607 was adopted.

Apart from the trade regulation Brazil has a variety of laws at national and state levels, which are relevant for the protection and conservation of pau-brasil, e.g. for the restrictions under which conditions native (endangered) species can commercially be used and the conditions which need to be fulfilled for the implementation of plantations for a future commercial use. There are also specific regulations for nurseries and the collection of seeds from native species. The main important laws for all forests in Brazil can be found in the forest protection law (Código Florestal), apart from this law there are several other specific laws concerning pau-brasil such as the law of the Atlantic Forest and the law of pau-brasil, which have to be considered.

According to several interviews and conversations with officers of IBAMA in the States Rio Grando do Norte, Paraiba and Espirito Santo, as well as with officers of CEPLAC it was possible to identify the following list of laws, shown in Table 4, as relevant for a commercialization and protection of pau-brasil within Brazil.

Table 4: Overview of all laws which are relevant for the actual protection and a commercial use of pau-brasil in Brazil

Description and explanation of the law	Relevance for pau-brasil and bow making
15/09/1965 LEI Nº 4.771 (including adaptations until 2015)	
New Forest Code includes definitions and laws for protection areas: This legal framework is of high relevance for the protection and enhancement of conservation areas. It implements three types of protected areas on private land. • Areas of permanent preservation (Áreas de Preservação Permanente (APPs))* • Legal Reserve area (Reserva legal (RL))* • Private reserve of Natural Heritage (Reserva Particular de Patrimonio Natural (RPPN))*	This law is the follow-up law to the First Forest Code from 1934 and is with some adaptations still in force. Especially the definition of the preservation areas are of relevance for the protection of forest areas, but it is also of high importance that these areas have to be taken in consideration for every kind of **commercial** plantation of pau-brasil and for further **conservation** options of this species.
07/12/1978 LEI Nº 6.607	
This law declares pau-brasil as national tree and wanted to implement the national day of pau-brasil for 3rd May, but in the moment of publication the specification of the 3rd May as the day of commemoration for the pau-brasil was deleted.	The declaration of pau-brasil as the national tree of Brazil and the announcement of a day of pau-brasil represent and strengthen the **cultural** importance of that tree for the Brazilian Nation.
31/08/1981 LEI Nº 6.938	
The law of the National Politic for the Environment broadly refers to all kinds of necessary regulations for environmental issues.	This law has a general importance for every environmental issue, but in this analysis no specific relevance for pau-brasil has been identified.
15/01/1992 Portaria IBAMA Nº 06-N	
IBAMA implements the new list of endangered plant species in Brazil, which includes *C. echinata*.	The listing of *C. echinata* as an endangered species within Brazil includes important consequences for a **legal use** and for **legal logging** of pau-brasil.
05/08/2003 LEI Nº 10.711	
This law regulates the collection of seeds and the requirements for legally licensed nurseries, especially for native species.	The regulations and restrictions for the seed collection and for nurseries which work with native species are essential for every **plantation project** as all of these projects will need seedlings and these need to be produced in a legal way.
22/12/2006 LEI Nº 11.428	
The implementation of the law for the Atlantic Forest has important consequences for the protection of native species, especially native endangered species.	The law of the Atlantic Forest strengthens the **protection** laws for the whole area of the Atlantic Forest and especially the restrictions for native species of the Forest. In consideration to this law and the listing of pau-brasil as an endangered species it is indispensable to accurately **register** every commercial plantation of pau-brasil to prevent that the planted trees could be considered as natural populations in the future and ensure that

	they really can be used commercially.
21/11/2008 DECRETO Nº 6.660	
Decree about the exploration and the ecological enrichment of the Atlantic Forest with native species. This is for native species under certain conditions also for a commercial use possible, but in **Art. 60** native species which are listed on the Official Brazilian list of endangered species are explicitly **excluded** from the possibility of an exploration in areas of ecological enrichment.	This decree is of high importance for the exploration of **areas of ecological enrichment,** which could also involve pau-brasil, but the decree clearly defines that a commercial use of pau-brasil is not possible in areas of ecological enrichment.
21/09/2012 PORTARIA Nº 320	
The regulation of pau-brasil pronounces the creation of the **National Conservation Programme of pau-brasil** (PNC Pau-brasil) with the objective of the promotion of strategic activities for the conservation of the species and its natural habitat. The working plan which should have been published latest after 180 days after publication of that regulation has never been published.	In theory the implementation of the National Conservation Programme of pau-brasil should have **actively** specified and intensified the protection efforts for that species. Unfortunately during the field work no concrete activity of this programme could be identified.
05/05/2014 DECRETO Nº 8.235	
The obligation for the registration of private properties in the **Rural Environmental Land Register** (Cadastro Ambiental Rural (CAR)) is one of the most important parts of this decree. As control gets easier the intention is to increase especially Legal Reserve Areas and increase the conservation of biodiversity and the protection of native species. All private properties have to be registered in the electronic System of the Rural Environmental Land Register (Sistema de Cadastro Ambiental Rural (SiCAR))	This implementation could facilitate the **registration of commercial plantations** for pau-brasil in the future as well as increased implementations of Legal Reserve Areas could include pau-brasil as one of the native species.
02/06/2014 DECRETO Nº 15.180 (State law of Bahia)	
This specific state law of Bahia is orientated on the agroforestry system of cocoa, the so-called *cabruca* system[9]. Interesting for the use of pau-brasil trees which naturally occur in the *cabruca* system, is the option of specific permissions to retrieve naturally fallen trees for commercial uses.	This can have positive and negative effects. On one side it might be an option for the use of trees from natural populations in the *cabruca* system in an **ecologically justifiable** way without actively cutting a tree; this admittedly has less environmental impact for the species. On the other side this could also be an incentive and a hole for illegal trade - apart from that fallen trees are also very important for a healthy ecosystem.

[9] The *cabruca* system is a traditional agroforestry system in Southern Bahia where cocoa is planted within the native forest in which the understory was cleared (Dawson et al. 2013; Sambuichi et al. 2012).

17/12/2014 PORTARIA MMA Nº 443	
The regulation specifies the use of cultivated endangered plant species, especially the **Art. 2º, § 1º** as it declares that the established restrictions for the listed endangered species in Brazil do not apply for plantations cultivated specimens, which were licenced from a competent environmental agency.	This is of great importance for future **commercial** plantations as it specifies that the cultivated plants can really be cut and will be available for the market.
24/12/2014 IBAMA INSTRUÇÃO NORMATIVA Nº 21	
This instruction of IBAMA mainly faces the control of exploration, commercialization and the use of products derived from planted native species with the introduction of the new Forest Control System (Sistema de controle florestal – Sinaflor). Sinaflor integrates various information from different registers, among others the information of SICAR. Several information have to be approved from a competent environmental agency for the registration in Sinaflor, amoung others the technical project, the georeferenced location, etc. **Art. 16** of this instruction clearly allows the exploration of plantations or reforestations with native species if the plantations were previously registered in Sinaflor and the exploration was previously declared.	This instruction of IBAMA gives explicit explanations about the conditions for plantations with native species and about the conditions for a future use of the species. Based on this instruction there are no restrictions how a plantation of native species has to look like, this opens the door to different plantation systems such as monoculture plantations, mixed plantations and agroforestry systems.
08/05/2015 IBAMA INSTRUÇÃO NORMATIVA Nº 9	
This instruction includes the regulations for specific permissions for the use of native protected species, which fell naturally.	This can have positive and negative effects. On one side it might be an option for the use of trees from natural populations in an **ecologically justifiable** way without cutting actively a tree for making violin bows; this has admittedly less environmental impact on the species. On the other side this could also be an incentive and a hole for illegal trade and apart from that fallen trees are also very important for a healthy ecosystem.

* Explanation of private protection areas:

- **Areas of permanent preservation (Áreas de Preservação Permanente (APPs))**: Law for the protection of water bodies, top of the mountains and everything above 1,800 m, areas with an inclination of more than 45°, headland, at the border of high plateaus.
- **Legal Reserve area (Reserva legal (RL)):** Every private area which is not APP has to have, outside of the Amazonas a minimum of 20 % of the area considered as Legal Reserve area with a limited sustainable use and the obligation to plant native species. This shall improve the protection of biodiversity and native flora and fauna. It is also possible to get a permission to have this area in another area outside the private area, as a compensation area. In such an area clear cutting methods for example will never be allowed.
- **Private reserve of Natural Heritage (Reserva Particular de Patrimonio Natural (RPPN)):** These are private areas which get voluntarily declared as a preservation area and therefore will be treated as conservation unity ('Unidade de Conservação') and imply certain privileges for the farmer such as easier access to credits within others.

In conversations with officers of IBAMA it was confirmed that there exists no law, which prohibits or limits the possibilities of a commercial use of mixed plantations or close-to-nature plantations as long as the registration and the management plan prove that the specific area is a plantation area where the native species were planted.

According to the juristic framework the online survey included as well questions about the trade limitations and provides further information about the perception and awareness of the trade regulations. In regard to trade restrictions and limitations for pau-brasil wood the following question was included:

"Does pernambuco wood need to be registered in some kind of way or are there any trade restrictions for pernambuco wood in your country?"

This question was only given to bow makers and persons who make bows; the question was answered by 117 participants. Figure 18 shows the answers in percentage.

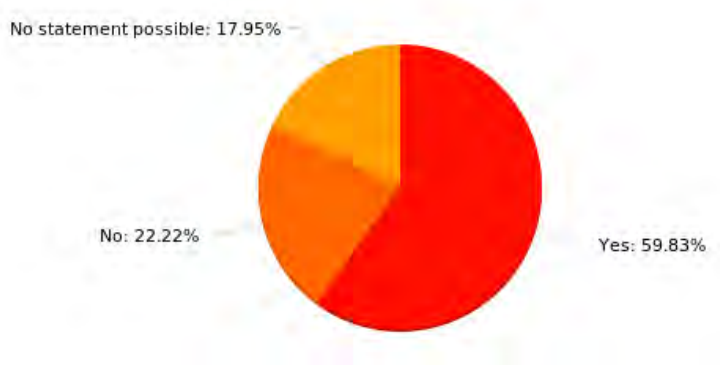

Figure 18: Answers to the question if there exist trade restrictions for pau-brasil wood

In regard to the finished bow of stringed instruments, one question of the survey was:

"Do pernambuco bows need to be registered in some kind of way or are there any trade restrictions for pernambuco bows in your country?"

Here the answers of the 270 participants are shown in Figure 19.

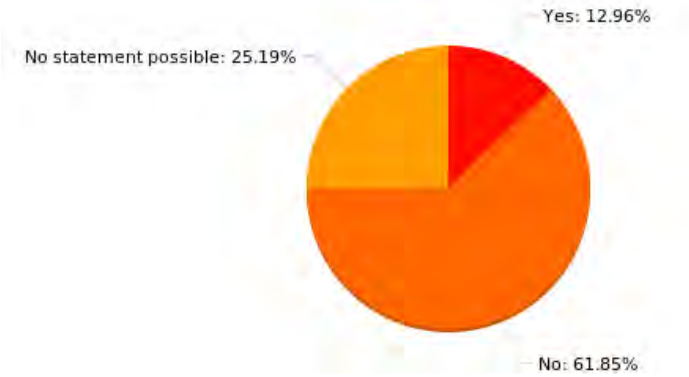

Figure 19: Answers to the question if there are trade restrictions for pau-brasil bows

The answers of these two questions give an idea about the awareness and knowledge of the existing trade limitations among the participating stakeholders.

One participant gave an interesting answer to the additional question *"What kind of restriction is it about?"* and mentioned significantly:

"Pernambuco is listed as an endangered species. As a plant material, it is under the control of the US Department of Agriculture. They do not currently restrict trade in finished items, but they do restrict trade in the raw material.

What they require for documentation is unclear and subject to politics. Right now, importers can import "bow blanks", as if they were finished items, but that may change. It is possible that full CITES documentation could be required, which would make importation of existing stock nearly impossible (since the documentation doesn't exist).

What has added to the uncertainty is the status of ivory. Importation of new ivory was banned in the 1970s, but existing stores (called "pre-ban ivory") could still be used. But now, politics have caused that ban to be extended to any ivory, and in some states to fossil ivory. Bows, even valuable antique bows, could be (and have been) seized at the border. The ban includes any sale. Ivory-tipped bows have become unsaleable. Players, worried

that border agents can't distinguish bone from ivory, have turned to CF [carbon fibre] bows to use while on tour.

All of this has caused people to worry about the use of pernambuco, because it could potentially be subject to similar retroactive restrictions."

This statement and the described situation of internationally known orchestras show how the inclusion of bows as end product in the Appendix II of CITES or even in the Appendix I could affect musicians and the classical music. The handling of the US in regard to endangered species, when listed in CITES, is of international importance and has big impacts to the other scales, due to the importance of the market and more than that probably due to the importance for international concert tours of musicians. The latest changes and restrictions in regard to ivory create big concerns of bow makers and violin makers that the same could happen in the future to pau-brasil as well.

The laws and regulations on each scale do have direct effects on different actors of the SES – mainly on musicians, violin and bow makers. The overview of the most important political events and periods are shown in Figure 20.

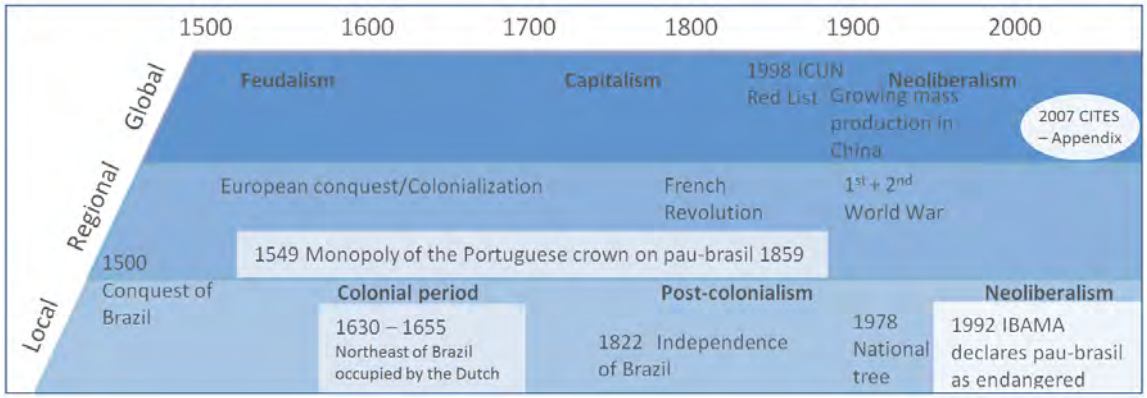

Figure 20: Overview of the most important political events and periods on three spatial scales

VIOLIN AND BOW MAKING

The origin of bows, and therefore of bow making, dates back to the 10th century and is rooted in the Arabic and Byzantine culture (Retford 1964). Sachs (2013) however mentions that the ancient origin of bows was most probably in India and later the bows were brought to Spain by the Arabs passing across Persia and North Africa. However, the development of the first violins and bows, how we know them today, arose in Europe. The colonialization was the beginning of the process of globalization and of immigration from Europe to other continents. This was the base for the distribution of the classical music and of violin and bow making around the world.

The tradition of violin making originated in Europe and evolved from the craft of constructing lutes. The lute was a common instrument in the 15th century, however, the first known violin dates back to 1511 and was built by Kaspar Tieffenbrucker whose origin was most probably in Bavaria or Tyrol (Schebeck 1877). This leads in some literature to the argumentation that the Italian tradition of violin making had its origin in Germany (Schebeck 1877). The most important representatives of the famous Italian or Cremonese violin makers were the Amati family, the Guarneri family and the family of Stradivari. Andrea Amati (1505 and 1577) was the first violin maker of this traditional line (Halbscheffel 2010). The perfection of the bowed stringed instruments was of great importance for the development of classical music. Until the late half of the 18th century bow making was part of the work of violin makers (Bunn & Seiber 1997). Prior to the mid-18th century various wood types, preferably from South and Central America, were used in the manufacturing of bows due to their high density and stiffness such as *Brosimum guianense* (snake wood) and *Zollernia paraensis* (Brazilian blackheart) (Baines 1961). In the early times of music, musicians considered bows of musical instruments mere accessories (Mnatzaganain 2002) rather than part of the instruments.

It was only from 1800 onwards, when bow makers started developing stronger and more responsive bows (e.g. bows that are easier, faster and more sensitive to react to musicians' techniques - a characteristic related to the stiffness), which required the use of wood species with different characteristics (e.g. elasticity, strength, bendability, etc.). During that time musicians started realizing that for improving sound quality the bow is equally important as the instrument itself (Mnatzaganain 2002). According to Skeaping (1955), the musical developments in the second half of the 18th century led to the growth of public music-making, the demand for more power and a wider range of dynamic variation in tone. The first response to these changes and new demands came from the bow makers and resulted in the evolution and ultimate standardization of the modern bow (Skeaping 1955). The use of modern bows increased the possibilities of power for the players and led to modifications in fitting the violin as well, to withstand the new forces (Skeaping 1955). Parallel to the fact that in the 18th century the making of bows began to be recognized as a specialized art, separate from violin making, mainly promoted in the workshop of Francois Tourte in Paris (Retford 1964; Bunn & Seiber 1997).

Tourte's introduction of the final pattern completed the experimental phase of bow making and initiated the process of standardization (Skeaping 1955). In the second half of the 18th century, Francois Tourte invented the classical modern violin bow model using wood of pau-brasil, which was identified as the ideal wood for the new model of modern violin bows (Baines 1961; Longui et al. 2010). The introduction of the modern violin bow represents an important shift in the tradition of bow making. After that pau-brasil became a highly important raw material for the production of high quality bows (Aguiar & Pinho 2007; Skeaping 1955). A recent anatomical analysis of historical French bows from the time period of Tourte and shortly after him indicates that the pau-brasil wood, which was used for these bows, most probably had its origin in the Northeast of Brazil (Macedo 2015).

In the late 18th century, bow making was still in its initial phase, but the French bow makers had abundant access to pau-brasil wood and from the beginning on they had a considerable economic advantage in comparison to their competitors in Germany and England (Bunn & Seiber 1997). From the 19th century onwards bow making could be found in three countries: Germany, France and England (Bunn & Seiber 1997). The German bow makers were mainly found in the small town Markneukirchen in Saxony, the French in Mircourt and Paris (Bunn & Seiber 1997). The first centres of bow production in manufactures existed in Saxony and Mircourt and represented a large-scale production scheme. For the years 1750 and 1930, the number of bow makers in Germany, France and England are shown in Table 5 and give an idea of how this profession evolved over the time and expanded within Europe.

Table 5: Number of registered bow makers in France, Germany and England (MODIFIED FROM BUNN & SEIBER 1997)

Year	Mircourt	Paris	Other towns	**France total**	Markneu-kirchen	Berlin, Dresden, Fleissen, Leipzig, etc.	**Germany Total**	**England Total**
1750	3	1	1	**5**	1	0	**1**	**no record**
1770	21	3	0	**24**	0	0	**0**	**2**
1790	10	2	2	**14**	1	0	**1**	**4**
1810	9	8	1	**18**	3	0	**3**	**6**
1830	5	1	1	**7**	5	2	**7**	**5**
1850	10	11	1	**22**	11	9	**20**	**3**
1870	15	15	1	**36**	26	9	**35**	**6**
1890	12	25	2	**39**	43	14	**57**	**10**
1910	18	26	4	**48**	51	15	**66**	**15**
1930	20	24	6	**50**	32	9	**41**	**14**

A historic document from 1872/73, from the Chamber of Commerce (Handels- und Gewerbekammer 1874) mentioned that violin and bow makers in Markneukirchen were complaining about the scarcity of high quality wood such as pau-brazil wood, snake wood and ebony. The same document reports that as a consequence wood prices had risen between 75 - 85 %. In the years of 1872/73 there were 70 master bow makers with 80 assistants and 32 apprentices in Markneukirchen, in total 132 persons (in 1871 there were only 96 reported). Apart from them there were 100 more bow makers who formed part of the association and employed 12 assistants and 12 apprentices. This shows that another 76 persons were occupied in the bow making profession. In this period 18,000 pau-brasil bows were produced per year, the total bow production in Markneukirchen was around 432,000 bows per year as shown in Table 6. The consumption of the raw material of pau-brasil was mentioned with 70 - 80 hundredweight, an ancient unit, which corresponds to about 3,500 – 4,000 kg or 3.5 – 4 tons. This is a relatively small number compared to the historical average exploitation of 9.5 and 557.8 tons per year. At those times, Markneukirchen was the leading market for musical instruments on the international level. According to conversations I had with several bow makers, Markneukirchen covered 50 % of the world bow production during that time. This corresponds to wood demand in the 21st century, so that the consumed 3.5 - 4 tons of material in Markneukirchen represent roughly half of the total consumed material for bow making in Europe, and the average of the consumed wood in the 20th and 21st century was 9.5 tons per year according to Rocha (2004). In Table 6 there is one category mentioned with the name horse wood bows, this term refers to the information of bow makers to bows made from massaranduba wood.

Table 6: Approximated production of bows in Markneukirchen and Region in the year 1972/73

Bow type	Amount in dozen[10]	Total amount
Pernambuco bows	1,500	18,000
Snake wood bows	500	6,000
Horse wood bows	18,000	216,000
Beech bows	16,000	192,000

In the Atlantic Forest bow making, apart from the wood trade, only became relevant with Horst John, who was of German origin and immigrated to Brazil after the 2nd World War. He founded a company for precious wood trade in 1951, with a special focus on pau-brasil, which he later transformed to a bow making company (John Cia. Ltda. 2003). This was the beginning of bow production for the international market in Espirito Santo in Brazil.

It was in the early 1980s that the first carbon fibre bows entered the market of bows for stringed instruments (Femke 2014). These bows were perceived as inferior to pau-brasil bows in the beginning, though quality has considerably improved within the last 30 years (Femke 2014) and the market share of carbon fibre bows is increasing continuously. More or less at the same time cheap, low quality musical instruments, as well as bows, including pau-brasil bows, entered to the international market (Hume 2008) - caused by the economic opening of China in 1978 (Lockett & Littler 1983). Today about 80 % of the global musical instruments market are produced in China (Böscher 2008). Chinese stringed instruments as well as the bows are produced in big manufactures at big scales; in the beginning their quality was very low but has improved considerably within in the last 20 years. However, these instruments from the big manufactures do not reach the level of high quality bows produced in traditional bow making workshops (a lot of them are in Europe).

[10] 1 dozen = 12

The online survey provides one question which shows the perception about the biggest threats for bow making. The question of the survey was:

"What do you consider is the biggest threat for the tradition of bow making?"

The percentage distribution of the answers is shown in Figure 21:

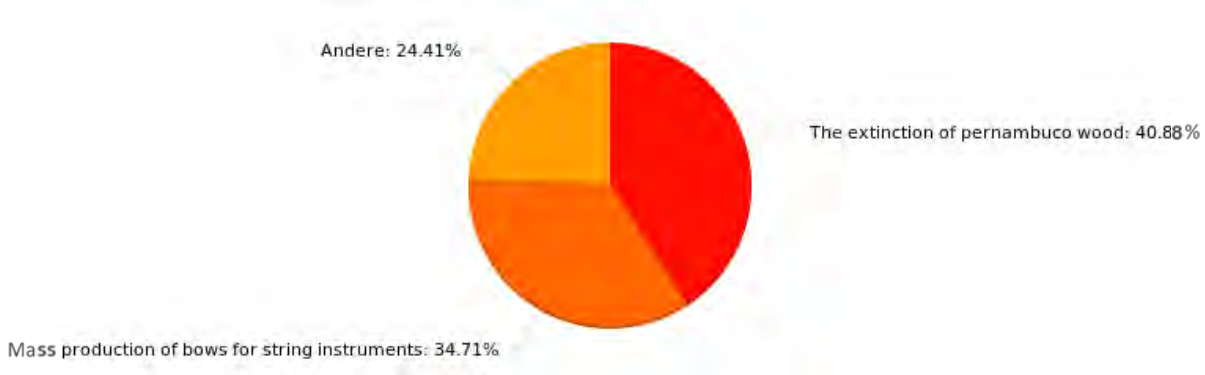

Figure 21: Perception of the participants of the online survey regarding the biggest threat for the tradition of bow making

Several answers to different questions of the online survey mentioned, that it is the Chinese market of cheap and low quality bows, made in mass production, which produces a big amount of cheap pau-brasil bows and contributes to a noteworthy part to the exploitation of pau-brasil in the Atlantic Forest.

It was in 1999 that Marco Ciambelli, son of a tortoiseshell workers family in France and Italy, got to know that the ecological situation of pau-brasil was very critical and that the species would possibly get placed in one of the Appendices of CITES (Rymer 2004). He had experienced the collapse of the family's business after the listing of tortoiseshell on CITES and therefore passed that information to bow makers in a meeting in France (Rymer 2004). Based on his personal experiences he strongly recommended to the bow makers to actively do something for the protection and conservation of pau-brasil. The information of Marco Ciambelli and the alarming threat that pau-brasil could reach a status of trade restrictions was responsible for bow makers getting active and founding IPCI in 2000 with

50 founding members from 18 nations (Gerbeth 2002). This was the beginning of the international campaign to save pau-brasil - the music tree (Rymer 2004). A series of activities for the conservation and plantation of pau-brasil started to take place in Brazil as well as on international and regional levels (Gerbeth 2002).

After the listing on CITES, which had not been avoided, trade is regulated and has to be registered. According to the CITES regulations legal importations and exportations of pau-brasil wood are internationally registered and are open for public access through the online trade database of CITES (trade.cites.org). Since the main use of pau-brasil nowadays is the construction of bows, it can be assumed that most or even all the registered export and imports were designated for the construction of bows for stringed instruments. Based on the available data since 2007 the movements can be summed up as shown in Table 7. In the original document the unit for the exported and imported amounts of wood are either given in m^3, cm^3, kg, g or there is no unit given at all. For a better comparison to other historical data the volumetric data (v) was transformed in an approximate way to the weight (w) in kg, considering an average density of pau-brasil with 1,026 kg m^{-3}. The average density was obtained from the measurements of Schimleck et al. (2009), there the density (δ) of pau-brasil varied between 855 kg m^{-3} to 1,197 kg m^{-3}. Based on these two values the average density is 1,026 kg m^{-3} by forming the mean value. Equation 1 shows how the weight is calculated.

Equation 1: $$w = \delta * \mathrm{v} = 1026 \frac{kg}{m^3} * \mathrm{v}$$

Table 7: Summary of the legal exportations and importations registered in CITES (ELABORATION BASED ON CITES 2015)

Year	Number of imp./ exp.	w in kg	V in m^3	w in kg (calculated)	Total in kg	Exports/imports without unit[11]
2007	2	25,144.53	-	-	25,144.53	3,000 (sw)
2008	7	1,408.00	1.002800	1,028.872800	2,436.87	200 (c)
2009	5	47.45	-	-	47.45	131 (c)
2010	8	59.10	19.000000	19,494.000000	19,553.10	17 (c) 580 (t) 9 (l)
2011	2		0.045093	46.265418	46.27	-
2012	4	4.26	-	-	4.26	159 (sw) 12 (c)
2013	16	72.00	12.496874	12,821.79	12,893.79	149 (c) 100 (sw)

According to these results the documented amount of pau-brasil wood which was traded varies considerably and no pattern can be identified. From the 44 registered exportations, 21 were exported from the US, seven from Germany, six from Brazil, three from France, two from Great Britain, one each from Japan, China, Spain and Canada and one exportation was not specified regarding to the exporter and importer. These numbers show that most of the legal traded pau-brasil wood came from the US between 2007 and 2013. In regard to the importations China received most frequently traded wood with a total of nine pau-brasil wood importations. Six importations went to the USA, four to Japan, three to each one of Germany, Switzerland, France, two to each one of Spain, Canada, New Zealand and Hong Kong, one to each one of Sweden, Poland, South Korea, Australia, Great Britain and Bulgaria. The purpose of almost all importations was declared as commercial, only in one case leaves were exported for scientific purposes and in another case the carving was determined for personal purposes. The exports/imports

[11] c = carvings, sw = sawn wood, t = timber, l = leaves

were declared as carvings, sawn wood, timber and leaves. This analysis of the exporter and importer countries shows how international and globalized the market for pau-brazil wood and the production of bows is nowadays.

A general overview on the current situation of exports and imports of stringed instruments on a global scale is available on the website of the International Trade Centre (International Trade Centre 2015a). The general trend in this sector is presented in two maps. Figure 22 shows a map of the exporters of stringed musical instruments requiring a bow; it can be seen that China is the main exporter of these products followed by Germany and the United States. However, this is a general overview and can only give an idea of the general trend of the actual situation of bowed stringed instruments and of the production of bows.

Figure 22: Exporters of stringed musical instruments played with a bow (International Trade Centre 2015b)

Figure 23 shows a map of the main importing countries of stringed instruments which also includes bows of stringed instruments. According to that analysis the United States of

America is the main importer; besides that Canada, Germany, Great Britain, France, Japan, Australia, South Korea and French Guiana also import stringed instruments.

Figure 23: Importers of stringed musical instruments played with a bow (International Trade Centre 2015c)

Nowadays bow making is not only limited to the regional scale (Europe) anymore, but Europe still represents somehow the core region of traditional bow making. Germany and France are still of special importance within Europe. According to internal information of German bow makers, there are about 50 bow makers in Germany and about another 50 bow makers in France. In general it has to be mentioned that the number of people working in this profession is, in comparison to other industries, very low. A German study from the 'Institut for Economy of Forestry and Wood Economy' (Institut für Ökonomie der Forst- und Holzwirtschaft) analysed the share of tropical wood on the imports of music instruments (Elsasser et al. 2011). According to this analysis the share is below 0.2 % of the German imports of tropical wood. This includes all imported musical instruments; bows for stringed instruments are only a small part of the whole group of musical

instruments. This study did only consider imported musical instruments, but not the imported wood for the construction or repairing of musical instruments and bows.

On the local scale five legal exportations of pau-brasil from Brazil had been registered in the Ministry of Environment between 1st January 2007 until 7th May 2015 (Ministerio do Meio Ambiente et al. 2015) and is shown in Table 8. The information of these exportations correspond to the online trade information on CITES and were included in the analysis of the global scale (see Table 7).

Table 8: Officially registered and legal exportations of pau-brasil between 2007 and 2015 (MINISTERIO DO MEIO AMBIENTE ET AL. 2015)

Date	Country of exporter	Country of importer	Amount in m^3	Term
25/11/2010	Brazil	Netherlands	9 UN	Leaf
12/12/2011	Brazil	United States	0.045	Timber
04/03/2013	Brazil	United States	0.045	Sawn wood
22/10/2013	Brazil	China	8.400	Sawn wood
23/12/2013	Brazil	Germany	0.011	Sawn wood

Internal information of IBAMA about illegal trade of pau-brasil in Brazil provided information about the officially registered sequestrations between 2007 and 2015 as shown in Table 9.

Table 9: Sequestered pau-brasil wood according to illegal trade within Brazil

Date	State	Place	Amount of pau-brasil in m^3
26/01/2007	Bahia	Una	0.000000439
06/08/2008	Amazonas	Maraa	1.005312000
01/10/2008	Bahia	Pojuca	5.980000000
23/06/2008	Bahia	Canavieiras	-
16/12/2007	Bahia	Camacan	-
07/11/2008	Bahia	Eunapolis	0.028800000
05/11/2008	Bahia	Eunapolis	1.520000000

09/07/2009	Espirito Santo	Aracruz	-
01/12/2010	Paraiba	Santa Rita	-
29/11/2010	Paraiba	Santa Rita	-
09/07/2014	Bahia	Camacan	-

Several sequestrations took place in the last eight years, unfortunately the responsible authorities in Brazil often neither do register specifically what kind of wood was sequestered nor the quantity of wood. Therefore the obtained data in Table 9 is incomplete.

According to the observations during the field study the majority of the bow making companies in Brazil is located in Espirito Santo. Mostly these bow making companies do also sell (legal) pau-brasil wood to the international market. This underpins that this is a very direct market. One of the last big companies which sold tropical wood for musical instruments in Germany was the company of Theodor Nagel which had to close due to insolvency in 2011 (Kohlhöfer 2014). The big unknown variable in the production of pau-brasil bows is the Chinese market.

Specific information on the use of pau-brasil for bows of stringed instruments is very limited; in particular no reliable data exist on the quantity of pau-brasil wood used for bow making at the global scale or at the national scale for Brazil (IUCN 2007). It is estimated that the demand worldwide fluctuates around 200 m^3; yet it is very likely that it is more than this, as this estimate does not account for the material loss during the process of production (CITES 2007). Building a violin bow requires approximately 1 kg of wood although the final bow has only a weight of about 60 - 64 g; therefore 70 - 90 % of the material gets presumably wasted (IUCN 2007).

Apart from the available general market situation the online survey included some quantitative questions about the production numbers of bows for stringed instruments.

The question *"On average, how many bows per year do you produce?"* was not sufficiently clear in the formulation, therefore it is not possible to know if the answers of the participants referred to the production of the whole company or only to the person who answered the survey. But the results show that from the 93 participants who answered the question in total 5,747 bows are produced, 12 participants mentioned that they were not or not anymore producing bows and one participant mentioned that he/she only produces baroque bows, usually not made of pau-brasil wood. The question included all kind of produced bows in general (baroque, carbon fibre, pau-brasil, etc.) and was not specified only for pau-brasil bows. This is why for all participants who did not only produce pau-brasil bows, the following question was given: *"How many bows per year do you produce considering the following wood types?"*. 56 participants answered this question, the results are shown in Table 10.

Table 10: Bow production per year differentiated between different types of wood

Produced bows per wood type	Number of produced bows
Pau-brasil bows	1,164
Massaranduba bows[12]	733
Carbon fibre bows	2,580
Ipe bows	87
Manilkara kauki bows	0
Bows of other materials	2,243

According to the answer of this question from the 93 participants of the question before, 43 do also produce bows with other woods. Therefore from the total produced number of bows from the first question (5,747 bows) only 4,494 bows are made of pau-brasil wood from bow makers who only produce pau-brasil bows. All of the other bow makers, who

[12] Massaranduba and brazilwood are terms which are for violin makers synonyms, in the survey they were asked separately here the answers are treated together

produce bows from different materials, made 1,164 pau-brasil bows. From 106 participants who make bows, in total 5,658 pau-brasil bows per year are produced.

To get an idea of the existing pau-brasil wood stocks the participants were also asked about them. This is important in regard to the dependency on the current pau-brasil wood trade, but also in regard of time for the regeneration of the species pau-brasil without losing the use of the species in bow making. The question of the survey was the following:

"For how many years will your stock of pernambuco wood last considering current production rates?"

This question was answered by 57 participants and can be summed up as shown in Table 11.

Table 11: Distribution of the existing pau-brasil stocks for the future in regard to the individual current production rates

Stock in years	0	1	2	3	5	6	10	12	15	20	25	30	40	50	70
No. of participants who have a stock for the corresponding years	1	1	1	2	3	1	8	1	5	11	3	6	2	11	1

Additionally 94 participants answered the question *"When did you buy pernambuco wood the last time?".* Figure 24 shows the percentage distribution of the participants and about when they bought pau-brasil wood the last time. After the CITES trade regulations between 2008 and 2015 pau-brasil wood was bought from 29 participants who answered this question.

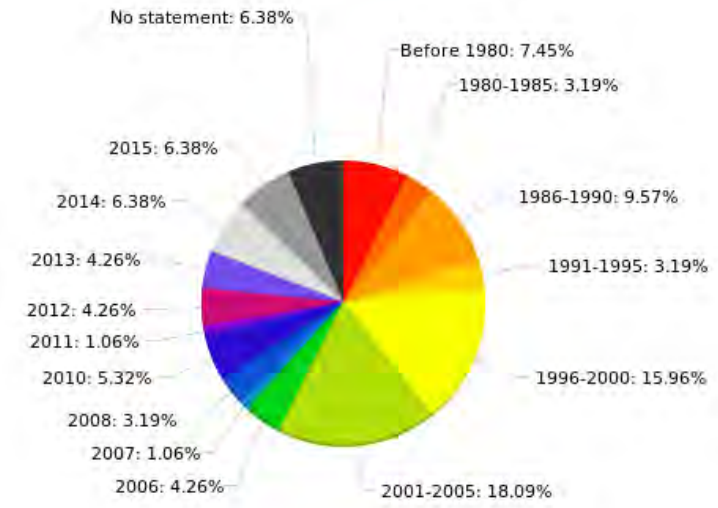

Figure 24: Percentage of the years when pau-brasil wood was bought the last time

In order to estimate the changes of the market for bows of stringed instruments, the following question was asked in the survey: *"Has your production changed over time?"* The distribution of the answer is shown in percentage in Figure 25. The question was answered by 100 participants.

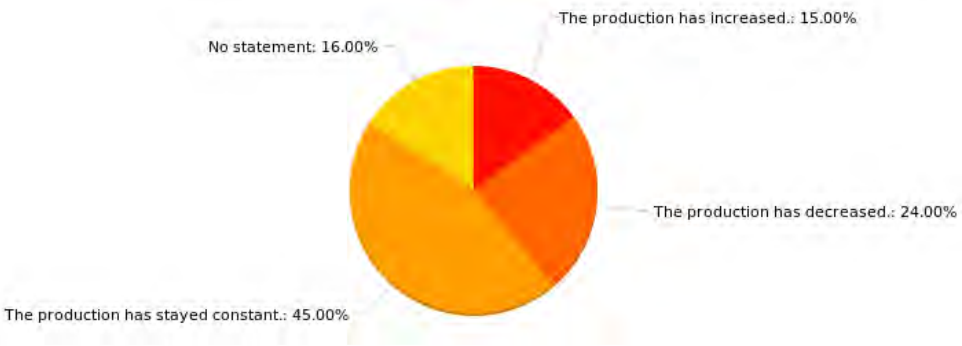

Figure 25: Production changes of bows for stringed instruments

Figure 26 provides an overview of the most important periods and events of the historical analysis of violin and bow making.

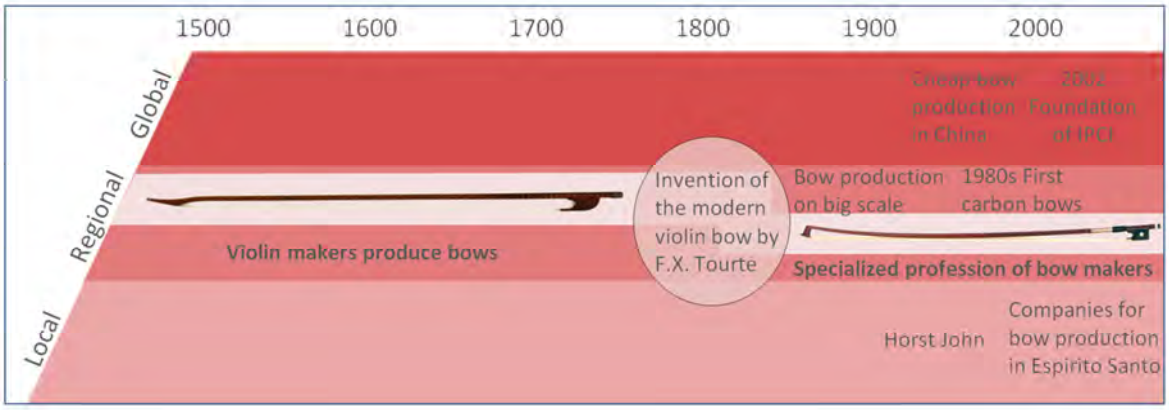

Figure 26: Overview of the historical development of bow making

CLASSICAL MUSIC

On the global scale, classical music spread worldwide in the course of colonialization. The first who brought classical music to other continents were often missionaries followed by European immigrants who brought their cultural habits including music with them. Pieces like the Symphony of the New World by Dvorak capture this moment of reaching another continent with all the impressions of meeting a new culture.

On the regional scale, in Europe it was during the Renaissance (1400 - 1600) when the tradition of instrumental music evolved, and its perfection was reached in the period of the baroque (Böhm 1983). It was during that time that the first violins appeared (Schebeck 1877). The baroque (1600 – 1750) represents a music style full of decoration and pomp (Böhm 1983; Brockhaus 1993). During that time, between the 17th and the beginning of the 18th century, the classical music had its centre in Italy – mainly in Venice (Böhm 1983). J.S. Bach and J. Händel were the best known composers of this epoch (Brockhaus 1993). The concerts mainly were for small audiences and in big parts they were reserved for the court of the royal houses. At this time, the first violin solo concerts and virtuous compositions for stringed instruments developed and led to the classic period between 1780 and 1830 (Brockhaus 1993). At the beginning of the 18th century Vienna became the capital of classical music for the next 200 years (Böhm 1983). During that time, music

became an issue of the middle class and the musicians themselves came from the middle classes (Böhm 1983). Some of the most known composers of classical music were Mozart, Beethoven and Haydn (Böhm 1983). One of the most famous violinists lived during that time, Niccolò Paganini (1782 - 1840), also known as the devil's violinist. He developed and improved the technique of violin playing to a degree of unprecedented perfection (Komission für Musikforschung 2013). Especially Paganini tried all kinds of different bows to find the most adequate one for the increasing technical requirements of the violin playing. All these changes caused musicians to realize the importance of the bow for a better sound quality (Mnatzaganain 2002). Romanticism marked a new period in musical history between 1820 - 1910 (Brockhaus 1993). This period was characterized by a turn away from the rigid composition structures of the classical period towards a more free and unbound way of compositions (Böhm 1983). The musical developments in the second half of the eighteenth-century led to the growth of public music-making (Skeaping 1955). During the romantic period the number of musicians in an orchestra increased noticeably, in response to new compositions by Wagner and Strauss (Bibliographisches Institut & F. A. Brockhaus AG 2015). Playing these new pieces required increasingly bigger concert halls designed for larger audiences. As a result especially the bowed stringed instruments required more power in sound and dynamic tone variation (Skeaping 1955). The modern bows increased the power possibilities for the musician and helped to respond to the new circumstances of bigger halls and orchestras (Skeaping 1955). Also the instruments of Stradivarius proofed their superiority in the carrying capacity of the sound (reach of the sound propagation), which became specifically more important due to the described changes. Important composers of the romantic period are Schubert, Mendelssohn, Chopin, Schumann, Berlioz, Liszt and Wagner (Böhm 1983). The music after 1908 is called new music or the modern era and includes a variety of music styles such as the twelve-tone technique, serial music, jazz and blues, electronic music and experimental music among others (Brockhaus 1993). This era is characterized by its diversity and the

development of a kind of new sound space (Brockhaus 1993). A loss of the importance of 'classical music' can be noted within Europe.

On the local scale of Brazil and the Atlantic Forest, classical music had been introduced by the missionaries. But only at the end of the 18th century, with Hector Villa-Lobos Lobos (1887 - 1959), one of the best-known Brazilian composers, classical music in Brazil gained international recognition.

In order to estimate the flexibility and adaptability of musicians to the ecological situation of pau-brasil the online survey tried to identify the willingness of musicians to use bows of alternative materials according to the opinion of the participants the question was the following one and was answered by all 340 participants:

"How would you describe the willingness of musicians to use a bow made of alternative woods/materials instead of pernambuco wood considering:"

The answers are summed up in Figure 27 and include the information of the determined standard variation and the mean average of the answers.

	Very low (1)		Low (2)		Middle (3)		High (4)		Very high (5)		No statement possible (6)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Kids using childrens' in...	2x	0,59	8x	2,35	45x	13,24	115x	33,82	152x	44,71	18x	5,29	4,36	0,90
Amateurs	5x	1,47	38x	11,18	154x	45,29	99x	29,12	31x	9,12	13x	3,82	3,45	0,99
Semi-professionals	35x	10,29	108x	31,76	142x	41,76	34x	10,00	11x	3,24	10x	2,94	2,73	1,07
Professionals	124x	36,47	123x	36,18	54x	15,88	19x	5,59	8x	2,35	12x	3,53	2,12	1,23

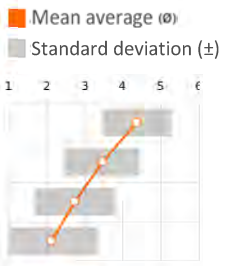

Figure 27: Perception of the willingness of musicians to use a bow made of alternative woods and materials

An overview of the historical analysis of classical music is shown in Figure 28.

Figure 28: Overview of the development of classical music relevant for bow making and pau-brasil

THE DYNAMICS OF THE SES OF *C. ECHINATA* AND BOW MAKING

The spatiotemporal analysis permits to identify several key cross-scale interactions and feedbacks in the focal system as well as important drivers. The most important ones had been analysed.

The colonialization of Brazil in 1500 (Rocha 2004) represents the beginning of a new regime in the focal system and represents the early *r* phase of an adaptive cycle. Together with the following monopoly of the Portuguese Crown on pau-brasil (1549 - 1859) (Dean 1996) the colonialization created a negative and positive feedback at the same time. The negative feedback on the focal system was the destruction and diminution of the natural populations of pau-brasil due to the exploitation of pau-brasil for the extraction of the red dye (Nehren et al. 2013). The positive feedback on the focal system was the introduction of tropical woods and exotic materials, which then started to form part of a lot of musical instruments and bows (U.S. Fish & Wildlife Service 2010). At the same time the colonialization was an important cross-scale interaction between the regional and local scale.

One of the most important periods of change in the focal system during the whole period of analysis was the time from the mid-18th century until the mid-19th century. Two

historical events were responsible for a regime shift - the introduction of modern bows in the second half of the 18th century (Baines 1961; Longui et al. 2010) and shortly after that another regime shift due to the discovery of the aniline colours in the mid-19th century (Aguiar & Pinho 2007). During the time when modern violin bows were developed three things happened simultaneously: 1) a change in the way of construction and the shape of the bows, 2) the construction of bows became more specific and 3) the profession of bow making became an own specialization, which also implied that violin makers no longer produced bows. The replacement of former materials with pau-brasil made this regime shift possible. The introduction of the modern bow and the use of pau-brasil had a positive feedback on the classical music. At that time musicians like Paganini improved the technique of violin playing (Komission für Musikforschung 2013) and musicians started to realize the importance of the bow for a better sound quality (Mnatzaganain 2002). This regime shift implied a negative feedback on the species of pau-brasil, as the production of bows made of pau-brasil started to contribute to the selective cutting of pau-brasil in the Atlantic Forest. The feedback on pau-brasil is a cross-scale interaction between the local and the regional scale. The discovery of the aniline colours represents an external driver of the focal system and induced another regime shift. By the end of the nineteenth century practically all natural dyes had systematically been replaced in the colour industry (Michaelson 1993). This had a positive impact for the whole focal system as it led to an enormous reduction in the exportation of pau-brasil and somehow slowed down the exploitation of the species pau-brasil (Rocha 2004) on the local scale as well as the importance of pau-brasil for international commerce decreased (Aguiar & Pinho 2007) while the importance for bows of stringed instruments on the regional scale have continued to be high until today (Aguiar & Pinho 2007). This was a cross-scale interaction between all three scales.

An important global driver influenced the focal system with the invention of carbon fibre bows in the early 1980s (Femke 2014) and the mass production of cheap and low quality

Chinese bows made of pau-brasil. The impacts on the focal system are negative for the cheap Chinese pau-brasil bows and for carbon fibre bows - they are positive and negative at the same time. For the cheap Chinese bows the negative impact is the effect on the tradition of bow making, based on the answers in the survey; according to the cheap labour costs in China and the low prices for bows of pau-brasil a competition is impossible for bow makers in Europe. A second negative impact is the increasing production number of cheap pau-brasil bows. This increased the demand for the wood from the species of pau-brasil. This is a cross-scale interaction between the global and the regional scale.

The most recent cross-scale interaction was induced by the listing of pau-brasil on the Appendix II of CITES in 2007 - a global driver – and caused a regime shift of the focal system. Already in advance the threat that pau-brasil could get listed on CITES was responsible for the foundation of IPCI at the global scale (Rymer 2004). This created a positive feedback as IPCI started to support conservation and plantation efforts of pau-brasil. The listing of pau-brasil in CITES was influenced by bow makers mainly from IPCI (Rymer 2004) and by internationally famous musicians such as Yo-Yo Ma (Sadler 2007). Apparently, they could influence in the last minute that the final product, the bow, was not included in Appendix II (Sadler 2007). Therefore we can speak here about a feedback effect. This shows that lobbying worked in favour of the tradition of bow making and in favour of the classical music. The listing of pau-brasil pushed the bow making part of the focal system on one side closer to a possible threshold, on the other side it supported the regeneration of the species pau-brasil and therefore had a positive impact on the species. Probably this is an example of what Folke et al. (2010) stated, sometimes the strong identity and cultural beliefs require a shock or noticeable crisis to overcome the state of denial and to trigger novelty and innovation.

An overview of the cross-scale interactions is shown in Figure 30. This is an approximation and highlights the main cross-scale interactions, feedbacks and drivers in regard to pau-

brasil and to bow making. The overview also marks the three identified regime shifts which the focal system passed through. The legend of the graphic is shown in Figure 29.

Figure 29: Legend to the graphic of the dynamics of the SES *C. echinata* and bow making

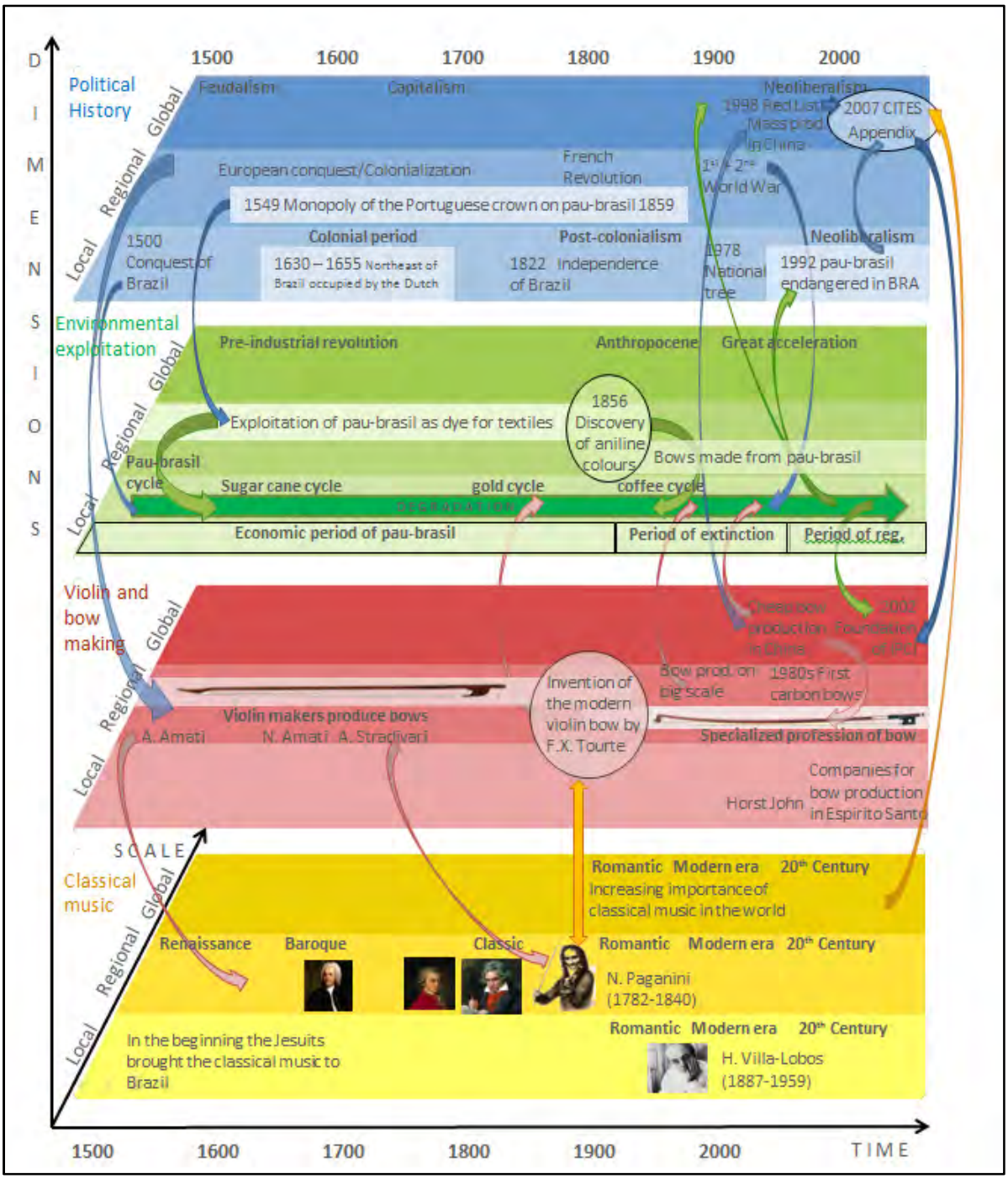

Figure 30: Dynamics of the SES *C. echinata* and bow making

Based on the spatiotemporal analysis it was possible to identify the key elements of the SES *C. echinata* – bow making shown in Figure 31. According to the realized analysis the most important slow variables of the SES are the tradition of bow making and classical music within the social properties and the natural genetic erosion of the species within the ecological properties. The conducted survey showed that the tradition in bow making is still of big importance and is shaping very much the opinions of bow makers and musicians, in the expert interviews it was explicitly pointed out that the natural genetic erosion is an important slow variable.

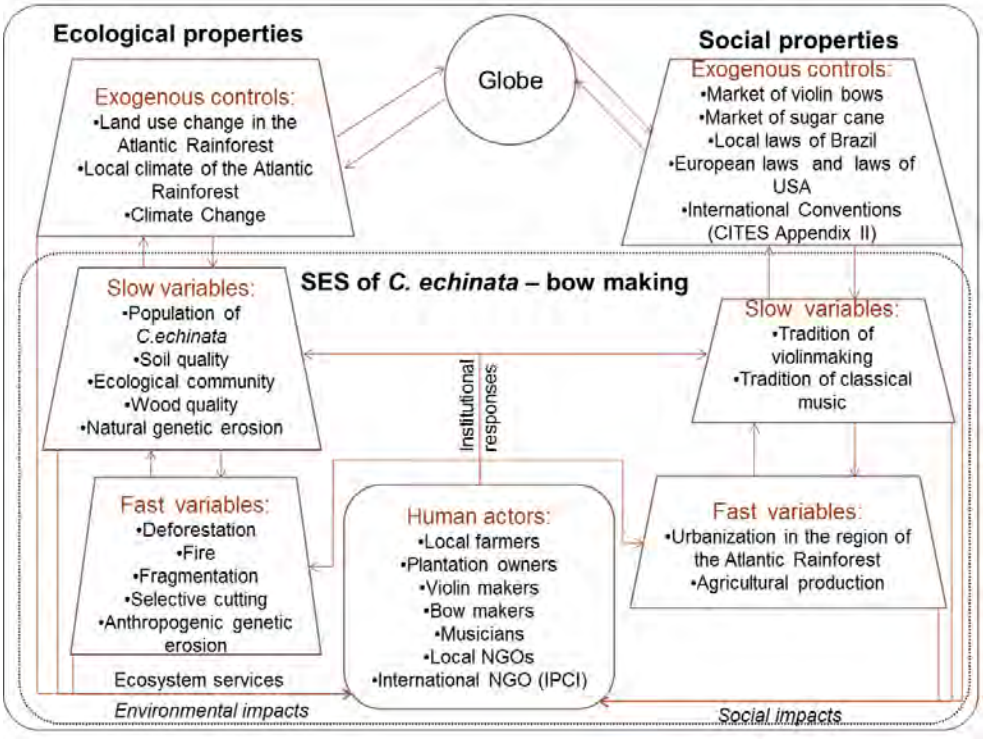

Figure 31: Identified key elements of the SES *C. echinata* – bow making (modified after Chapin et al. 2009)

Due to the perspective of this study on the SES, the resilience of the whole focal system depends on the resilience of the species pau-brasil in combination with the resilience of the tradition of bow making. Due to these two aspects the resilience of the focal system needs to considerate ecological and social resilience.

DISCUSSION

CONCEPTUAL MODEL OF THE SES *C.ECHINATA* – BOW MAKING

The SES *C. echinata* – bow making exhibits a variety of facets and is hallmarked by unpredictability and contradiction. Based on the complete analysis of this study the system state can be described as being in the very early phase of reorientation (α phase) or a late release phase (Ω phase) still with a lot of disorientation and considerable unpredictability (Figure 32).

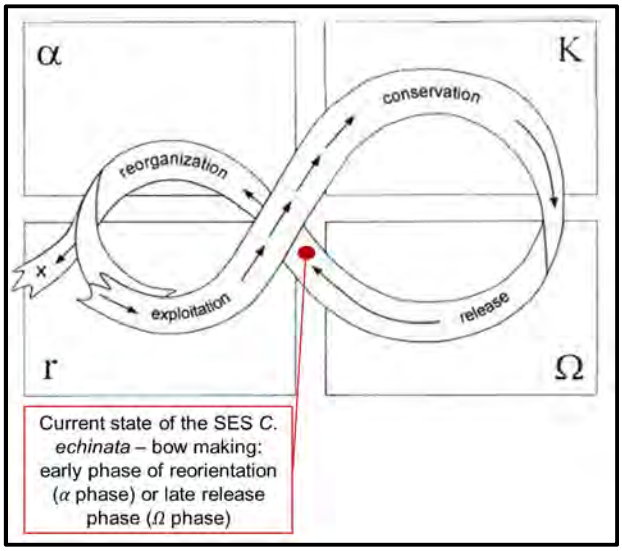

Figure 32: Current state of the SES *C. echinata* – bow making in the adaptive cycle (modified after Holling 2001)

A resilient SES *C. echinata* – bow making would imply to increase the ecological resilience of the species pau-brasil and at the same time the social resilience of bow making, because the SES consists of both parts and crossing a threshold either for pau-brasil or for bow making would imply a regime shift with the loss of key elements of this SES. The actual status of the system does not fulfil this criterion of resilience and therefore cannot be described as sustainable in the long-run. The main threats and possible thresholds that can be identified for bow making (social properties) are the listing of pau-brasil on the

Appendix I of CITES, the extinction of pau-brasil, diminution of classical music and the disappearance of the small workshops that transmit the tradition of bow making due to cheap mass production with increasing quality, but also an improvement in the construction of carbon fibre bows or a slow change of the preferences of musicians could induce a regime shift. For the species pau-brasil the main threats or thresholds is the reduction of the natural habitat to a size where no regeneration is possible anymore, this would imply the extinction of the species. Another threat is the complete disappearance of making bows with pau-brasil wood because then conservation and protection efforts of bow makers would completely disappear, while the external drivers of the sugar cane industry and the pulp- and paper industry would continue to exist and to threaten the natural habitat of pau-brasil. The unpredictability of the system is: a change in the CITES listing, missing experiences of commercial plantations of pau-brasil and it is unpredictable if bow making, in the long-run, will continue using pau-brasil as main raw material.

According to personal observation in the field the exchange and cooperation between local NGOs in Brazil is increasing, but is still directly connected to the international NGO IPCI. Most of the local conservation initiatives are depending on the financial support of IPCI to protect and plant pau-brasil. The support comes from bow makers, violin makers and musicians, the same actors that use the raw material they are trying to protect. The local NGOs are still in their initial phases of commercial plantations of pau-brasil - experiences do not exist in a sufficient way yet.

According to the answers of the online survey, the world of music - musicians, violin makers and bow makers - is more and more divided into the ones who are slowly opening their minds for rethinking and the ones who are holding on the tradition, but therefore at the same time preserve the tradition. The trade restrictions of CITES necessitates them to rethink existing opinions and ways of acting. The whole interconnections of the current situation of the SES can be described as shown in Figure 33. All identified actors are included in the form of bigger groups. Bow makers, violin makers and musicians have

been grouped across the local and regional scale and have not been divided anymore. The thin arrows indicate feedbacks between the different stakeholders and pau-brasil, including the natural populations and the human induced conservation and plantation efforts. The thick arrows describe the external drivers for this SES.

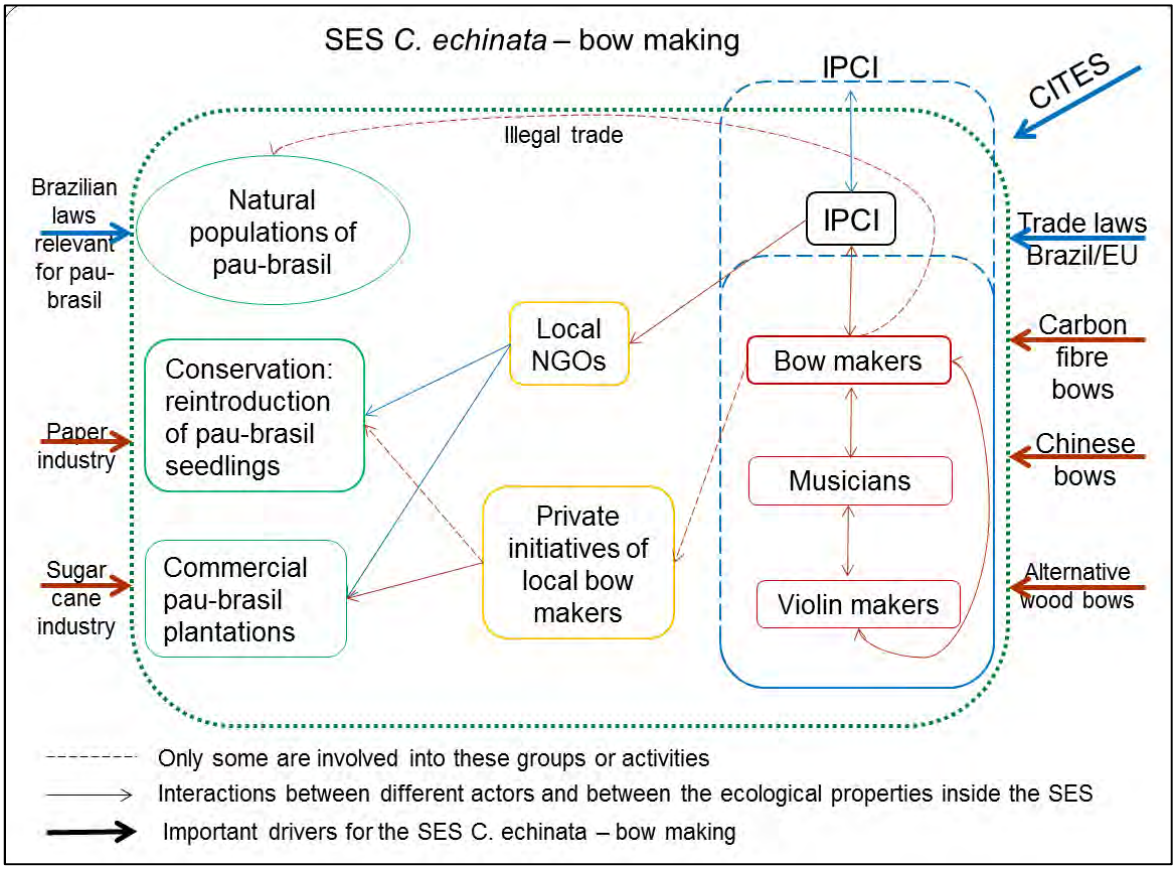

Figure 33: Model of the current SES *C. echinata* –bow making

For a more sustainable SES *C. echinata* – bow making several elements would be necessary to change or to influence in another direction, to stabilize key elements such as the protection and conservation of the natural populations of pau-brasil. Illegal trade would need to be reduced, possibly not only through stronger controls, but also through information and education about the problem of pau-brasil, especially for musicians. This could support more conscience in the decision-making process of the musicians. To

reduce the pressure of external drivers, it could be tried to involve, for example, the pulp and paper industry as well as the sugar cane industry into conservation efforts in a way that could improve their image and also show their social and ecological responsibility. It would be necessary to discuss if the inclusion of bows in the Appendix II can be a tool for a controlled increase of resilience that possibly could prevent crossing a threshold into an undesired state of the SES. The external drivers of carbon fibre bows and alternative wood bows have a positive effect on pau-brasil, as they contribute to a decreasing demand for pau-brasil wood. They represent the innovations which are taking place in bow making. For a more sustainable SES it is indispensable to understand the Chinese market in a better way. This perception of the current situation leads to two possible scenarios.

SZENARIO OF STRICT TRADE REGULATION

A continuation of the destruction of the natural habitat of pau-brasil and the selective illegal cutting might lead to significant declines of the natural pau-brasil populations and finally result in the listing of pau-brasil on the Appendix I. With this listing the priority of the protection and preservation of pau-brasil would, in its consequence, basically stop the trade of pau-brasil completely and, in the best case, help the species to recover in its natural habitat. On the other side the listing would create a feedback loop and bow makers and musicians would probably reduce or stop their plantation and conservation efforts completely. This would have a negative feedback on the conservation of pau-brasil, also as the main efforts, financial efforts to protect the species actively and to improve its situation, come from IPCI and its members (bow makers, violin makers and musicians). For bow makers this decision would represent a regime shift and they would lose their livelihood. The listing would induce the collapse of the current SES *C. echinata* – bow making. Although this collapse holds the chance of innovation and adaptation for bow makers and could lead either to a completely undesirable state that in the consequence would have negative impacts on the classical music, it could lead to an alternative, yet

unknown state, for bow making under completely new conditions with positive innovation for musicians and in its consequence for the classical music.

OPTIMISTIC SCENARIO

The ongoing plantation and conservation efforts of IPCI and the local NGOs in Brazil would improve the situation of pau-brasil in a long-run, and the experiences in Brazil would lead to successful results in regard to the wood quality. Through the promotion of planting pau-brasil, new types of plantations would probably evolve and contribute to the inclusion of other native species, and farmers would experience this way of planting as an alternative land use on a part of their land. The success of the plantations would lead to the offer of sufficient sustainably produced wood for the construction of bows. The whole process of the conservation of pau-brasil, together with the commercial plantations, would lead to a regeneration of natural populations. Due to these developments bow makers would continue to use pau-brasil wood, obtained from the successful commercial plantations. The ongoing process of improvements for carbon fibre bows as well as the increasing acceptance of musicians would lead to a reduction of the use of pau-brasil for cheap and low quality bows. Therefore, even on the Chinese market, the use of pau-brasil for low quality bows would decrease and pau-brasil would slowly reach to be used only for the high quality sector of bow making. In a long-run the ecological resilience of pau-brasil would improve as well as the resilience of the tradition in bow making.

CONCLUSION

The spatiotemporal analysis of this study provided multiscale information about the historical background of the current SES *C. echinata* – bow making and showed clearly how important it is to understand the historical background of the exploitation of the Atlantic Forest – for the most part, it was the selective exploitation of pau-brasil for the use as a colorant in Europe together with the land use changes in the history. The

identification of the main external drivers such as the invention of the modern violin bow by Tourte, the discovery of the aniline colours in Europe and recently the inclusion of pau-brasil in the Appendix II of CITES shaped the historical development of the SES *C. echinata* and bow making in a fundamental way. Internal factors such as the feedback loops between the classical music and bow making, or between bow making and pau-brasil shaped the classical music and bow making (e.g. Paganini and Tourte). The main actors contribute in different ways to this complex SES, but the involvement of the bow makers, violin makers and musicians in the current conservation and plantation efforts is very characteristic for the system, as they are the most resource dependent actors. Most of them are not in the ecological region of natural occurrence of pau-brasil, but are financially involved in activities for the protection and plantation of pau-brasil. At the same time some of the bow makers are the ones who still contribute and induce still selective illegal cutting. The local NGOs are the most important partners for realizing the plantation efforts for conservation and commercial plantations. The elaborated model of the current situation provides a good initial point for future analysis of other SES of a similar context such as ebony (species of the genus *Diospyros)* used for musical instruments or African blackwood (*Dalbergia melanoxylon)* used for clarinets.

For the realization of this study I incorporated my academic knowledge on Environmental and Resources Management as well as my experiences and knowledge of being a violin maker myself, having worked in that area in different countries and different contexts as well as having played the violin since my childhood.

In the process of analysis it was recognized that this study shows a lack of representing and involving the actor group of musicians. The final ‘consumer’ of pau-brasil – the audience of a concert – was far too less represented in this analysis. Involving their perception, knowledge and opinion in regard to pau-brasil and violin bows would have contributed to a more complete analysis. Still this analysis is a helpful approximation to this complex social-ecological problem and can be taken as base for the elaboration of

possible future interactions for a more sustainable use of pau-brasil and for increasing the resilience of pau-brasil and bow making.

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APPENDICES

APPENDIX I

Survey about the tradition of bowmaking and the importance of pernambuco wood

Bitte wählen Sie eine Sprache aus. / Please choose a language. / Por favor, seleccione un idioma./ Veuillez s'il vous plaît choisir une langue. / Selezionare una lingua. / Por favor escolha um idioma.

Deutsch
○ English
○ Español
○ Français
○ Português
○ Italiano

Page 1

1. In which category would you place your company/yourself? *

☐ Violin making ☐ Bow making ☐ Dealer/seller of string instruments and equipment
☐ Other

2. What applies to you? *

○ Employed
○ Self-employed
○ Doing a training/an apprenticeship/studies
Other

Page 2

3. How long have you already worked as a bow maker/violin maker/dealer for string instruments? *

4. Where are you doing your training/apprenticeship? *

5. When did you start your training/apprenticeship? *

6. In what country(-ies) is/are your company(-ies) located? *

Page 3

7. How big is/are your company/companies? *

- 1 person
- 2-3 persons
- 4-6 persons
- 7-10 persons
- 11-20 persons
- 21-50 persons
- More than 50 persons
- No statement

Page 4

8. When was your company/workshop founded?

Page 5

9. Do you also make bows in your company? *

- Yes
- No

Page 6

10. Do you know in what country(-ies) the pernambuco tree whose wood is used in bow making grows? *

- Yes
- No

Page 7

11. Where does the pernambuco tree grow? *

12. What do you know about the forests and ecosystem where pernambuco trees grow?

13. How would you describe the willingness of musicians to use a bow made of alternative woods/materials instead of pernambuco wood considering: *

	Very low	Low	Middle	High	Very High	No statement possible
Kids using childrens' instruments	○	○	○	○	○	○
Amatuers	○	○	○	○	○	○
Semi-professionals	○	○	○	○	○	○
Professionals	○	○	○	○	○	○

14. What do you consider are potential constraints for using bows made of alternative woods/materials to pernambuco wood in respect of musicians?

Page 9

15. What do you consider are the main constraints for using alternative woods/materials to pernambuco wood in bow making?

16. What do you, as a violin maker/dealer of string instruments, consider are potential constraints for using alternative woods/materials to pernambuco wood for making new high quality bows?

Page 10

17. Do you consider the use of pernambuco wood in bow making has a positive, negative influence or no relevance onto/for the natural forest populations of pernambuco trees? *

- ○ The use has no relevance.
- ○ The use has a positive influence.
- ○ The use has a negative influence.
- ○ No statement possible

Page 11

18. Due to your opinion, why is it like that?

Page 12

19. On average, how many bows per year do you produce?

pieces

20. Has your production changed over time? *

- ○ The production has increased.
- ○ The production has decreased.
- ○ The production has stayed constant.
- ○ No statement

Page 13

21. Which materials do you use for the production of your bow sticks? *

- ☐ Pernambuco wood
- ☐ Brazilwood
- ☐ Ipe
- ☐ Carbon fiber
- ☐ Manilkara kauki
- ☐ Massaranduba
- Other

Page 14

22. How many bows per year do you produce considering the following wood types?

	Pieces
Pernambuco	
Brazilwood	
Massaranduba	
Manilkara kauki	
Ipe	
Carbon fiber	
Other	

Page 15

23. Did you notice any change of the quality of pernambuco wood within the last 20 years?*

- ○ Yes, wood quality increased.
- ○ Yes, wood quality decreased.
- ○ Yes, there can be noticed more variation in wood quality.
- ○ No, I didn't notice any changes.
- ○ No statement possible

Other

Page 16

24. What would you attribute these changes to?

Page 17

25. On average, how long do you stock your pernambuco wood before making a bow?

Page 18

26. How would you describe the development of the production of pernambuco bows in your own country? *

	Rising production	Constant production	Decreasing production	No statement possible
Student bows	○	○	○	○
Nickel silver bows	○	○	○	○
Silver bows	○	○	○	○
Gold bows	○	○	○	○

27. How would you describe the development of the production of pernambuco bows worldwide? *

	Rising production	Constant production	Decreasing production	No statement possible
Student bows	○	○	○	○
Nickel silver bows	○	○	○	○
Silver bows	○	○	○	○
Gold bows	○	○	○	○

Page 19

28. Did you notice any change of the prices for pernambuco wood in bow making within the last 20 years? *

- ○ Yes, the prices for pernambuco wood increased.
- ○ Yes, the prices for pernambuco wood decreased.
- ○ No, I didn't notice any change.
- ○ No statement possible

Page 20

29. What do you attribute this change of price to?

Page 21

30. Do you sell bows in your company? *

- ○ Yes
- ○ No

Page 22

31. How would you describe the price development of pernambuco bows within the last 20 years? *

	Rising prices	Constant prices	Dropping prices	No statement possible
Student bows	○	○	○	○
Nickel silver bows	○	○	○	○
Silver bows	○	○	○	○
Gold bows	○	○	○	○

Page 23

32. For how many years will your stock of pernambuco wood last considering current production rates?

This question needs not to be answered.

[ ] years

33. When did you buy pernambuco wood the last time?

Please select

Page 24

34. Do you also sell bows of other bow makers/companies? *

○ Yes

○ No

Page 25

35. How would you describe your main market?

○ Mainly or only direct selling to the musicians

○ Mainly or only selling to other companies, violin makers and dealers

○ Both, direct selling and selling to other companies, violin makers and dealers

○ No statement possible

Page 26

36. On average, how many bows do you sell per year?

[ ] pieces

37. How many of these bows are made of pernambuco wood per year?

[ ] pieces

Page 27

38. What other types of wood/materials are the bows you sell made of?

- [ ] Brazilwood
- [ ] Massaranduba
- [ ] Carbon fiber
- [ ] Manilkara kauki
- [ ] Ipe

Other

Page 28

39. What is the percentage of the bows you sell?

	%
Student bows	
Nickel silver bows	
Silver bows	
Gold bows	

40. Where are the bows you sell mainly produced? *

- [ ] Germany
- [ ] France
- [ ] England
- [ ] Italy
- [ ] China
- [ ] USA
- [ ] Canada
- [ ] Brazil
- [ ]

Page 29

41. To your knowledge have there been included other, previously unknown, wood varieties in bow production over the last 20 years? *

- ○ Yes
- ○ No
- ○ No statement possible

Page 30

42. Which wood varieties have been added?

43. Did you notice any change in the bow quality of new bows within the last 20 years? *

- ○ Yes, the quality of new bows generally increased.
- ○ Yes, the quality of new bows generally decreased.
- ○ No, I didn't notice any changes.
- ○ No statement possible

Other

Page 31

44. What do you think is the reason for these quality changes?

Page 32

45. Does pernambuco wood need to be registered in some kind of way or are there any trade restrictions for pernambuco wood in your country? *

- ○ Yes
- ○ No
- ○ No statement possible

Page 33

46. What kind of restriction is it about?

Page 34

47. Do pernambuco bows need to be registered in some kind of way or are there any trade restrictions for pernambuco bows in your country? *

- ○ Yes
- ○ No
- ○ No statement possible

Page 35

48. Do these kind of restrictions or reglementations also apply for pernambuco bows and what are the restrictions about?

Page 36

49. If the pernambuco tree was going to extinct, would this affect you using/promoting this wood for bow production? *

Multiple selection possible

- ☐ I would prefer to buy wood originating from pernambuco plantations.
- ☐ I would still try to get wood from pernambuco trees from leftovers of natural forest populations.
- ☐ I would try to promote the conservation of the forest of origin.
- ☐ I would use alternative woods/materials for making bows.
- ☐ If there was still a demand of the musicians for new bows made of pernambuco wood from natural populations, I would try to get wood from the leftover pernambuco trees in natural populations.
- ☐ I would inform the musicians about the situation of the pernambuco tree.

Other

50. If the pernambuco tree was going to go extinct, would this affect you selling/promoting new bows made of pernambuco wood? *

Multiple selection possible

- [ ] I would prefer to sell bows made of pernambuco wood originating from plantations.
- [ ] If there was still a demand of the musicians for new bows made of pernambuco wood from natural populations, I would try to get new pernambuco bows which are made from wood of the leftover pernambuco trees in natural populations.
- [ ] I would try to promote the conservation of this forest type.
- [ ] I would sell new bows made of alternative materials.
- [ ] I would definetly try to buy pernambuco bows made of pernambuco wood of trees from leftovers of natural forest populations.
- [ ] I would inform the musicians about the situation of the pernambuco tree.
- [ ] Other

Page 37

51. What do you consider is the biggest threat for the tradition of bow making? *

- ○ The extinction of pernambuco wood
- ○ Mass production of bows for string instruments
- ○ Other

52. Why do you think this is the biggest threat for the traditional profession of bow making?

Page 38

53. Which age group do you belong to?

- ○ Under 25 years
- ○ 25-30 years
- ○ 31-40 years
- ○ 41-50 years
- ○ 51-60 years
- ○ Over 60 years

54. Would you like to get back your data and the results of the survey after the evaluation?

- ○ Yes
- ○ No

You have completed the survey. Thank you very much for your participation.

You can now close the window.

APPENDIX II

Characteristics of pau-brasil plantations in the Atlantic Forest:

Localities	Morphotypes																	
	Small*						Medium						Big					
	n	Diameter, cm	High without branches, m	Total high, m	Diameter of treetops, m	Appearance of, n	n	Diameter, cm	High without branches, m	Total high, m	Diameter of treetops, m	Appearance, n	n	Diameter, cm	High without branches, m	Total high, m	Diameter of treetops, m	Appearance, n
Area CEPLAC 1	11	9.34, 1.36	2.27, 0.44	6.50, 0.91	3.74, 0.88	Straight, 8 Irregular, 3	7	2.63, 2.39	1.78, 1.08	3.67, 2.05	0.93, 0.64	Straight, 6 Irregular, 1	14	7.08, 2.17	2.70, 1.12	5.60, 2.07	2.66, 0.94	Straight, 10 Irregular, 2 Bent, 2
Area CEPLAC 2	5	8.10, 3.17	2.33, 0.57	5.72, 2.26	3.69, 0.99	Straight, 3 Irregular, 2	10	7.43, 2.66	2.47, 1.05	4.89, 1.17	2.47, 0.81	Straight, 7 Irregular, 3	4	5.87, 2.08	3.19, 1.32	5.25, 0.50	2.03, 0.39	Straight, 3 Bent, 1
Jacy casa	2	14.2, 0.7	3.5, 0.7	11.5, 1.4	5.0, 0.4	Straight, 2	27	9.74, 2.5	7.0, 3.5	10.09, 1.5	3.12, 1.0	Straight, 23 Irregular, 4	13	5.52, 4.72	2.79, 2.02	5.62, 3.88	2.0, 1.30	Straight, 7 Irregular, 4 Bent, 2
Marco Raposo	13	5.0, 2.1	2.2, 0.7	8.2, 0.9	3.2, 0.9	Straight, 11 Irregular 2												
Fazenda Maristela 1	57	8.1, 4.4	2.9, 1.2	5.1, 2.4	ND	Straight, 46 Irregular, 10 Bent, 1												
Fazenda Maristela 2	29	9.84, 3.20	2.86, 0.66	7.82, 2.26	4.00, 1.18	Straight, 21 Irregular 6 Bent, 4												
Fazenda Maristela 3	30	9.72, 4.67	3.67, 1.16	7.39, 3.07	3.74, 1.49	Straight, 18 Irregular 10 Bent, 2												
Fazenda Nova Aurora	35	9.17, 1.26	3.36, 1.26	7.01, 3.19	3.31, 1.45	Straight, 16 Irregular 14 Bent, 5												
Fazenda Transval	30	8.29, 3.39	2.90, 0.58	6.61, 2.80	3.11, 1.27	Straight, 16 Irregular 11 Bent, 3												
Fazenda Floriano 1							15	14.2, 5.27	1.66, 0.68	6.89, 1.32	4.02, 0.97	Straight, 8 Irregular, 7						
Fazenda Floriano 2							23	15.7, 6.07	1.60, 0.74	5.07, 1.59	4.27, 1.14	Straight, 10 Irregular, 10 Bent, 3						
Fazenda Floriano 3							22	17.57, 5.22	0.98, 0.67	7.82, 1.09	4.93, 1.23	Straight, 3 Irregular, 18 Bent, 1						
Santa Roca							30	11.4, 6.31	3.69, 2.23	11.82, 4.22	3.63, 1.50	Straight, 24 Irregular 4 Bent, 2						
Renato Casarao 1							22	15.53, 9.58	1.85, 1.31	8.95, 2.44	3.75, 1.25	Straight, 8 Irregular 13 Bent, 1						
Renato Casarao 2							22	11.45, 5.52	1.53, 1.51	6.90, 1.00	2.34, 0.72	Straight, 7 Irregular 8 Bent, 9						