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MANAGING THE DRIVER OF CLIMATE CHANGE IN THE CONTEXT OF SUSTAINABLE TROPICAL FOREST MANAGEMENT THROUGH REGULATION OF ECONOMIC ACTIVITIES IN FOREST COMMUNITIES WHILE ANALYZING SOCIAL-ECONOMIC INTERACTIONS

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Elena Mechik

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The following evaluators recommend the admission of the dissertation:

Prof. Dr. Hermann Held
and
Prof. Dr. Michael von Hauff

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ABSTRACT

Tropical forests store and exchange carbon through biomass, supporting biodiversity cycles while acting as sources of timber and Non Timber Forest Products (NTFP), and are biomes inclusive of human habitation. For centuries, most tropical forest communities actively stewarded forests through sustainable management processes. The sustainment of living conditions through livelihoods continues to be an important contributing driver of environmental conservation and the climate control. These conservation based livelihoods are being increasingly threatened and disincentivized over the last few decades by commercial timber, cropland and pasture industry that plunders tropical forests for the extraction of valuable timber or farming purposes.

This thesis presents an option of how the economic and social livelihood of tropical forest communities can be secured and improved while contributing to the sustainable tropical forest management, and thus stabilizing the climate. The first part of this dissertation describes the results of a field research of economic activities from two Brazilian forest communities. Brazil has been chosen as the research site as it has the largest area of tropical forests in the world and experiences one of the highest rates of deforestation. After conducting the field research, three stages of a longitudinal experimental research were conducted while applying the Fair Trade concept. A team of NTFP harvesters has been organized and a harvesting strategy was developed with the provision of pre-financing capital for the stock creation of NTFP.

Analysis of these interventions suggested that through organizational support and pre-financing, harvesters are able to organize themselves, to increase their income and to manage forest territories sustainably. Interdependency could be identified between the external support continuity, the size of pre-financing and the number of participants, their income as well as the size of managed forest territory. Clear land tenure as well as technical, organizational and marketing assistance is essential throughout the first years of intervention.

In the second part of this thesis the aim was to generalize the results of the previous study and to develop a global concept of how tropical forest conservation and livelihood creation can be achieved in tropical forest communities. Based on the global Poverty and Environment Network (PEN) study organized by the Center for International Forestry Research (CIFOR) which analyzed 334 forest villages from 24 tropical forest countries of Asia, Latin America

and Africa, global conclusions on social, economic and ecological interrelations could be made.

After formalizing qualitative causal relations it could be concluded that sustainable development in forest communities cannot be achieved without 1) legal rights for forest management, 2) targeted investments and initial capital for the organization of economic activities with ecological and social responsibility, and 3) organizational, technical, and methodical support. As the result the compatibility of the forest communities' realities with the theoretical concept of the sustainable development could be analyzed and the concept of the Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR) introduced. The SSFESR is defined as an enterprise managed and employed by indigenous and other local forest communities, which is aimed at making profit from sustainable harvesting, processing and trade of NTFP and sustainable timber management practices.

In the third part of this thesis, a quantitative assessment of the ecological, social, and economic returns on investments into the development of the SSFESR is presented. The Optimal Investment Forest Conservation and Livelihood Creation Model (OIFC) has been developed 1) which determines the environmental and social benefits of investments into SSFESR and 2) mathematically formalizes the interdependencies between the investments into development of SSFESR, poverty alleviation, forest conservation, and carbon benefits in conserved forest territory. The extent of forest conservation is restricted by the number of people living and working in the forest community and the maximal sustainable yield for the chosen NTFPs. This model can become a tool for policy makers for decision making on allocation of resources into the forest conservation and poverty alleviation in tropical forest regions.

Applying the model to a case study of the Banglapadigai region, India, shows that already an investment of 50USD per household leads to the establishment of 65 working places for men and to 75 working places for women. For comparison, the investments of 150USD per household lead to the creation of 253 working places for women but also to 65 working places for men. Both investment volumes lead to the conservation of 3600ha of forest and to the sequestration of 9400tC.

The model results show that investments into the SSFESR can simultaneously address social, economic and environmental objectives. In particular, it can increase the income of local inhabitants from the sale of processed NTFP, expand the range of activities, increase the conserved forest area covered, and also create new jobs and decrease the level of poverty.

ZUSAMMENFASSUNG

Tropische Wälder speichern Kohlenstoff, unterstützen Biodiversitätszyklen, dienen als Quelle für Holz und Nicht-Holz-Waldprodukte (NHWP) und bilden einen Lebensraum für Lebewesen. Seit Jahrhunderten bewirtschaften die meisten tropischen Waldgemeinden die Wälder durch nachhaltige Managementprozesse. Die Erhaltung der Lebensbedingungen durch die Gemeindeeinwohner ist nach wie vor ein wichtiger Beitrag zum Umweltschutz und zur Klimakontrolle. Diese naturschutzbasierten Lebensgrundlagen wurden in den letzten Jahrzehnten zunehmend von der Holz-, Acker- und Weideindustrie, die die tropischen Wälder zur Gewinnung von wertvollem Holz oder für landwirtschaftliche Zwecke plündern, bedroht und abgebaut. In diesem Kontext stellt sich die Frage, wie die nachhaltige Bewirtschaftung der Wälder unterstützt und gefördert werden kann.

Diese Dissertation präsentiert daher eine Möglichkeit, wie die soziale und ökonomische Lebenssituation der Tropenwaldgemeinden gesichert und verbessert werden kann, während sie zur nachhaltigen Tropenwaldbewirtschaftung beitragen und so das Klima stabilisieren. Im ersten Teil dieser Dissertation werden die Ergebnisse der Feldforschung über die wirtschaftlichen Aktivitäten zweier brasilianischer Waldgemeinden beschrieben. Brasilien wurde als Forschungsstandort gewählt, da es weltweit das größte Gebiet von tropischen Wäldern umfasst und momentan eine hohe Entwaldungsrate aufweist. Nach der Durchführung der Feldforschung wurden unter Anwendung des Fair-Trade-Konzepts drei Phasen eines Langzeitexperiments umgesetzt. Durch die Bereitstellung von Vorfinanzierungskapital für die Erstellung von NHWP-Lagerbeständen konnte ein Team von NHWP-Sammlern organisiert und eine nachhaltige Erntestrategie entwickelt werden.

Die Analyse dieser Interventionen zeigte, dass die organisatorische Unterstützung sowie das Vorfinanzierungskapital dazu führen, dass sich die NHWP-Sammler organisieren, ihr Einkommen steigern und in der Lage sind, Waldgebiete nachhaltig zu bewirtschaften. Es konnte eine Wechselwirkung zwischen der Kontinuität der externen organisatorischen Unterstützung, dem Vorfinanzierungsumfang, der Anzahl der Sammler und der Größe des verwalteten Waldgebietes identifiziert werden. Klare Landbesitzrechte sowie technische, organisatorische und Vertriebsunterstützungen sind entscheidend während der ersten Jahre der Interventionen.

Der zweite Teil der Dissertation beschäftigt sich mit der Verallgemeinerung der Ergebnisse der vorherigen Studie und der Entwicklung eines globalen Konzepts, wie der tropische Wald

geschützt und die Existenzsicherung in tropischen Waldgemeinden erreicht werden kann. Auf Grundlage der internationalen Studie des Zentrums für internationale Forstwissenschaft (CIFOR), die 334 Waldgemeinden aus 24 tropischen Waldländern Asiens, Lateinamerikas und Afrikas analysierte, konnten globale Schlussfolgerungen zu sozialen, ökonomischen und ökologischen Zusammenhängen gezogen werden. Nach der Formalisierung qualitativer Kausalbeziehungen kann festgestellt werden, dass eine nachhaltige Entwicklung in Waldgemeinden nicht ohne 1) Rechte für die Waldbewirtschaftung, 2) gezielte Investitionen und Anfangskapital für die Organisation von Wirtschaftsaktivitäten mit ökologischer und sozialer Verantwortung und 3) organisatorische, technische und methodische Unterstützung erreicht werden kann. Als Ergebnis konnte die Vereinbarkeit der Waldgemeinden-Realität mit dem theoretischen Konzept der nachhaltigen Entwicklung analysiert und das Konzept des Kleinwirtschaftsunternehmens mit sozialer und ökologischer Verantwortung (SSFESR) vorgeschlagen werden. Das SSFESR ist definiert als ein Unternehmen, welches von indigenen und anderen lokalen Waldgemeindeeinwohnern verwaltet wird, mit dem Ziel, durch Verarbeitung und Handel von NHWP und durch nachhaltiges Holzmanagement Gewinn zu erzielen.

Im dritten Teil der Arbeit wird eine quantitative Bewertung der ökologischen, sozialen und ökonomischen Rentabilität der Investitionen in SSFESR anhand eines Investitions-Optimierungsmodels durchgeführt. Das Investitions-Optimierungsmodel zum Waldschutz und zur Schaffung von Existenzgrundlagen wurde entwickelt, um 1) die ökologischen und sozialen Vorteile von Investitionen in die SSFESR zu ermitteln und 2) die Wechselbeziehungen zwischen diesen Investitionen, dem Waldschutz und der Armutsminderung mathematisch zu formalisieren.

Das Ausmaß der Waldbewahrung wird durch die Anzahl der Menschen, die in der Waldgemeinschaft leben und arbeiten, und die maximale nachhaltige Bewirtschaftung der ausgewählten NHWP eingeschränkt. Die Anwendung des Modells auf eine Fallstudie in der indischen Banglapadigai Region mit einer Gesamtanzahl von 380 Haushalten, zeigt, dass bereits eine Investition von 50USD pro Haushalt zur Gründung von 65 Arbeitsplätzen für Männer und 75 Arbeitsplätzen für Frauen führen kann. Zum Vergleich führen Investitionen von 150USD pro Haushalt zur Schaffung von 253 Arbeitsplätzen für Frauen, aber auch zu 65 Arbeitsplätzen für Männer. Beide Investitionsvolumina führen zur Erhaltung von 3600 ha Wald und zur Sequestrierung von 9400 tC.

Die Modellergebnisse zeigen, dass Investitionen in die SSFESR gleichzeitig soziale, ökonomische und umweltpolitische Ziele ansprechen können. Insbesondere kann es das Einkommen der örtlichen Einwohner aus dem Verkauf von verarbeiteten NHWP steigern, das Spektrum der Wirtschaftsaktivitäten erweitern, den Erhalt der bewirtschafteten Waldflächen erhöhen und die Schaffung neuer Arbeitsplätze sowie die Verringerung des Armutsniveaus bewirken.

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1 INTRODUCTION

The consequences of climate change are becoming more visible with around 17.4 percent of global GHG emissions coming from the forest sector and especially from the deforestation in developing countries (UNEP & INTERPOL, 2012; FAO, 2016). Tropical forests not only assimilate carbon from the atmosphere and store it in their biomass, but also regulate the gas exchange between the land surface and the atmosphere. They represent the habitat for around 75 percent of the terrestrial biodiversity, and act as a source of timber and Non Timber Forest Products (NTFP) (FAO, 2016).

Decreasing deforestation is considered as a cost-effective option for reducing GHG emissions (FAO, 2016). The estimated yearly economic value of illegal logging, along with processing, is between 28 and 96 billion USD, or 10–30% of total wood trade (UNEP & INTERPOL, 2012). Tropical forests export primary and secondary timber products exceeding a value of 23 billion USD annually (FAO, 2010). There is a global growing demand for timber and timber products which generates pressure on tropical countries for the production of cheap pulp and timber.

The challenge of tropical forest conservation coexists with the challenge of poverty alleviation in tropical forest communities. A large fraction of forests is located in poor and rural areas of developing countries where household livelihoods depend on extractive forest uses (Sunderlin et al., 2008). There are around 1.2 billion people worldwide who mainly and directly depend on the tropical forests and obtain a significant part of their livelihood from NTFP (Chao, 2012; Dieterle, 2009; FAO, 2009, 2007; Vantomme, 2011).

Decreasing the level of deforestation together with the decrease of the number of the poor are important topics in achieving the social and environmental sustainability (Hammond & Zagt, 2006; World Bank, 2005). The loss of the natural capital might be an irreversible change (Ruta et al., 2010). Until now there is no effective mechanism which can conserve the tropical forests.

The governments of countries with tropical forests within their territory, the international community, and the World Bank try to reduce destructive forest use including deforestation and degradation. Despite their efforts, the global net natural forest loss accounts for 6.5 million hectares per year for the time frame between 2010 and 2015 (FAO, 2015). During the United Nations Climate Summit 2014, more than 150 partners have signed the “Declaration on Forests” which calls for “cutting the loss of forests in half by 2020 and ending the

deforestation by 2030" (UN Climate Summit, 2014). Additionally there is an internationally broad discussion that a strong expansion of the forest areas is a central contribution to climate stabilization.

The top-down conservation strategies such as unpeopled and protected forest areas are widely disputed due to their negative social and economic impact on forest communities and their contribution to the protection of natural resources (Albers, 2001; Albers & Grinspoon, 1997; Ghimire, 1994; Hares, 2006; West & Brechin, 1991). These conservation strategies have been questioned during the last three decades because of their negative impact on the social and economic structures of forest communities and unsatisfactory protection of natural resources (Newmark & Hough, 2000; Salafsky & Wollenberg, 2000; Spiteri & Nepal, 2006). According to Shyamsundar & Kramer (1995), the main reason for the failure to protect forests through the demarcation of "protected zones" is the lack of integration between forest management strategies and the well-being of local inhabitants.

Studies show that bottom-up forest conservation approaches by forest communities result in lower and less variable deforestation rates than the top-down conservation strategies (Baland & Platteau, 1996; D. Bray, 2013; Ezebilo, 2010; Porter-Bolland et al., 2012). Forest communities are considered as the best positioned actors to confront the destructive forest use processes because of their proximity to the forests and their direct benefits from the long-term conservation of the environment (David Barton Bray et al., 2008; Hajjar, 2011; Klooster & Masera, 2000; A. Molnar et al., 2004, 2008; Pagdee, 2006; Scherr, White, & Kaimowitz, 2003; J. H. Smith, 2003). Governments realize that local communities may provide a more sustainable and a cost-effective way for natural resource management than biodiversity conservation institutions (Ezebilo, 2010). Additionally, numerous studies show that community managed forests represent a possibility to enhance the conservation and sustainable use of tropical forests and to alleviate poverty (David Barton Bray et al., 2008; David Barton Bray, Antinori, & Torres-Rojo, 2006a; Dev & Ravi, 2003; Fomété, Vermaat, & others, 2001; A. Molnar et al., 2004, 2008, 2008; Pagdee, Kim, & Daugherty, 2006; Scherr et al., 2003; F. Smith, 2006; J. H. Smith, 2003). Case studies from tropical forest regions indicate that community forest enterprises can create more sustainable sources of income in forest communities and contribute to the conservation and monitoring of forests (D. B. Bray et al., 2003; D. B. Bray, Ellis, Armijo-Canto, & Beck, 2004; David Barton Bray, Antinori, & Torres-Rojo, 2006b, p. 200; Dev & Ravi, 2003; Augusta Molnar et al., 2007) under the condition of legally secured access to the near-by forest and clear ownership rights to use and

manage the forest resources (Abdulai, Owusu, & Goetz, 2011; Prodyut Bhattacharya, Pradhan, & Yadav, 2010; Boulay, Tacconi, & Kanowski, 2012; David Barton Bray et al., 2006b; Mekonnen, 2009; B. E. Robinson, Holland, & Naughton-Treves, 2011).

As Darr et al. (2014) argue, since the rural areas in the tropics and subtropics face a diversity of challenges, the suggested solution for successful development of these areas should be highly customized and adapted to these challenges.

1.1 Outline of Thesis

This thesis presents a global concept which can be customized to different forest communities' realities with the goal of achieving sustainable development of tropical forest regions including non-destructive forest use and poverty alleviation in tropical forest communities. To identify the main challenges of forest communities, I have conducted field research in forest communities in India, Brazil and Thailand, investigated the economic activities and the overall livelihood of these communities and their dependency on the forests.

In this thesis, three interdisciplinary studies are presented. In Chapter 2 (*Analysis of the Changes in Economic Activities of Brazilian Forest Communities after Methodical Support and Provision of Pre-Financing Capital*), the aim is to identify the factors which would lead to local sustainable development in the tropical forest regions. On the example of two Brazilian forest communities the goal is to answer the question of whether communities' inhabitants are able to increase their income and to conserve the forest sustainably through working with Brazil Nuts as a valuable NTFP. The literature regarding the question of whether social improvement and forest conservation can be achieved with help of NTFP is mostly analyzing the status quo of the current income which is being raised with help of NTFP and the current state of forest management without intervention. Analyzing an intervention requires initial effort for organizing this intervention and may take several years, until touchable results and proof or disproof of the concept can be seen.

An investment experiment has been initiated in 2008 in collaboration with the Brazilian Nongovernmental Organization for the Support and Development of the Riverside Communities in the Amazon Rainforest (NAPRA) with the aim of analyzing whether development of an enterprise for the work with NTFP can simultaneously lead to non-destructive forest use and social development in tropical forest communities. The methodical procedure of the Fair Trade concept has been applied throughout this study. The investment

experiment involved three interventions: A non-refundable investment into the self-organization of Brazil Nut harvesters with initial intervention, a refundable investment with the support of a technical supervisor, and a refundable investment with limited support of a technical supervisor. The outcomes of these interventions have been investigated in 2014 and 2015 and are presented in detail in this study.

This chapter has been accepted for publication and will be published in a similar form in April 2017 in the peer-reviewed international *Journal of Tropical Forest Science*[1].

Consecutive on the main results of the investment experiments from Chapter 2, the aim of the next chapter is to identify a scalable concept of how non-destructive forest use and poverty alleviation can be achieved in tropical forest communities. The Chapter 3 (*Requirements for the Sustainable Development of Economic Activities in Tropical Forest Communities*) describes an option for achieving sustainable development of economic activities in tropical forest communities.

With help of the global Poverty and Environment Network (PEN) study organized by the Centre for International Forestry Research (CIFOR) which provides social, economic, and environmental data from 334 forest villages from Asia, Latin America and Africa, the main social, economic, and environmental patterns of tropical forest communities are identified (PEN, 2016). After determining the main patterns of tropical forest communities, these patterns are analysed according to the concept of sustainable development. As the result, the global theoretical concept of the Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR) is introduced. SSFESR is defined as an enterprise which is managed and employed by indigenous and other local forest communities and aimed at making profit from sustainable harvesting, processing and trade of Non-Timber-Forest-Products (NTFP) and sustainable timber management practices. Social and ecological responsibility within the SSFESR describes the need for sustainable forest management and for raising the living standards of forest communities' inhabitants.

A similar form of Chapter 3 has been accepted for publication in the peer-reviewed *European Journal of Sustainable Development*[2].

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[1] Mechik E, von Hauff M, de Moura LHL, Held H. 2017. Analysis of the Changes in Economic Activities of Brazilian Forest Communities after Methodical Support and Provision of Pre-Financing Capital. *Journal of Tropical Forest Science, 29(2).*

For political decision-making on allocation of investments into the development of SSFESR, there is a need for organizational arrangements and justification for the investment size. The determination of optimal investments in tropical forest enterprises is a complex economic challenge, which includes diverse private and public costs and benefits.

In order to quantitatively assess the ecological, social, and economic returns on investments into the development of SSFESR, a mathematical Optimal Investment Forest Conservation and Livelihood Creation (OIFC) model has been developed and is described in Chapter 4 (*Investments in Tropical Forest Community Enterprises for Livelihood Creation and Climate Change Mitigation*). This model is a mixed integer programming model written in the General Algebraic Modelling System (GAMS) - software package. Mixed integer programming models provide a possibility to constrain some of the variables to being integer and leaving other variables unconstrained. In the OIFC model, only the assets-investment-variable is constrained to being integer. OIFC couples the investments into the development of the SSFESR with the social and environmental benefits on investments such as the developed working places and the conserved forest territory together with the captured carbon on this area. In this chapter, ten scenarios with various investment limits and carbon prices are presented on the example of a case study from a South-Indian forest region. The presented model can become a tool for policy makers for well-founded decisions on allocation of investments into the development of social enterprises inside of forest communities.

This chapter is planned to be submitted to the international *Forest Policy and Economics* Journal.

The results of the three described studies, the summary and conclusion in Chapter 5 all aim at answering the questions of how non-destructive forest use and livelihood creation can be achieved in tropical forest regions and how high are the required investments to accomplish that.

1.2 Practical Significance of Thesis

The research results of this thesis have not only been presented at international conferences such as the “Non-Wood Forest Produce for Sustainable Livelihood” conference in Bhopal,

[2] Mechik E, von Hauff M. 2016. Requirements for the Sustainable Development of Economic Activities in Tropical Forest Communities. European Journal of Sustainable Development, 5(4), 107–120. https://doi.org/10.14207/ejsd.2016.v5n4p107

India (November 2011), the "Sustainable Business in Asia" conference in Bangkok, Thailand (November 2012), the "Tropentag" Conference in Prague, Czech Republic (September 2014) or the International Sustainable Development Conference, Rome, Italy (September 2016) but also at the Royal Forest Department, Thailand. The Director of the Bureau of Community Forest Management, Mr. Pralong Dumrongthai, and the Director of Community Forestry Development Division, Mrs. Nantana Boonyananta, from the Royal Forest Department of Thailand expressed their interest in my research and considered the practical implementation of the research results (Annex 1).

During a meeting with Dr. Barbara Hendricks, the German Federal Minister for the Environment, Nature Conservation and Nuclear Safety, I presented a possibility for practical implementation of my research and received a written approval with suggestions for funding possibilities (Annex 2).

Together with Aaron Mendonca, a Master Student from the Harvard University, we proposed the concept of Small Scale Forest Enterprises with Social and Environmental Responsibility at the Seed for Change Competition 2016, South Asia Institute, Harvard University. We achieved the 2nd place in this competition and received an initial funding volume of 5000USD for project implementation in India (Annex 3).

2 ANALYSIS OF THE CHANGES IN ECONOMIC ACTIVITIES OF BRAZILIAN FOREST COMMUNITIES AFTER METHODICAL SUPPORT AND PROVISION OF PRE-FINANCING CAPITAL

2.1 Motivation

In this chapter, the aim is to identify the factors which would lead to local sustainable development in the tropical forest regions. On the example of two Brazilian forest communities we intend to answer the question of whether communities' inhabitants are able to increase their income and to conserve the forest sustainably through working with Brazil Nuts as a valuable NTFP. Some studies show the positive effect of certain NTFP and their potential to promote social development in forest communities (Tieguhong et al. 2012, Shackleton et al. 2011, Marshall et al. 2006). Contradictorily, there are studies demonstrating the inability of NTFP to lift people out of poverty and the negative impact that the overharvesting of NTFP may have on forests (Belcher & Schreckenberg, 2007; P. Bhattacharya & Hayat, 2004; Escobal & Aldana, 2003; Muler et al., 2013; Nambiar & Sadanandan, 2015; Poschen, Sievers, & Abtew, 2014; Ros-Tonen & Wiersum, 2005).

We argue that common literature regarding the question of whether social improvement and forest conservation can be achieved with help of NTFP is mostly analyzing the status quo of the current income which is being raised with help of NTFP and the current state of forest management without intervention. Analyzing an intervention requires initial effort for organizing this intervention and may take several years, until touchable results and proof or disproof of the concept can be seen.

Since August 2008, three phases of the experiment have been initiated within the organization of Brazil Nut harvesters and storage of Brazil Nuts in São Carlos do Jamari and Cuniã forest communities, Rondônia state, Brazil. The first phase of the experiment was organizing a group of Brazil Nut harvesters, storing a stock of nuts with help of initial capital and establishing a sales strategy for stored nuts between the harvesting seasons. It also included the overcoming of the intermediaries and the negotiation of the selling prices in Porto Velho. This intervention included non-refundable pre-financing as an initial capital for storing a stock of nuts and the possibility to sell the stock between the harvesting seasons once the selling price rises. Initial organizational and methodical support was provided. The

second phase included a continuous support of a technical supervisor with a refundable investment. The third phase consisted of a refundable investment with the interrupted support of a technical supervisor. These interventions were organized in collaboration between the researchers and the Brazilian Nongovernmental Organization for the Support and Development of the Riverside Communities in the Amazon Rainforest (NAPRA). Implementing projects in forest communities is a lengthy task with a high level of uncertainty. Thanks to the longevity of the initial intervention, the growing group members and high motivation level of the Brazil Nut group, more funds could be raised for the established Brazil Nut project.

In this study, we present the outcomes of these investment interventions and the main challenges faced throughout this work. The overall aim of this study was to give the real case scenario estimates on whether non-destructive forest use and social development in tropical forest communities can be achieved simultaneously.

2.2 Method

This research can be regarded as a pilot exploratory study aimed at testing the hypothesis on the cause-and-effect relationship between the financial, organizational, and methodical intervention into the economic activities of Brazil Nut harvesters as the cause and the management of the ecological system of the forest as well as the increase in income of the local inhabitants as the outcome.

We chose Brazil as our research region as it has the greatest area of tropical forests in the world and concurrently experiences one of the highest rates of deforestation. The two described forest communities are located at the arch of the "Arc of Deforestation" in the Rondônia state, Brazil (Figure 2-1). We concentrated on the work with Brazil Nuts as an example of a unique NTFP which is primarily collected from the wild, and which optimal natural regeneration depends on an intact and healthy ecosystem (Mori & Prance, 1990; Ortiz, 2002; Zuidema, 2003).

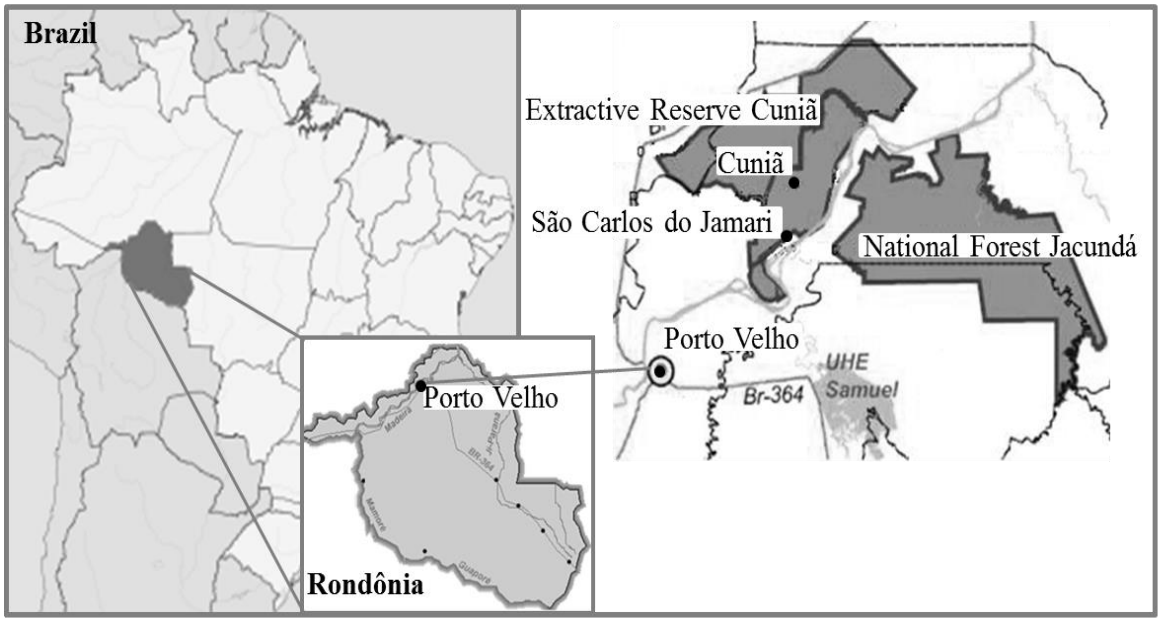

Figure 2-1: Map of Brazil, state Rondônia and conservation units (Modified from "Map of Rondônia, Brazil," 2006, NordNordWest, 2009, ICMBIO, 2008)

Throughout the study methodical procedure of the Fair Trade concept has been applied, including organization of a Brazil Nut group, workshops on sustainable Brazil Nut harvesting and good handling practices, setting a minimum selling price for the nuts, pre-financing the initial nut sale, and supporting the group in the final sale of the products (v. Hauff & Claus, 2012) (Figure 2-2).

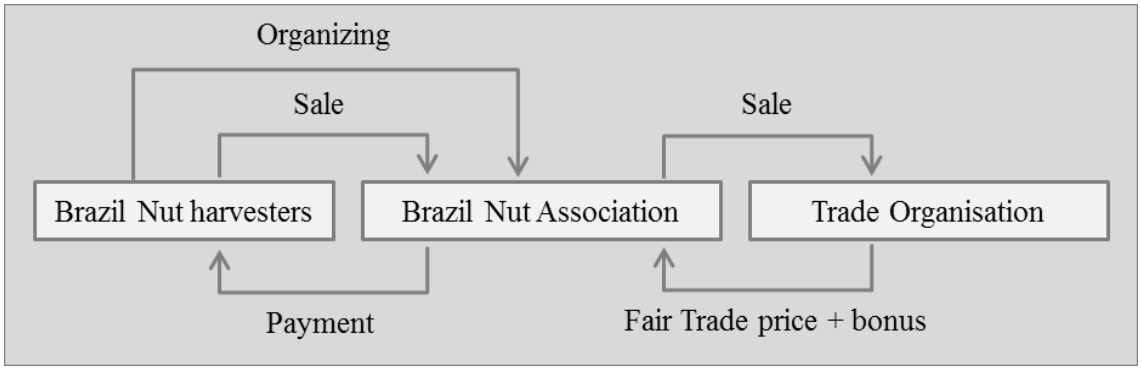

Figure 2-2: Fair Trade cooperative structure (Modified from Nicholls & Opal, 2005)

We first conducted field research of economic activities with Brazil Nuts in forest communities and initiated a longitudinal experiment (2008-2015). We were introduced to the communities as the members of NAPRA. The treatment group of Brazil Nut harvesters was selected by visiting and inviting all Brazil Nut harvesters (28 families) of the São Carlos do Jamari community to participate in the Brazil Nut project. No randomization of the group participants had to be done as all Brazil Nut harvesters of the community could be visited.

Because of the unsatisfying experiences local inhabitants had with previous interventions, only three Brazil Nut harvesters agreed to participate. Out of the three participants, two were from São Carlos do Jamari and one from the Cuniã community who was visiting São Carlos. The non-participating Brazil Nut harvesters were considered as the control group.

The first intervention included non-refundable pre-financing with initial support (2008-2009) and was followed by two interventions with the expanded group of Brazil Nut harvesters. These interventions included two refundable pre-financing cases with a continuous support of a technical supervisor (2013-2014) and an interrupted support of a technical supervisor (2014-2015).

These interventions were limited by the pre-financing amounts and the number of participants willing to become Brazil Nut group members. As in the beginning merely three persons were willing to participate; only one group of Brazil Nut harvesters has been initiated. Since 2008, new members were joining the group and the subsequent experimental interventions were conducted with the same growing group of harvesters.

We analyzed and evaluated the results obtained throughout the interventions. The analyzed data represents the increase in the number of group members, the possibility of paying back the initial investments, the forest being used for the harvesting of Brazil Nuts and the verbal statement of the harvesters whether they are using the forest sustainably.

2.3 Results

2.3.1 Field research

2.3.1.1 Livelihood

São Carlos and Cuniã were established in the late 19th century by the descendants of rubber collectors who came to this region during the rubber boom, and Indians who were the original inhabitants of these regions. In the year 2010, the population of Cuniã consisted of 83 families (290 persons) and of São Carlos of 370 families (1317 persons) (SEMUSA 2010). The main economic activities of the Extractive Reserve (RESEX) Cuniã and the São Carlos are the production of cassava flour (*farinha de mandioca*), harvesting of NTFP, mostly açaí and Brazil Nuts, agriculture, and fishing. These products are either used for own consumption or traded with local intermediaries, who sell them further to the city markets. In 2011, a project has been initiated for the sustainable management of the black caimans in Cuniã as the caimans were propagating expeditiously inside the lake and represented a danger for the

inhabitants. The population of Cuniã is organized as an association – the Residents Association of Cuniã (ASMOCUN). All the economic activities of Cuniã are organized through ASMOCUN. This association is directly cooperating with the Chico Mendes Institute for Biodiversity Conservation (ICMBio). In São Carlos do Jamari, there are four associations which face serious difficulties regarding organization. São Carlos' inhabitants show mistrust towards the associations' leaders and associations' work which leads to a low willingness to participate and to become a member of these associations (Candido 2010).

2.3.1.2 Legal situation

The lake Cuniã region became an Extractive Reserve as the legal entity in 1999. RESEX Cuniã is state-owned but the community has the rights to access, to use and to extract the natural resources. The inhabitants of Cuniã have the right to collectively use the land and have autonomy over the territory which they have traditionally occupied. On the contrary, the São Carlos inhabitants live in a chaotic land situation. They find themselves in a mixture of tenure regimes which consists of formal owner (*de jure*) of the land which is mostly the state and informal land use (*de facto*) of the inhabitants which evolved historically. A lot of land used by São Carlos inhabitants belongs to the Extractive Reserve Cuniã and the National Forest Jacundá (Candido 2010). The São Carlos inhabitants have restricted access to these areas they have traditionally used. The creation and localization of these reserves occurred without the participation of São Carlos inhabitants. In areas that are outside the limits of the reserves, according to the National Institute of Colonization and Agrarian Reform, most inhabitants do not have any rights to the land they occupy, and if they do, they do not pay any taxes. This situation makes the inhabitants of São Carlos unable to ensure their autonomy over the occupied territories for generations.

Most of São Carlos' and Cuniã's inhabitants perceive the forest as an important component of their livelihood, a part of their home and a place which provides them food and shelter. The connection to the forest is different in the two analyzed communities. If deforestation is taking place around the São Carlos do Jamari community, São Carlos inhabitants may realize it, but have no information on whether legal or illegal deforestation is taking place and have no means to counteract. Since RESEX Cuniã's creation as a legal entity, there was no record of illegal logging. The total reserve area contains 50603.84 ha of forest. The Cuniã inhabitants know exactly who is allowed to log trees and how much can be logged.

2.3.1.3 Economic activities based on Brazil Nut example

Brazil Nuts (Bertholettia excelsa H. B. K.) is a wild growing NTFP which represents an important source of income for indigenous and traditional inhabitants of the Amazonian forest communities including São Carlos do Jamari and Cunhã communities. The Brazil Nut tree, as a wild species, has an irregular natural production with alternating high peaks and low production levels. Harvesting and working with Brazil Nuts is a traditional knowledge forwarded from generation to generation. Currently many young community inhabitants are not willing to assist their fathers in this work as it provides a low income but requires hard work of carrying a heavy load over long distances. As not many income options are available in the communities, they consider moving to a nearby city once graduating from the school. The harvested unprocessed nuts are sold short after the harvesting to intermediaries at the local harbor. Historically, Brazil Nut harvesters are used to work independently from each other. The price of the nuts is set by the intermediaries. The harvesters do not have the market information on the current nuts' price and do not bargain about the price offered by the intermediaries. If one harvester does not sell for the suggested selling price, the intermediary will buy from another harvester for the price he sets. While receiving a low income for this work, the harvesters have no means to increase their income because of no other connection to the market.

Storage of Brazil Nuts would lead to a price increase as the price for nuts is higher in-between the nut seasons and lower during the season. But the community's inhabitants cannot afford to wait and to store the products as they have no savings and need the income right after they convey the work. Another challenge is the lack of storage facilities. Storing Brazil Nuts without sufficient air circulation can lead to the occurrence of aflatoxin (toxic fungi) of Brazil Nuts. The community members could also increase the selling price of the nuts by adding value to the products through processing, receiving certification, marketing, and transporting of the final product to the markets. Adding value to Brazil Nuts not only requires investments into storage and processing facilities, but as well in attracting engineers and managers. The forest communities are not adding value to Brazil Nuts as the initial capital for storage or processing of nuts is not available. An additional challenge is the missing knowledge of how to organize the work and the sale of the products.

We interviewed São Carlos' Brazil Nut harvesters on the prices they receive for the unprocessed Brazil Nuts during the harvesting season and between the seasons and investigated the Brazil Nut prices on the Porto Velho market and in the shops of São Paulo

and Berlin in the year 2009. As the result, we identified the price differences of Brazil Nuts as presented in Figure 2-3. The selling price of Brazil Nuts depends on the value addition and the nuts' supply. Herewith, a more than threefold rise in the selling price is induced by the step from unprocessed to processed nuts on the local market of Porto Velho.

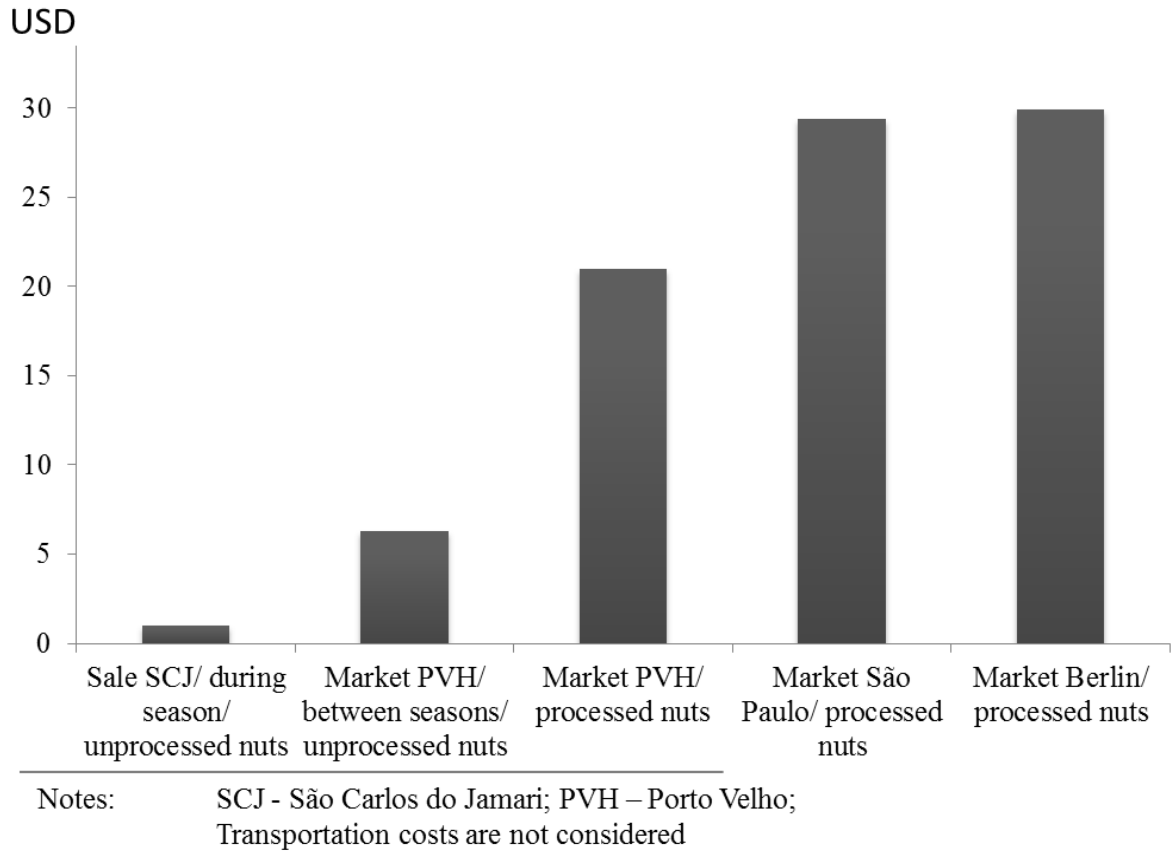

Figure 2-3: Brazil nut price change depending on season, processing, and selling market per kg (own research results from interviews with Brazil Nut traders, 2009)

2.3.2 Organization of Brazil Nut harvesters

In July 2008, following the Fair Trade concept, we organized a group of Brazil Nut harvesters which is an important step for the improvement in working conditions and negotiation power of the producers. Becoming a group member implied participation in the Brazil Nut good handling workshops, usage of the provided initial capital, storage of Brazil Nuts, price negotiation with the buyer, and organized sale of the stored Brazil Nuts. Although only three persons were willing to participate in the workshops initially, a strong motivated group has been established. In an interactive manner the good practices for sustainable Brazil Nut harvesting have been discussed with the harvesters and adjusted to the communities' reality.

Because of the mouth propaganda of the motivated core team and the first year's results, more harvesters wished to become group members so that the team grew up to twelve members with three members from São Carlos do Jamary and nine from Cuniã by summer 2009. In 2010, with the support of NAPRA, the group was legally registered as an independent association – the Association of Arts and Brazil Nuts of São Carlos do Jamary and Cuniã (Associação arte e castanha de São Carlos do Jamary e Cuniã).

In 2012, the Brazil Nut Association with the support of NAPRA managed to raise financial capital from the Ecumenical Coordination Service (CESE) for the construction of a storehouse in Cuniã. As soon as the funds for the construction have been received the Brazil Nut group self-organized to construct the storehouse. In the winter 2013/14, the São Carlos do Jamari community has been flooded completely and Cuniã partly. The inhabitants of São Carlos do Jamari were evacuated. By that time only harvesters from Cuniã continued working with the Brazil Nut group including 20 families by the year 2014. The storehouse in Cuniã is located on a terra firme (dry land), so that it was not affected by the flood. Throughout the flooded time, the storehouse was easily accessible by a boat. Organization of the harvesters was the first significant step towards the implementation of the economic interventions.

2.3.3 Economic experiment

The economic experiment started in 2008 and consisted of three stages, in terms of financing and methodical support including the main components of the Fair Trade concept such as fixing a minimum selling price for the Brazil Nuts, support of producers through provision of pre-financing and initiating reliable trade relationships between the producers and the customers.

As the harvesters of Brazil Nuts depend on the immediate income from the nuts' sale, we provided pre-financing capital for the payments to Brazil Nut collectors straight after the harvesting. This capital allowed the harvesters to store the nuts and to wait for a higher selling price between the harvesting seasons. The harvesters were supposed to receive the income twice: First, after the harvesting when delivering the nuts to the storage facility, and the second, after the final sale to the wholesale buyer between the harvesting seasons. The price during the harvesting season was intended to be above the price paid by the middlemen at the riverside.

One member of the group was elected as the manager and one as the accountant. The rules of the group were to have quarterly meetings discussing the actual situation of how many nuts

have been stored, how many members collected the nuts, the current market prices and the flow of funds.

	1st intervention 2008 - 2009	**2nd intervention 2013 - 2014**	**3rd intervention 2014 - 2015**
Type of investment	Non-refundable	Refundable	Refundable
Size of investments, USD	2.470USD	2.200USD	11.600USD
Source of investments	Private	Private	CONAB
Organized by	Researchers and NAPRA	NAPRA	NAPRA
Support	Initial support	Continuous support	Interrupted support
Outcome	Funds partly lost	Funds increased	Funds increased/ partly lost

Table 2-1: Case studies' overview

Three different interventions have been undertaken with a growing group of Brazil Nut harvesters. The first intervention was initiated in 2008 and 2009. It included nonrefundable pre-financing of R$716 (470USD) in 2008 and R$3.757 (2.005USD) in 2009 with the initial task division of the Brazil Nut group and no future external intervention and support. The second initiative included a refundable investment of R$5.000 (2.200USD) with continuous support from an environmental technician in 2013/2014. The third intervention contained a refundable investment of R$40.000 (11.600USD) with interrupted support from an environmental technician in 2014/2015 (Table 2-1).

2.3.3.1 First intervention (years 2008 – 2009): Non-refundable investment into the self-organization with initial intervention

In the year 2008, 470USD have been provided to the Brazil Nut group with the goal of letting the group members collect the nuts during the season, store the nuts, receive the payments with a price of 2R$ (1USD) above the local market price and to wait for a higher price in-between the seasons for the final sale of the product. By the year 2009, one of three members has received the payments and brought nuts for storage. All three members had difficulties in collecting the nuts as the harvesting season in 2008/2009 was Brazil Nut unfruitful. In-

between the seasons it was difficult for the members to decide when to sell the stored nuts. They missed the time spot of the highest price they could gain of 22R$/lata (12USD/lata) in July 2009 and sold the nuts only in October 2009 for a price of 20R$/lata (11USD/lata). One lata is a local volume measurement unit and equals to 20 liter and around 10kg of nuts. Due to different levels of humidity and the according weight variations, lata proved itself as a reliable measurement. Additional pre-financing of 2005USD has been made for the continuation of the storage project to the group of 12 members in 2009. The accountant has received the funds and was supposed to use these funds as the initial capital for payments once the harvesters would bring the nuts for storage. The banking infrastructure is not developed in the remote community region and the accountant was unwilling to keep 2005USD at his home. He decided to distribute the funds between the group members equally and to receive the according amount of nuts once the harvesting season would begin. As the result, an informal system of prepayment arose because the harvesters had the possibility to receive money in exchange for a set amount of nuts to be harvested in the future. The received funds were mostly used for the personal needs and the purchase of new equipment for the Brazil Nuts collection such as machete, boots, knifes or improvement of the boat (e.g. repairing the motor).

In September 2009, each team member received R$500 (270USD). In the harvesting season of the year 2009/2010, the group members were not able to collect sufficient amount of nuts due to the unproductive season. In the harvesting season of the years 2010/2011 eight group members harvested the set amount of nuts (50 latas). The challenge was as two members of the group received the funds but neither brought collected nuts nor gave back the funds. The group was not prepared for such an occasion and had no means of how to counteract and to return the funds. Two members of the group did not harvest but returned the funds they have received. In August 2011, the team sold the nuts for 25R$/lata (14USD/lata), making an average profit of 500R$/family (286USD/family) (Table 2-2).

The meetings continued until the end of the year 2009. Afterwards, the manager has not set up any appointments and the group was not informed about the actual financial situation. This has led to increasing mistrust towards the accountant. Since the year 2009, there were no elections neither for the accountant nor the manager positions. The manager while being from São Carlos had difficulties to come to Cuniã, to control the accountant and to organize the group meetings. The funds have been spent on unclear matters.

	2008/ 2009	**2009/ 2010**	**2010/ 2011**	**2011/ 2012**	**2012/ 2013**	**2013/ 2014**	**2014/ 2015**	**2015/ 2016**
Exchange rate [1.08.2009-16] 1R$= x$	0,64	0,54	0,57	0,64	0,49	0,44	0,44	0,29
Investments [R$]	730	3713					5000	40000
Investments [$]	467,2	2005,02					2200	11600
# of group members	3	12	12	10	10	14	20	20
# of harvesters this season	1	0	8	5	6	2	10	20
Total collected Brazil Nuts [lata]	50	0	400	100	120	200	200	2000
Total collected Brazil Nuts [ton]	0,5	0	4	1	1,2	2	2	20
Price paid by the middlemen [R$/lata]	8	0	8	8	8	11	11	11
Price paid by the middlemen [$/ton]	512	0	456	512	392	484	484	319
Price paid straight after harvesting [R$/lata]	12	0	12	12	12		20	20
Price paid straight after harvesting [$/ton]	768	0	684	768	588	0	880	580
Selling price [R$/lata]	20	0	25	30	35	28	30	45
Selling price [$/ton]	1280	0	1425	1920	1715	1232	1320	1305
Total income [R$/lata]	1000	0	10000	3000	4200	5600	6000	90000
Total income [$/ton]	64000	0	570000	192000	205800	246400	264000	2610000

Additional expenses [R$/lata]	3	0	3	3	3	3	3	10
Additional expenses [$/ton]	192	0	171	192	147	132	132	290
Total additional expenses [R$]	150	0	1200	300	360	600	600	20000
Total additional expenses [$]	96	0	684	192	176,4	264	264	5800
Total revenue [R$]	250	0	4000	1500	2400	5000	1400	30000
Total revenue [$]	160	0	2280	960	1176	2200	616	8700
Average revenue [R$/family]	250	0	500	300	400	2500	140	1500
Average revenue [$/family]	160	0	285	192	196	1100	61,6	435

Table 2-2: Group dynamics and income flow from the work with Brazil Nuts

2.3.3.2 Second intervention (years 2013 – 2014): Refundable investment with the support of a technical supervisor

In the year 2014, the environmental technician employed by the NGO NAPRA raised 5.000R$ (2.200USD) from private supporters. These funds were used as initial capital. Together with the accountant, the technician was paying the harvesters a price of 20R$/lata which was 9R$/lata above the local market price but only when the nuts were delivered to the storehouse. In that way they could overcome the challenge that some group members might not harvest the nuts nor pay back the funds. Some of the harvesters were unsatisfied with this approach. They argue that being payed after the harvesting makes the accountant no different from an intermediary. Another argument why the harvesters were unsatisfied is the disappearance of the possibility of acquiring prepayment and the inability of purchasing the required items they might need before the Brazil Nut harvesting season.

In this year 10 families have participated in the harvesting of Brazil Nuts and achieved to harvest 2 tons of Brazil Nuts. Straight after the collection they have received R$20/lata and additional R$10/lata between the harvesting seasons after the final sale. All the initial capital could be returned (Table 2-2).

2.3.3.3 Third intervention (years 2014 – 2015): Refundable investment with limited support of a technical supervisor

In the year 2015, with assistance of the environmental technician the team achieved to receive a credit of R$40.000 (11.600USD) from the Brazilian National Supply Company (CONAB). This credit is provided from CONAB for the stock formation of products such as Brazil Nuts which selling price varies immensely between the harvesting and the non-harvesting seasons. The Brazil Nut group achieved to harvest 20 tons of Brazil Nuts in the harvesting season of 2014/2015. They received R$20/lata during the harvesting season which is R$9/lata above the local market price. As the capacity of the storehouse and the initial capital of this season were high, 20 families of Cunhã were active in the harvesting of Brazil Nuts. The harvesters rediscovered new forest territories for the collection of nuts and were travelling up to one day to reach remote abandoned forest areas for harvesting. Three of the most distant Brazil Nut groves were prepared for harvesting and utilized by the group members while acquiring a greater control over their forest territory.

The technical assistant managed to sell the nuts partly for a price of R$50/lata and partly for R$40/lata between the harvesting seasons in 2015. The challenge occurred when the technical assistant had to leave the community for two months and a politician from the community assigned himself as an additional accountant of the group and acquired R$3.000 (870USD) from the group's income.

The additional expenses for the sale of the nuts including the packaging and the transportation costs rose from the usual 3R$/lata to 10R$/lata without the support of a technical assistant (Figure 5). After the sale, the harvesters could pay back the 11.600USD they received from the CONAB and yet gained 435USD/family.

2.3.3.4 Control group

In the control group, the harvesters continued working independently and selling the nuts to the intermediaries on the riverbank for the price set by the intermediaries during the harvesting season. Once the Brazil Nut group has moved totally to the Cunhã community more Brazil Nut harvesters were willing to participate in the Brazil Nut group. Around ten remaining Brazil Nut harvesters of Cunhã were not willing to become part of the group. Some of these harvesters are related with the intermediaries and/or do not wish to neglect their relationship with the intermediary. In many cases the intermediary provides capital or required paraphernalia to the harvesters before the Brazil Nuts harvesting season. Some

harvesters regard being part of the Brazil Nuts group as burdensome as the intermediaries would come to buy the nuts directly from their houses. As the Cuniã community is dispersed around the Cuniã lake, a part of the harvesters live nearby the Madeira river and prefer selling their products to the boots on the Madeira river.

2.4 Discussion

According to the results of our research there is a correlation between the pre-financing amount, the number of group members and the forest territory observed by the group members. The larger the investments, the more Brazil Nut harvesters are willing to become group members and as larger forest territory is managed for the harvesting of Brazil Nuts.

Another correlation exists between the continuity of the technical support and the income of the Brazil Nut harvesters. Since the initial establishment of the group in 2008, the group was not able to become independent of the external support. As soon as the support was missing, difficulties emerged such as the acquisition of the group's funds by an outside party or decrease in motivation to continue working. This finding can be compared to the findings of Donovan et. al. (2008) who mention that the rural community enterprises only reach maturity after two to five decades of operation (Donovan et al., 2008; Stoian, Donovan, & Poole, 2009).

The described interventions caused endogenous rural development with increased harvesters' income from the work with Brazil Nuts, formation of a legally registered Brazil Nut association, establishment of new infrastructure such as the storage room in Cuniã and larger observed forest territory by the community. The described Brazil Nut enterprise can be classified as a form of solidarity economy. The emphasis of the Brazil Nut group is not the profit maximization of the group members but the symbiosis between the income increase and the maintenance of the healthy ecosystem of the forest.

The establishment of the Brazil Nut group and the provision of pre-financing capital has led to new interpersonal relationships as well as social conflicts between the group members such as the increasing mistrust towards the accountant or the exclusion of group members for not paying back the funds. According to rural sociology studies, these occurrences are not seldom (Bell & Newby, 2012; Yang, Ryan, & Zhang, 2013). In the process of the income increase internal conflicts within the team may occur. The described tensions evolved in the time slots of a missing technical supporter. To overcome these tensions, the presence of methodological guidance of the enterprise seems to be essential in the first years of operation.

The technical guidance is also important for obtaining pre-financing in the stock creation of Brazil Nuts. Receiving credits as initial capital seems to be impossible without the external support due to the administrative barriers throughout the application process but the access to capital is essential in the development of small scale enterprises and the work with NTFP (Kunwar et al., 2013).

The eager participation of Cuniã's inhabitants and the transfer of the Brazil Nut group from São Carlos do Jamari to Cuniã shows the importance of the property rights. The property rights of Cuniã's inhabitants provided by the state include the legal rights to access the land, to use and to extract the forest resources (Section 2.3.1.2). The inhabitants of Cuniã have the right to collectively use the land and have autonomy over the territory which they have traditionally occupied. If logging occurs around the Cuniã community, the Cuniã's inhabitants will know whether it is legal or illegal and will have the measures to counteract. On the contrary, the São Carlos do Jamari community's inhabitants won't know whether it is legal or illegal, once logging occurs.

Institutional economics predict that property rights may develop stepwise and without conflict, if resources' values change successive and various economic actors synchronize their activities accordingly (Alston, Libecap, & Mueller, 1999; De Jong, Ruiz, & Becker, 2006). Alston et al. (1999) argue that it is the state's responsibility to define property rights. Similar to the findings of Cunningham (2011) and Donovan et al. (2006), our research shows that granting and enforcing legal access to forest resources are important requirements for the motivation and the willingness to work with Brazil Nuts as well as to manage the forest sustainably.

2.5 Conclusion and outlook

Analysis of the results of our interventions suggests that with the help of organizational support and external investments, the Brazil Nut harvesters are in a position to organize, to discover new forest territories for larger Brazil Nut collection, and to increase their income. Our study shows that throughout the interventions and the longevity of the Brazil Nut project, continuous external organizational and accounting assistances are required. Human capital such as technical, marketing, organizational assistances are of essence and equally important as the financial capital. A responsible, knowledgeable, and trustable person is of essence that will be assisting the community throughout the establishment and the first years of running a small scale enterprise.

Although the Brazil Nut group was established in São Carlos, after the first year, through mouth-to-mouth propaganda most new team members came from Cuniã. Due to clear legal rights, Cuniã's inhabitants are able to receive the funds, to identify a location and to construct a storehouse. The motivation in working and sustainable harvesting is higher in Cuniã due to clear land tenure and a feeling of responsibility for the territory they can legally use.

The described interventions result in the observation of a larger forest territory by the Brazil Nut group. The pre-financing capital stimulates the group members to rediscover three abandoned distant Brazil Nut groves and leads to an overview and management of larger forest territories.

The presented interferences show that the analyzed forest communities are willing to accept and embrace changes in their daily economic activities. Although only three members were willing to participate initially, high level of motivation of the group members lead to an increase in the number of group members once the team members advertised their work.

The lack of financial savings or bank accounts of most communities' inhabitants and the missing insurance infrastructure inside the communities make communities extremely vulnerable in emergency situations such as the flood in 2014 and leads to a dependency on the external financial support. Creation of an informal insurance system inside the forest community may be a possibility to overcome the unforeseen situations such as illnesses or natural disasters. An organized enterprise can be a possibility for the accumulation of capital and for the organization of such an insurance system.

In order to develop sustainable sources of income for forest communities, one option can be to concentrate on the work with various NTFP. Concentrating on only one product, as in our case on Brazil Nuts, is only a seasonal source of income which may not be sufficient to generate the income needed for the families for the whole year. Also, serious income outfalls can arise when the Brazil Nut prices drop in a peak year with a high supply of Brazil Nuts or the supply drops during an unfruitful season as in the year 2009. As most of the currently economically valuable NTFP are seasonal, an option can be to establish value chains for various NTFP which will provide a yearlong employment.

The standard modern way of soil use is related to one highly profitable activity such as soy plantation or cattle raising. Hence, the forest is deforested for the highest profit possible. For centuries, Amazonian indigenous and traditional communities have been living in symbiosis with the forest, using the soil in multiple ways without depredating it. The multiple uses of

the forest such as work with NTFP represent a way for generating income, providing an economic alternative for the communities and maintaining the forest.

Support of the government in the establishment of the small scale forest enterprises is important. This support might be similar to the support provided by the Brazilian government for agriculture and cattle raising including the supply of technical and transportation assistances, financing the stock formation with low administrative barriers, cutting taxes etc. This support may result in forest conservation and simultaneously lead to an increase in income of local inhabitants.

Further long-term empirical research of economic activities is required in other forest communities of Brazil as well as different tropical forest countries. The aim is to identify the main bottlenecks in other tropical forest regions after providing the pre-financing capital and initial assistance for the establishment of small scale forest enterprises in forest communities. The overall aim of further research is to develop a global concept of how non-destructive forest use and poverty alleviation can be achieved in tropical forest communities. In order to achieve this aim, the following chapter presents the main economic, social, and environmental patterns of tropical forest communities after analyzing the global Poverty and Environment Network (PEN) study organized by the Centre for International Forestry Research (CIFOR) which combines data from 334 villages from 24 countries in South America, Africa and Asia. As the result, the main outcomes of the PEN study analysis are compared with the sustainable development concept and the concept of the Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR) is presented as an option to achieve non-destructive forest use and livelihood creation in tropical forest communities.

3 REQUIREMENTS FOR THE SUSTAINABLE DEVELOPMENT OF ECONOMIC ACTIVITIES IN TROPICAL FOREST COMMUNITIES

3.1 Motivation

With this chapter we aim to develop a global concept of how three Sustainable Development Goals inside of tropical forest communities can be achieved, including poverty alleviation, sustainable communities' development, and sustainable forest management (United Nations, 2015). The question we aim to answer is of how to provide the inhabitants of forest communities a perspective so that they can live in the future from the sustainable forest management. It can be assumed that people in the forest communities have originally conducted sustainable forest management, as long as they were not beset by commercial interests of timber companies or were displaced. Currently the existence of many forest communities is destroyed or at least threatened directly or indirectly by the commercial timber industry.

Historically, through sustainable forest management the forest communities have not only retained their own existence, but also made an important contribution to the climate protection (Poffenberger & McGean, 1996). Today, climate change has reached an alarming high degree dimension, harming many people in the world particularly affecting the poor population of developing countries (Edenhofer et al., 2008; IPCC, 2014; Risbey, 2008; Wheeler & Von Braun, 2013).

According to Berke and Conroy (2000) there is no general agreement on how the concept of sustainable development can be translated into practice as it requires complex simultaneous decision-making processes to pursue environmental protection, social equity, and economic development (Blower, 1993; Conroy & Berke, 2004). Hall (1997) and Perz (2001) suggest to look at sustainable development as productive conservation meaning that forest communities can generate acceptable income while sustaining the forest resources. Puettmann et al. (2013) suggest managing forests as 'complex adaptive systems' which might lead to a sustainable forest management (Spathelf, 2009). Establishment of small and medium scale enterprise in forest communities is considered as an option to improve the economic well-being of forest communities' inhabitants (Akinnifesi et al., 2006; Ambrose-Oji, 2003; May, da Vinha, & Macqueen, 2003; Mayers, 2006; Tieguhong et al., 2012; Warner, 2007).

We look at main patterns of tropical forest communities and various components of sustainable development such as economic, environmental, and social and their interactions in order to analyze how sustainable development can be practically implemented into economic activities of tropical forest communities. In this study we present a conceptual framework of how sustainable development in tropical forest communities can be achieved and formalize the interconnections between the social, environmental and economic dimensions of the sustainable development concept.

3.2 Methods and materials

In this study we first present the main relevant data regarding the tropical forest communities' livelihood of the Poverty and Environment Network (PEN) study organized by the Center for International Forestry Research (CIFOR). We then introduce the concept of sustainable development and its main components in the context of forest communities. As the result we analyze the compatibility of the forest communities' realities with the theoretical concept of the sustainable development and introduce the global concept of Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR) as a possibility to achieve the non-destructive forest use and poverty alleviation in tropical forest communities. We theoretically develop a concept of how the desired equilibrium between the social, economic and environmental components and its interactions can be achieved.

3.2.1 Common environmental, social and economic characteristics of tropical forest communities

We are using the data regarding the forest communities' livelihood of the Poverty and Environment Network (PEN) study organized by the Center for International Forestry Research. This study combines data from 33 PEN partners including socio-economic and environmental data from 8301 households in 334 villages from 24 countries with close proximity to forests located within tropical or sub-tropical regions of Asia, Africa and Latin America. The miscellaneousness of this study allows making overall assumptions of communities' livelihood (Table 3-1).

We analyze three components of the PEN study: the ecological, economic and social components. Regarding the ecological component we conclude that although the governmental rules regulating the forest use might exist in many forest communities, they are mostly unclear and not respected by the communities. In Asia and Africa 23% and in Latin

America 50% of all interviewed households are occasionally clearing the forest and the average clearing area is 1.4 ha for Africa, 0.8 ha for Latin America and 0.95 ha for Asia. The forest cleared by the households is mostly because of the need for cropping area. Land tenure insecurity is considered as one of the main factors for deforestation. (PEN, 2016)

		Latin America	**Asia**	**Africa**
Ecological	Existing governmental rules that regulate forest use			
	yes, but the rules are vague/unclear	27.19	29.5	14.62
	yes, clear rules exist	8.75	21.64	44.47
	Governmental rules are respected by the community	0.94	4.59	9.68
	Written permission required to harvest forest products	15.31	7.87	24.9
	Forest cleared by communities (pct. of HH clearing forest out of total interviewed HH)	50.14	23.33	23.56
	for cropping (pct. of HH which are clearing forest)	91.7	60.28	91.3
	for tree plantations (pct. of HH which are clearing forest)	1.36	3.97	1.35
Economic	Forest and non-forest environmental income as pct. of total income	31.9	23.2	30.8
	Most important factors to increase income from most important forest products			
	Better protection of forest, avoiding overharvesting	43.46	43,29	41.2
	Better skills and knowledge on harvesting	22.51	21.81	14.42
	Legal rights for forest use	1.57	18.46	8.43
	Better access to credit/capital	14.66	7.05	2.62
	Food production and income sufficiency (just about sufficient or sufficient)			
	just about sufficient	42.26	47.27	39.49
	sufficient	27.41	31.56	45.74
Social	Life satisfaction perception			
	satisfied	38.47	46.48	53.64

	very satisfied	3.92	6.08	7.08
	Consider the village as a good place to live			
	partly	19.77	19.81	14.36
	totally	69.35	77.21	77.03

Table 3-1. Representation of the livelihood reality of tropical forest communities (data in percentage of total interviewed participants) (PEN, 2016)

Regarding the economic component we see that forest and non-forest environmental income represents about 1/3 of the total income of communities which approximately equals the income from agriculture. In order to increase the income from the most profitable forest products, the communities consider better protection of the forest, better skills and knowledge on sustainable harvesting practices as well as legal rights for the use of the forest as most important factors. Better access to credit and capital is an additional factor which in their opinion leads to improved conditions of economic activities. Communities' inhabitants mostly consider their income as just about sufficient for their livelihood. (PEN, 2016)

The social component of the PEN study reveals about the overall satisfaction of the respondents. Although communities' inhabitants can be considered as poor or very poor, this does not decrease their life satisfaction. Most communities' inhabitants (over 70%) consider the villages they are living as a good place to live. (PEN, 2016)

3.2.2 Sustainable development concept

Sustainable development is characterized by two constitutive features: 1. the three-dimensionality whereby ecology, economy and social issues should be guided towards a balance and 2. the intra- and intergenerational equity. Intragenerational equity aims to achieve a fair allocation of resources between the people of developed and developing countries and between competing interests at the present time whereas the intergenerational equity points towards the justice in distribution of resources between the present and the coming generations (Jabareen, 2008). Especially for forest communities both constitutive features of sustainable development are highly relevant.

The sustainable development of economic activities in tropical forest communities can be realized on the background of national wealth as a socio-economic category which describes the initial and final stages of economic activity. Forests represent a potential national wealth of the country and concurrently an importance for the international community as they affect

the climate stability, the atmospheric balance, and maintain the biodiversity. With the growth of national wealth, the awareness of the international community for their social responsibility and the importance of environmental concerns increase, in particular, in the need to conserve the tropical forests. Understanding is rising that tropical forests are of environmental and economic importance and require compensation for their "work".

Institutions can act as an enforcement tool in order to achieve sustainable development. They are defined as systems of instituted and common social rules that organize social interactions (Hodgson, 1988). In the context of the sustainable development, the institutional development can be described as the ecologically and socially oriented direction of a legislation aiming to organize social responsibility of entrepreneurial activities.

Conservation of forests and sustainable development of forest communities is an interrelated process. The concept of sustainable development for tropical forest communities can be formulated as such: Achieving welfare for forest communities through economic activities and obligatory monitoring and conservation of the forest and its biodiversity. The aim of forest communities' sustainable development is to conserve tropical forests and to make it a "plantation" with a stable source of income for local inhabitants. Sustainable development of communities' economic activities implies the combination and equilibrium of the following environmental, social and economic dimensions.

3.2.2.1 Ecological Dimension

Environmental development will enable forest management, reforestation and conservation of tropical forests. Jabareen (2008) defines natural capital as all natural assets which can be modified, but not created by humans. Sustainability in his interpretation is the stock of natural capital which should be maintained in order to provide opportunities for future generations to create wealth and well-being (Jabareen, 2008). Already in the year 1713, Hans Carl von Carlowitz has proposed not to log more wood per year than what can regrow. With this statement, he has set a resource-economic principle which is valid until today. Von Carlowitz is viewed as the forerunner of sustainable yield forestry (von Carlowitz, 1713; Von Hauff, 2014).

Our research is based on the context of natural capital such as tropical forests. Particularly for low-income countries natural capital is a critical asset as it represents an important share (36%) of the total wealth according to the World Bank (2012). Livelihoods of many subsistence communities in tropical forest countries directly depend on healthy ecosystems

(World Bank, 2012). At the present stage of development, the international community is no longer considering natural capital as a costless factor in the economic process. Uncertainty with respect to future value of tropical forests as natural capital limits the ability to determine whether it will be possible to fully compensate its lack in the future.

3.2.2.2 Economic Dimension

Economic development of forest communities may be possible through management and technology in terms of ecological forest management. The outcome can be the creation of new working places with NTFP and the sustainable forest management.

Traditional economics argues that profit maximization plus customer satisfaction in the market system is consistent with maximization of well-being and that market failure can be corrected through governmental policies. Currently, a consensus is arising that profit maximization can no longer be regarded as the exclusive goal of companies (Kleine & Hauff, 2009). The emergence of the sustainable development concept changes the attitude towards fundamental basis of conventional economics as of unlimited economic growth. A combination between social and environmental factors has to be considered for economic development. Economics in terms of sustainable development believes that short-term profit maximization and short-term meeting of consumer's needs could lead to depletion of natural or social resources, the degradation of society, nature or biodiversity, or to climate change.

3.2.2.3 Social Dimension

Social development of forest communities will enable communities' inhabitants to organize, to divide tasks and as a result to benefit from economic development such as living standard improvement, poverty alleviation, education, and health care provision. The social component of the sustainable development concept is focused on human rights and aims to develop and, at the same time, maintain the stability of social and cultural systems. Part of this approach is the division of benefits which provides or may provide the tropical forest to the local communities.

The social capital is a component of sustainable development and can be understood as the ability of people to work together for common purposes in groups and organizations (Fukuyama, 1995). In the context of tropical forest communities, without investments into social capital as economic and social resource for obtaining public benefits from forest

conservation, predatory use of tropical forests and exploitation of forest communities' inhabitants might continue.

Another part of the social component is human capital. Human capital is regarded as a complex of knowledge and skills that are used to meet the needs of individuals and the society as a whole (Burkhard, 2004). Human capital of communities' inhabitants lies in the traditional knowledge about the forest, forest products, and traditional medicine. Schultz (1982) argues that improving the wellbeing of poor people does not primarily depend on the land, natural resources and technology, but on their knowledge. The "heart" of human capital theory is the added value that employees can create for their organization. It considers employees as assets and stresses that investing in them will increase the profit of the organization. Human capital is needed in order to achieve sustainable development in tropical forest communities.

3.3 Results: Compatibility of the sustainable development and forest communities' economic activities – Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR)

The tropical forest communities live substantially through a subsistence economy wherein the living standard remains low. For sustainable development of economic activities in forest communities, economic strategy and investment schemes might be required.

According to the analyzed PEN study the main challenges for poverty alleviation in forest communities and for the organization of economic activities are (1) the lack of legally secured access to the nearby forest, (2) lack of skills and knowledge on sustainable NTFP harvesting practices, (3) the lack of legal rights to use and manage the forest resources, (4) the lack of initial investments into the establishment of enterprises, and (5) the lack of methodological, technical, and organizational support for enterprise development.

Our hypothesis is that the establishment and development of an enterprise in a forest community as a legal entity may allow increasing the revenue of communities' inhabitants with organizational methods and lead to sustainable forest management. As such it may lead to acquisition of credits for initial investments into enterprise establishment including implementation of processing facilities for adding value to forest products and organization of a team of workers who will be able to negotiate on the selling prices of their products with the intermediaries or overcome the intermediaries and transport their products further to the markets.

The actions which might lead to the non-destructive forest use nearby the communities are a combination of: (1) legally secured access to the nearby forest based on a forest management contract, clearly defining the rights and responsibilities of the community in the use and management of forest resources, (2) means of reporting about illegal logging to authorities, (3) methodological support in sustainable harvesting and forest usage practices, and (4) economic incentives for forest conservation. Legal rights provide an incentive for non-destructive forest use and forest conservation.

The combination of the action strategies targeted at overcoming the two challenges, destructive forest use and poverty in forest communities, suggests the establishment of a Small Scale Forest Enterprise with Social Responsibility (SSFESR) as a legal entity in targeted forest communities. We define SSFESR as an enterprise managed and employed by indigenous and other local communities, which is aimed at making profit from sustainable harvesting, processing and trade of Non Timber Forest Products (NTFP) and sustainable timber management practices. In our study, social responsibility describes the need for conserving tropical forests and for raising the living standards of forest communities' inhabitants. As a consequence of the SSFESR, following benefits can be achieved: an environmental benefit through the forest conservation and forest monitoring, an economic benefit through the increase of income, and a social benefit through the creation of working places, poverty alleviation, infrastructure development, and the professional training. Figure 3-1 highlights the cause-and-effect relationships of the SSFESR.

SSFESR can be developed on the background of institutional development with legally secured access to the nearby forest, the rights to use and manage the forest resources, a taxation framework and the contractual framework between the forest owner and the forest users while describing the legal basis for external financial investments. In our case institutional development would also include legal rights for forest management with regulated ownership of forest territory which can be used for economic activities and is to be monitored.

Organization of economic activities through the establishment of SSFESR on the basis of a mandatory condition for monitoring and conserving the forest might empower sustainable forest conservation and at the same time increase the welfare of forest communities through work with NTFP. SSFESR is based on the assumption of equal rights between all community members for the collection of NTFP inside the forest and for the usage of processing facilities. The assets of the enterprise include the legal rights for forest management. The

legal rights allow the forest communities' inhabitants to manage the forest and to harvest the NTFP, providing the information regarding the borders of the legally accessible forest territory. As the result of the established SSFESR in combination with the legal rights, communities' inhabitants are in a position to observe the forest territory they are assigned to and to manage it sustainably as their livelihood directly depends on this territory. The main activity of the forest enterprise, which does not own the forest, can result on the basis of a forest management agreement. Without such an agreement, legal enterprise activities inside of forest communities might not be possible.

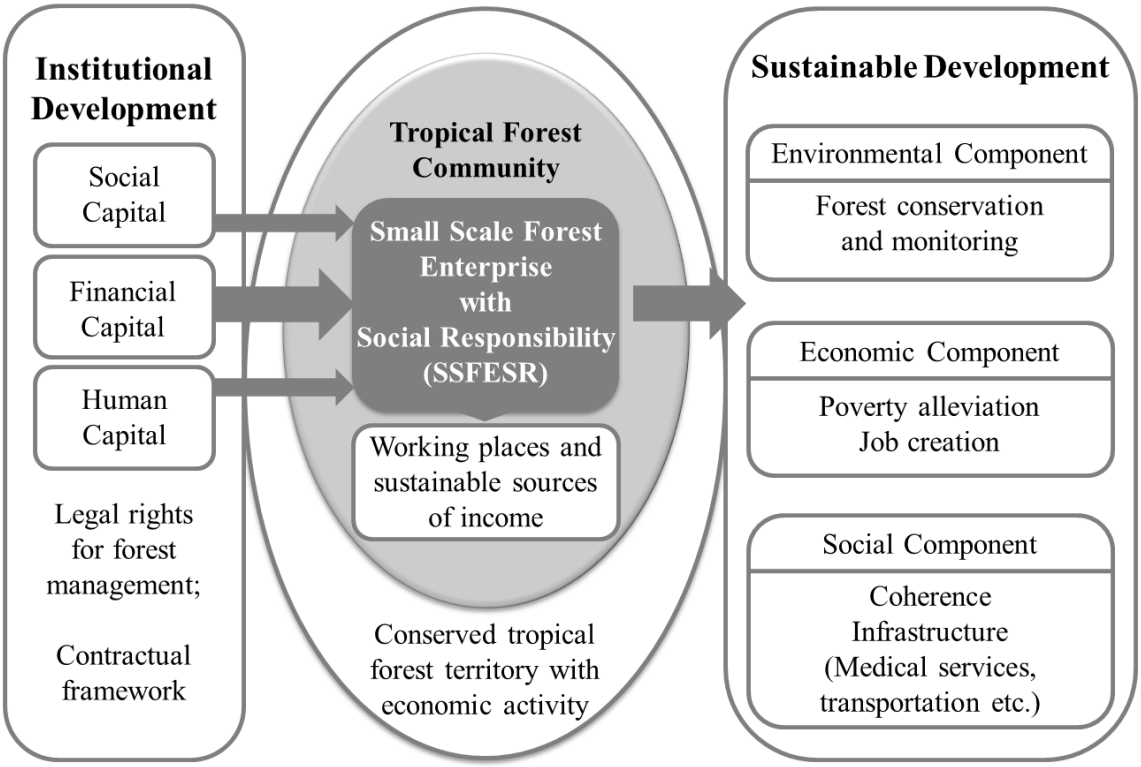

Figure 3-1: Cause-and-effect relationships of the Small Scale Forest Enterprise with Social and Ecological Responsibility

SSFESR employees are dedicated to monitor and conserve the forest, to apply the sustainable forest usage practices, and to inform the authorities about illegal logging. Means of reporting to authorities are a possibility to inform the higher instances if illegal logging is happening in the nearby forest area.

The benefit from the investments into the SSFESR is the poverty alleviation and the conservation of tropical forests for future generations as a component for climate stabilization and biodiversity conservation. SSFESR is not an aim in itself but a tool for establishment of sustainable income sources for communities' inhabitants. It is a legal entity which is a

requirement for receiving financial investments and legal rights for forest management and monitoring, for accessing the wholesale markets, for obtaining bank loans, and a fair distribution of income between forest communities' inhabitants. To create SSFESR external investments may come from governments, international community, and from companies with corporate social responsibility. As a legal entity SSFESR is able to receive financial capital for the enterprise development.

We link the sustainable development of tropical forest communities to the social responsibility within the SSFESR and within the national government and international community. For the international community the conservation of tropical forests has a direct benefit of climate stabilization and biodiversity conservation for future generations.

For the development of the SSFESR, social and human capitals are needed. Increasing the social capital in forest communities would lead to environmental benefits such as organized forest conservation or sustainable harvesting practices and economic benefits such as the division of tasks or the negotiation power on selling prices for the produced goods.

	Indication of sustainable development processes for tropical forest communities
Economic Component	Investments into development of forest community's economic activities
	Value of output obtained after investment
Social Component	Number of working places in forest community before investment
	Number of working places after investment
	Increase in the number of working places
Environmental Component	Forest area monitored by the community

Table 3-2. Processes characterizing the sustainable development components for tropical forest communities

Social and environmental challenges in tropical forest communities depend on the solution of economic organization of forest communities' inhabitants. The proposed interaction mechanisms present functional causal relations of theoretical concepts. Basic parameters of

economic, social and environmental components within the concept of sustainable development are presented in Table 3-2.

3.3.1 Interaction between economic and environmental components

The interaction between economic and environmental components creates the possibility for valuation of tropical forests' conservation and for calculating the environmental impact. The World Bank report notes that a farmer who cuts down one hectare of tropical forest with its rich biodiversity, in order to make a pasture worth 289,-USD, releases 500 tonnes of carbon dioxide into the atmosphere while burning the felled trees. For such emissions companies in industrialized countries with carbon price pay about 7.200,-USD to meet their obligations of reducing carbon emissions (Chomitz, Buys, De Luca, Thomas, & Wertz-Kanounnikoff, 2007).

The economic approach is the maintenance of total capital through which revenue is produced. In case of forest communities, this capital is the tropical forest which is an integral part of natural and social capital of humanity.

Trees and products growing in the forests, fish inside the river etc. are of no value from an economic point of view. The price for these products is created through the work which is invested into the harvesting, processing, packaging of these products and bringing them to the market. In a free market, value is created by workers of the enterprise, but the main income receives the manager during final sale of the product. An option is that income from NTFP processing would stay inside the community but marketing and sale would be handed over to qualified specialists with social responsibility under the condition of profit sharing with the small scale forest enterprise.

Increase of investments into the infrastructure development results in a rise of monitored forest area incorporated into communities' economic activities. There is a correlation between the investments volume I, [USD], increased value of produced products L_x, [USD/kg], number of workers ΔP, [person], and monitored forest area S_0, [ha]. This correlation is presented in Equation (3-1). S_0, [ha] is a discrete value and cannot exceed forest area assigned to the community for use and monitoring.

$$S_0 = F\,(I, L_x, \Delta P) \qquad \textbf{(3-1)}$$

3.3.2 Interaction between environmental and social components

In this study, social responsibility describes the need for conserving tropical forests and for raising the living standards of forest communities' inhabitants. The interaction between environmental and social components discloses the possibility to address the social justice within the current generations in regard with the next generations. Environmentally balanced economic activity inside of tropical forest communities is an inseparable complementary process. Monitoring and conservation of forests, controlling of harvesting and usage of NTFP, reforestation of degraded and deforested areas are criteria of the environmental component of forest communities' sustainable development. Harvesting of NTFP should remain sustainable and not result in overharvesting or interference with natural regeneration and maintenance of biological balance.

Investments into development of economic activities lead to job creation, to forest conservation, to maintenance of community living in this region, and might lead to a decrease of migration to metropolitan areas. The formalization of the sustainable development components allows showing the interdependence between the number of workers F (ΔP), [person], and the monitored forest area S_0, [ha], see Equation (3-2).

$$F(\Delta P) = F(S_0) \quad \textbf{(3-2)}$$

3.3.3 Interaction between social and economic components

By providing technical assistance in organization of economic activities for harvesting, processing, and marketing of NTFP with sustainable forest management to forest communities, both intra- and intergenerational justices can be achieved. This includes fair trade of NTFP between developing and developed countries and sustainable forest management by forest communities' inhabitants. An option for assistance of communities' inhabitants is to include the creation of new workplaces and establishment of processing facilities for local NTFP, as a possibility to add value to the products.

Forest communities' inhabitants should be involved in the processes that shape their sphere of life, should contribute to decision making processes and monitor the implementation of these decisions. A social topic of forest communities is the fight against poverty, improvement of living standards and the stabilization of demographic situation such as lessening the migration of community's youth to the metropolitan areas and, ultimately, conserving the forest communities.

People are required who on the one hand understand the importance of the challenge of conserving tropical forests and on the other hand have managerial skills of organizing a small scale forest enterprise. Local inhabitants of tropical forest communities mostly do not have trained labour that would be able to organize and to manage small scale forest enterprises. There is a need either for training of local inhabitants or for external managers. In order to make the concept multipliable, a possibility of providing human capital to forest communities might be environmental voluntary and within it volunteers that would bring economic, organizational and technical knowledge to forest communities. Through investments *I*, [USD] into development of economic activities, new working places for P_2, [person] are being established. This increases not only the income and quality of life of the workers but also of their families. The determining factor in improving quality of life is the growth of working places ΔP which is the result of investments *I*, [USD], see Equation (3-3).

$$\Delta P = F(I) \qquad (3\text{-}3)$$

3.3.4 Interactions between various components within the concept of sustainable development

The proposed functional dependencies allow making predictions of economic development with an analysis of possible outcomes as well as recommendations of best practices for environmental and economic policies while providing social outcomes. The proposed interaction mechanisms present functional causal relations of theoretical concepts. These interactions between various components within the sustainable development concept present a dynamic model of interdependent quantifiable variables (Figure 3-2).

All parameters have discrete values, wherein the amount of investments depends on specific technical conditions. In particular the number of jobs in a community cannot exceed the number of community's inhabitants, and the forest area used for collection of NTFP cannot exceed the forest area legally approved to be monitored by community inhabitants.

For this model profit is not the main factor determining a usual private investment, but the environmental and social returns on investment. Environmental solutions with social consequences and a base on economic methods depend on the use of proposed tools.

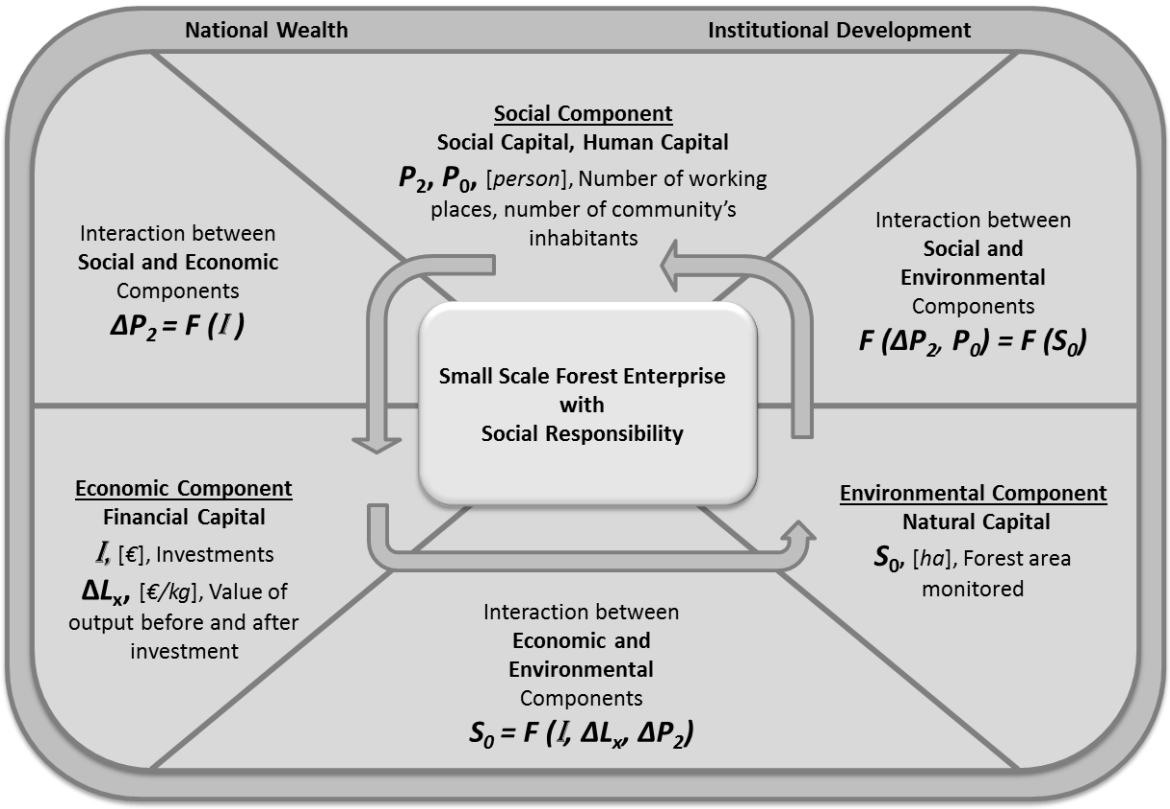

Figure 3-2: Sustainable development of tropical forest community and its components

3.4 Conclusion and outlook

In this study we propose a concept of the Small Scale Forest Enterprises with Social and Environmental Responsibility (SSFESR) inside of forest communities as an option for sustainable forest management and working places creation in tropical forest communities. Sustainable development of tropical forest communities can be achieved with help of external support such as financial capital which includes initial capital for the establishment of the SSFESR, human capital with methodical and organizational assistances, and institutional development including legal rights of forest communities for forest management. Benefit of international community for investments into SSFESR is the conservation of tropical forests for future generations as a component for climate stabilization and biodiversity conservation. Sustainable development of the tropical forest community can become a consequence of financial investments supported by social and human capital realized on the basis of institutional development.

Further research is required in order to quantify the required investments into the establishment of SSFESR and the returns on investments. For SSFESR, the returns on investments include the social, environmental and economic benefits. In the following

chapter, a mathematical model is presented which can determine the returns on investments into the SSFESR regarding the different investment options.

4 INVESTMENTS IN TROPICAL FOREST COMMUNITY ENTERPRISES FOR LIVELIHOOD CREATION AND CLIMATE CHANGE MITIGATION

4.1 Motivation

Climate change mitigation and livelihood creation are important challenges of today. The previous Chapter 3 presents an option for climate change mitigation and poverty alleviation with help of the establishment of Small Scale Forest Enterprises with Social and Environmental Responsibility (SSFESR) inside of tropical forest communities. Research shows that external investments into the development of socially and environmentally responsible enterprises in tropical forest communities allow organizing forest monitoring and forest protection from illegal logging by communities and lead to the creation of working places (FAO, 2016). Investments into the development of forest communities' infrastructure are necessary to alleviate poverty and conserve forests (Donovan et al., 2006; Mechik & von Hauff, 2016; Sachs et al., 2004). For political decision-making on allocation of investments into development of SSFESR, there is a need for organizational arrangements and justification for investment size (Antinori & Bray, 2005; Hill, Ouedraogo, & Conditamde, 2007; Kambewa & Utila, 2008; Lecup & Nicholson, 2000; D. Macqueen, 2009; D. J. Macqueen, 2007; Mechik & von Hauff, 2016; Augusta Molnar et al., 2007; Ros-Tonen & Wiersum, 2005).

The determination of optimal investments in tropical forest enterprises is a complex economic problem, which includes diverse private and public costs and benefits. A review of the scientific literature showed a lack of sophisticated quantitative assessments which i) determine the environmental and social benefits of investments into enterprise development in forest communities and ii) mathematically formalize the interdependencies between these investments, forest conservation, and poverty alleviation (Dhakal, Bigsby, & Cullen, 2010, 2007; Herbohn, Emtage, & Harrison, 2002; Kaimowitz & Angelsen, 1998; E. J. Robinson, Albers, & Williams, 2008). This study addresses this deficiency and quantitatively assesses the ecological, social, and economic returns on investments into the development of the Small Scale Forest Enterprises with Social Responsibility (SSFESR). SSFESR are defined as enterprises which aim at generating livelihood income from harvesting, processing and trade of Non Timber Forest Products (NTFPs) while using the forest in a non-destructive way (Mechik & von Hauff, 2016).

We chose India as our case study as it has the largest number of poor in the world with around 275 million people living in and around forest areas equaling to around 9% of the world's poor (Chao, 2012). 64 million poverty-stricken working-age citizens put steady pressure on Indian forests. The Indian government has attempted to slow forest losses and tackle poverty through a series of policy shifts since 1957, when forests were nationalized (Springate-Baginski & Blaikie, 2013).

In our case study, we use empirical data from the Banglapadigai region, India with a particular focus on commercializing shikakai (*Acacia concinna*), puchakai (*Sapindus sp.*), amla (*Phyllanthus sp.*), kadukai (*Terminalia chebula*) and seemar (*Pheonix sp.*) as examples of valuable NTFP. To perform a comprehensive economic analysis, we develop a mixed integer mathematical programming model, which is hereafter called the Optimal Investment Forest Conservation and Livelihood Creation (OIFC) model. The model estimates the size of the conserved forest territory, the established number of working places, and the income generated from work inside the enterprise depending on the investments into the SSFESR. The model can be used to provide scientific guidance for policy decisions on allocation of funds into the decrease of deforestation through the establishment of SSFESR as an option for climate change mitigation. While the current data are specific for the case study region, the mathematical structure and formulation is generic and can be used for assessments of other regions. To apply the model in other regions or for other forest products, all relevant input data and labels need to be adjusted.

4.2 Methods and Data

This section documents the essential structure of the OIFC model. In section 4.2.1 we present the conceptual approach of the model and in section 4.2.2 the general mathematical model structure. Section 4.2.3 details the empirical data used for the case study application of the model.

4.2.1 Conceptual description of the OIFC Model

The conceptual framework of the OIFC Model is presented in Figure 4-1 representing the main interdependencies between the investments into the development of SSFESR, the forest conservation, and poverty alleviation. OIFC is based on the hypothesis that investments into the development of SSFESR in tropical forest communities will protect the forest against

illegal logging in the area of community's economic activities and therefore mitigate climate change, and alleviate poverty through the creation of livelihood opportunities.

Through the investments into the SSFESR, processing and storage facilities can be created leading to more working places for communities' inhabitants and to larger forest territories observed and conserved by the harvesters. The workers of the SSFESR are obliged to harvest the NTFP sustainably and to conserve the forest.

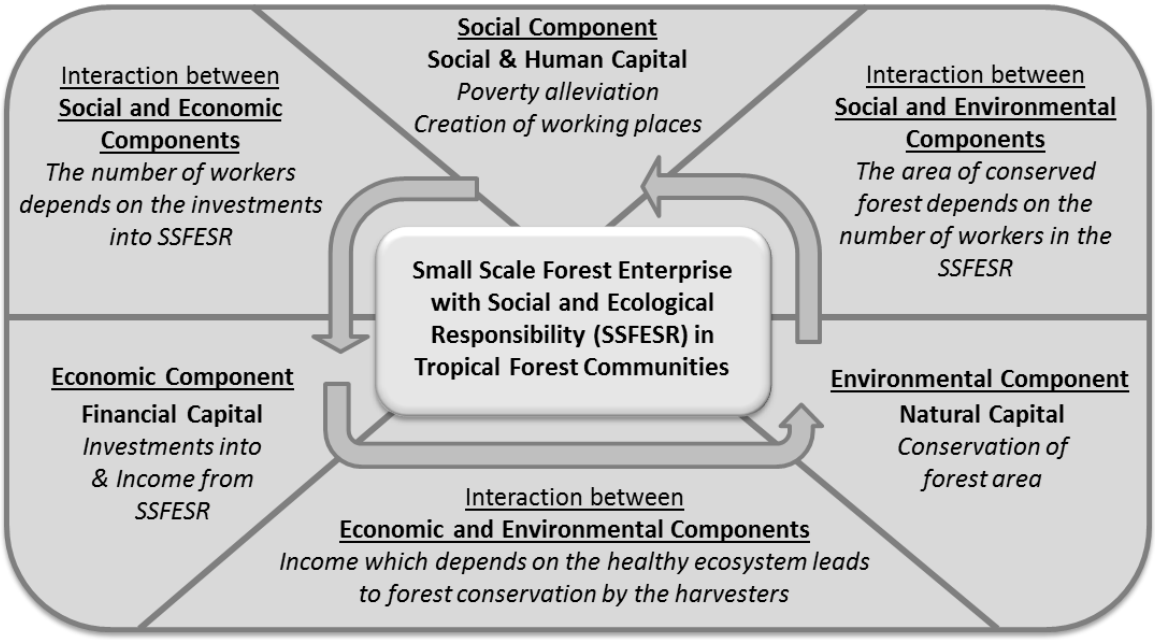

Figure 4-1: Conceptual framework of the Optimal Investment Forest Conservation and Livelihood Creation Model

An important objective of the model is to quantify interdependencies between investments into development of SSFESR, forest conservation, and carbon benefits in conserved forest territory. The extent of forest conservation is restricted by the number of people living and working in the forest community and the maximal sustainable yield for the chosen NTFPs. Available NTFP processing facilities are characterized by their investment, maintenance and operational costs, their technical efficiency, and capacity limits. In this case study, we do not consider the full range of processing or storage facility configurations but select only a few major alternatives.

The model optimization happens from the society's and policy makers' point of view. The assumption is that the policy makers are interested in the environmental benefits such as forest conservation and carbon sequestration and the social benefits such as working places creation and poverty alleviation besides the economic benefits of the enterprise development.

It is a normative model taking as the status quo the data from Indian forest communities with established processing and storage facilities.

The model is programed in a generic way that it can be applied to various forest communities in different tropical forest regions. In this study we concentrate on one specific case study as an example for model application.

The following model assumptions are the result of research inside of forest communities and literature review.

Social assumptions:

- All communities' inhabitants in the working age want to increase their income and improve their livelihood and are willing to work in the SSFESR.
- Number of workers for employment in SSFESR is limited due to limited number of forest communities' inhabitants.
- All the workers have the same productivity differing only in the activities they perform.

Economic assumptions:

- Processed NTFP can achieve higher prices.
- The more working places are provided inside of SSFESR the more communities' inhabitants are willing to work.
- The local inhabitants are not initiating new activities after the initial interventions.
- The policy makers and the international community are willing to invest into development of SSFESR as the SSFESR provide a climate change mitigation option and poverty alleviation possibility for these regions.

Environmental assumptions:

- No logging activities are allowed within SSFESR.
- The size of the conserved forest area and the associated carbon storage benefits are proportional to the magnitude of NTFP production.
- NTFP production is related to the forest's access, the markets and the value that will be derived from the sale of NTFP.
- The harvesters are obliged to harvest the NTFP sustainably.

Legal assumptions:

- Communities' inhabitants receive equal legal rights for forest management, forest usage, forest monitoring, and for sustainable harvesting of NTFP.
- Forest territory which can be occupied and used by communities' inhabitants is limited due to legal rights.

4.2.2 Mathematical structure of the OIFC Model

OIFC Model is a mixed integer programming model written in the GAMS-software package (www.gams.com). The equations of the model are presented below.

The objective of the model is to maximize the net benefits *B*, [USD] from investments into the development of SSFESR. These benefits are computed as the sum of environmental benefits and the economic benefits minus the total costs of all economic activities. All variables of the model except the objective variable *B* are restricted to nonnegative values. The variable *I* is integer.

The environmental benefits are described as the sum over eco-services set *e* including forest conservation or avoided emissions, with $p^{E}_{t,e}$, [USD/t] representing the price of environmental services and *t* being the set of time running from 2017 until 2029. $E_{t,e}$ is the environmental variable representing the total amount of ecosystem services. The total environmental benefit equals the product of individual environmental service *E* -measured in physical units- times its monetary value *p* summed over all distinct services *e*. The generic formulation of environmental benefits permits the accountancy of a large number of distinct ecological services. While our case study only considers the amount of conserved forest area and the associated carbon storage, future applications may include other environmental benefits such as erosion control, pharmaceutical use of NTFP, micro-climate regulation, provision of wildlife habitat, and others.

The economic benefits are a special consumer welfare measure that is commonly used in economic equilibrium models. It depicts the area underneath the inverse commodity demand curve and represents the total Marshallian utility from consumption. The magnitude of this measure is equal to the sum of consumer surplus plus consumer expenditure. We use this measure to portray market price responses to changes in commodity supply. The market price is presented with $p^{M}_{t,s,b,y}$ differing regarding the produced NTFP shown by the set *y*, the

selling seasons *s* - whether harvesting or non-harvesting, and the set of buyers *b* varying between the middleman, local, national or international markets. *S* represents the sale variable showing the total amount of the sold products.

The total costs of all economic activities demonstrate the variable costs of production, the variable costs of storage, the costs of labor, and the fixed investment costs. The variable costs of production are described as the product of the production costs $c^{P}_{t,s,i}$, [USD/t], and the production variable $F_{t,s,i}$ summed over the set of seasons *s* and the set of production activities *i* including harvesting, processing, and storing of the NTFP. The variable costs of the storage are the product of the storage costs $c^{S}_{t,s,o,y}$ and the storage variable $T_{t,s,o,y}$ summed over season *s*, product *y* and the set of storehouses *o*. The labor costs are the product of the labor costs c^{L}_{r} depending on the set of resources *r* such as the labor time, light unskilled labor, heavy unskilled labor, etc. multiplied with the labor resources $r^{F}_{t,s,i,r}$ and with the production variable $F_{t,s,i}$. The labor costs are summed over the season *s*, the production activities *i*, and the resources *r*. The final part of the total costs of economic activities is the fixed investment costs of the assets *a* such as the storehouse, the processing center, and the certificates for national or international sales. The various certificates such as national or international certificates are considered as the assets of the enterprise leading to the possibility of selling the products on the national and the international markets. The fixed investment costs are described as the product of the investment costs of the assets $c^{I}_{t,a}$ multiplied with the investment variable $I_{t,a}$ and summed over the assets *a*. The value of the discount factor ∂_t is set to 1 as we are primarily interested in the environmental and the social returns on investments rather than on investments' pay-off.

The objective equation is presented in Equation (4-1).

$$Max \quad B = \sum_{t} \partial_t \left(\begin{array}{l} +\sum_{e} \left(p^{E}_{t,\mathrm{e}} \cdot E_{t,\mathrm{e}} \right) + \sum_{s,b,y} \int p^{M}_{t,s,\mathrm{b},y} \left(\cdot S_{t,s,b,y} \right) \ \mathrm{d}S \\ -\sum_{s,i} \left(c^{P}_{t,s,i} \cdot F_{t,s,i} \right) - \sum_{s,o,\mathrm{y}} \left(c^{S}_{t,s,o,y} \cdot T_{t,s,o,y} \right) - \sum_{a} \left(c^{I}_{t,a} \cdot I_{t,a} \right) - \sum_{s,i,r} \left(c^{L}_{r} \cdot r^{F}_{t,s,i,r} \cdot F_{t,s,i} \right) \end{array} \right) \qquad \textbf{(4-1)}$$

Equation (4-2) presents the investment constraint. The demand for assets including the demand for processing, storage and certificates is constrained by the supply of SSFESR's assets. The demand for processing facilities' capacity is described as the product of enterprise yields $u^{F}_{t,s,i,a}$, [t/year] and the enterprise variable $F_{t,s,i}$ summed over the season *s* and the

production activities *i*. The demand for storage capacity is presented as the product of storage yield $u^{T}_{t,s,o,y,a}$ multiplied with the storage variable $T_{t,s,o,y}$ summed over the season *s*, the storehouses *o* and the products *y*. The demand for market certificates is described as the product of the sale parameter $u^{A}_{t,s,b,y,a}$ multiplied with the sale variable $S_{t,s,b,y}$ summed over all seasons *s*, all the buyers *b*, and all the products *y*. The supply of the assets is described as the product of the assets' capacity $z_{t,a}$, [t/year] multiplied with the assets variable $A_{t,x,a}$ and summed over the assets' investment age *x*.

$$\sum_{s,i}\left(u^{F}_{t,s,i,a}\cdot F_{t,s,i}\right)+\sum_{s,o,y}\left(u^{T}_{t,s,o,y,a}\cdot T_{t,s,o,y}\right)+\sum_{s,b,y}\left(u^{A}_{t,s,b,y,a}\cdot S_{t,s,b,y}\right)-\sum_{x}\left(z_{t,a}\cdot A_{t,x,a}\right)\qquad\leq 0\qquad\forall t,a \qquad \textbf{(4-2)}$$

The supply demand constraint is presented in Equation (4-3). The sum of the commodity sale cannot exceed the number of products which have been harvested, processed and stored previously. The harvested products are presented as the product of the harvesting yield $u^{h}_{t,s,h,y}$ multiplied with the $H_{t,h}$ harvesting variable and summed over harvesting activities *h* including harvesting of different NTFP. The processed products are presented as the product of the processing yield $u^{f}_{t,s,v,p}$ multiplied with the processing variable $F_{t,s,v}$ and summed over the set of production activities *v* including harvesting and processing of the NTFP. The stored products are described as the product of the coefficient of damaged stored products *q*, [t/year] multiplied with the storage variable *T* summed over the storage facilities *o*. The total sales are presented as the variable $S_{t,s,b,y}$ summed over all the buyers *b*.

$$-\sum_{h}\left(u^{h}_{t,s,h,y}\cdot H_{t,h}\right)-\sum_{v}\left(u^{f}_{t,s,v,y}\cdot F_{t,s,v}\right)-\sum_{o}\left(q_{t,s,o,y}\cdot T_{t,s,o,y}\right)+\sum_{b}S_{t,s,b,y}\leq 0\qquad\forall t,s,y \qquad \textbf{(4-3)}$$

The resources limitations are presented in Equation (4-4). The productivity of the SSFESR is limited by the maximal potential number of workers. The workers of the SSFESR are considered as the resources of the enterprise. The female workers are mostly involved into the processing and are not able to harvest and transport the products from the forest to the community as it requires strength for carrying heavy loads up to 60kg.

The number of labor working in the processing or storage facility or harvesting the products cannot exceed the total available number of communities' inhabitants in the working age. The total available number of communities' inhabitants in the working age is represented as the product of the labor resources parameter $r^{N}_{t,g,k}$, [man days] multiplied with the total population variable $N_{t,g,k}$ and summed over the inhabitants' gender *g* and their age *k*.

The model considers the labor transfer from heavy workers to light workers and from skilled workers to unskilled workers, for example, in a situation when more male workers are available than female on the market and more processing power is required. The labor transition is described as the product of the days per season parameter d_s multiplied with the resources transfer parameter r_l^L and the labor transfer variable $L_{t,l}$ summed over the set of labor *l*. The set of labor *l* differentiates between the female and the male workers and between the skilled and the unskilled labor. The parameter r^L shows the possibility of transfer from skilled to unskilled workers and from heavy to light workers.

The next part of the equation represents the product of the labor resources parameter which is required for processing of the NTFP $r_{t,s,i}^F$ multiplied with the enterprise variable $F_{t,s,i}$ and summed over all the production activities *i*.

The labor force for harvesting the products is described as the product between the resources' parameter for harvesting $r_{t,h,j}^H$ multiplied with the harvesting variable $H_{t,h,j}$ and summed over the set of harvesting activities *h* including harvesting of various NTFP and over the set of different distances *j* between the forest community and the harvesting regions.

$$-\sum_{g,k}\left(r_{t,g,k}^N \cdot N_{t,g,k}\right)-\sum_{l}\left(d_s \cdot r_l^L \cdot L_{t,l}\right)+\sum_{i}\left(r_{t,s,i}^F \cdot F_{t,s,i}\right)+\sum_{h,j}\left(r_{t,h,j}^H \cdot H_{t,h,j}\right) \quad \leq 0 \quad \forall t,s,r \qquad \textbf{(4-4)}$$

The population dynamics are described through the initial number of inhabitants inside the described case study communities, the average fertility rate and the average death rate of tribal people in India, see Equation (4-5). We describe the population dynamics with help of age categories differentiating between the children from 0 to 14 years old, the working age *w* citizens between the 15 and 59 years and the elderly population of over 59 years old.

The initial population is described as the total number of communities' inhabitants $d_{t,g,k}^{\text{number}}$ in the initial year depending on their gender *g* and age *k*. The fertility of the inhabitants is described through the average fertility rate $d_{t,g,\bar{k}}^{\text{birthrate}}$ during the fertility age $\bar{k}$ multiplied with the total population variable $N_{t,g,\bar{k}}$. The population change is shown as the product of the population change parameter $d_{t,g,w}^{\text{age}}$ for the working age *w* multiplied with the population variable during the working age $N_{t,g,w}$.

$$\sum_{w}\left(d_{t,g,w}^{\text{age}} \cdot N_{t,g,w}\right)+d_{t,g,k}^{\text{number}}\Big|_{t="t_0"}+\sum_{\bar{k}}\left(d_{t,g,\bar{k}}^{\text{birthrate}} \cdot N_{t,g,\bar{k}}\right)\Big|_{k="k_0"}-N_{t,g,k}=0 \;\forall t,g,k \qquad \textbf{(4-5)}$$

4.2.3 Case study description and data for the OIFC Model

As input for the OIFC model, we use collected data from the Bangalapadigai village and the surrounding villages Gherkiyur, Naddur, Mallikopai, Bargur, Kandished, Karapanai, Pongamokkai, Mudiyur, Bavikaarai, Chakapadigai, Vakanamaram, Samaigudal, Kokoda, Gudagur, Mettukal, Bhaviyur, Kambayur, Kollikuttai, Koppaiyur, Anthiyarai. These villages are located about 80km north of Coimbatore, Tamil Nadu, India (Figure 4-2).

We chose this region as the case study because it has over 12 years of collaboration experience with the Keystone Foundation, a local Indian Non-Governmental Organization, which works with indigenous people on natural resource conservation and rural development addressing the challenges of eco-system conservation, livelihoods and enterprise development. The Keystone Foundation provided us a thorough documentation of their work with the NTFP and the forest communities.

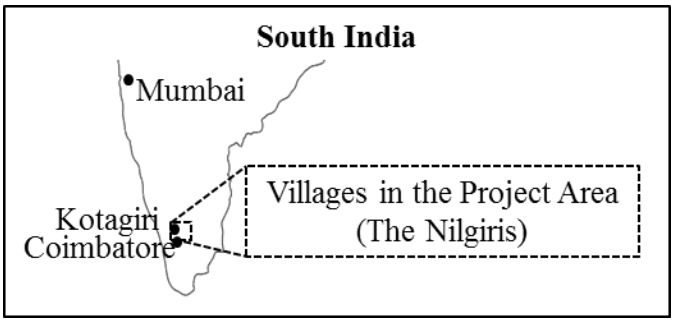

Figure 4-2: Map of South India and the villages in the project area

The model application simulates both the Bangalapadigai village and the surrounding villages with their inhabitants. As the processing and storage facilities are located in the Bangalapadigai village, we describe this village in detail. Bangalapadigai is classified as a self-governed village, a so-called Gram Panchayat. The inhabitants from Bangalapadigai are from two tribal communities – Irulas and Kurumbas. They are found in the middle elevations of the Nilgiri Biospher e Reserve. In the year 2015, the population of Bangalapadigai consisted of 147 persons. Most Bangalapadigai village inhabitants are dependent on agriculture or agricultural wage labor, mostly in and around their village.

Currently there is one processing facility located in Bangalapadigai which processes amla (*Phyllanthus sp.*), kadukai (*Terminalia chebula*), puchakai (*Sapindus sp.*), seemar (*Pheonix sp.*), and shikakai (*Acacia concinna*) products. Amla or Indian gooseberry is used as food supplement for its high concentration of vitamin C and for medicinal purposes. Kadukai is an Ayurvedic and Tibetan medicinal plant which can also be used for tanning leather and dyeing wool, silk and cotton. Puchakai is used for its lathering property in natural hair wash and

seemar grass is used for making brooms or mats. Shikakai is traditionally used for hair care and as an Ayurvedic medicinal plant.

Assets	Investment costs [USD]	Capacity [t/year]	Variable costs [USD] 2014/15	Variable costs [USD] 2015/16
Processing center	12400	50	3370	4350
Storage facility	21000	10		
National certificate	350			
International certificate	5000			

Table 4-1: Assets data

The harvesting of the products occurs in the surrounding villages Gherkiyur (40), Naddur (23), Mallikopai (27), Bargur (15), Kandished (7), Karapanai (7), Pongamokkai (5), Mudiyur (7), Bavikaarai (5), Chakapadigai (7), Vakanamaram (23), Samaigudal (13), Kokkode (23), Gudagur (8), Mettukal (60), Bhaviyur (15), Kambaiyur (15), Kollikuttai (12), Koppaiyur (20), Anthiyarai (13). Numbers in brackets indicate the number of households in these villages. The main data which has been used in the model as this case study is presented in Table 4-1 and Table 4-2. Table 4-1 represents the specific data regarding the fixed and variable costs of the assets. Table 4-2 shows the selling prices of the presented NTFP depending on the market (intermediary inside the village, local market, national and international markets), the selling season (harvesting or non-harvesting season) and the processing stage (raw or processed products). The intermediary inside the village is usually purchasing the raw products for a much lower price than the local market. In order to sell officially on the national or international markets certificates are required. The certificates require additional investments on the one hand but lead to higher selling prices on the other. As the supply of the NTFP is higher during the harvesting season and lowers between the seasons, the prices for the NTFP vary depending on the season and represent the need for an investment into a storage facility. While mostly men are involved in the harvesting due to the heavy weight of the raw products, women dominate the processing of the products. The model considers the possibility of men working in the processing facility if more processors are required than available on the market.

Selling prices in USD/t							
Market	**Middlemen**	**Local**				**National**	**Internat.**
Selling season	**Harvesting season**	**Harvesting season**		**Between seasons**		**Both seasons**	**Both seasons**
Processing stage	**Raw**	**Raw**	**Processed**	**Raw**	**Processed**	**Processed**	**Processed**
Shikakai	453	755	3775	906	3775	7550	64900
Puchakai	332,2		3775		3775	3775	49900
Kadukai	226,5		3020		3020	17818	29900
Amla	226,5	3322	6040	3775	6040	7550	34900
Seemar	755		15100		15100	15100	

Table 4-2: Selling prices of Non-Timber Forest Products

The described forest region can be considered as montane wet life zone. According to (Kerr, Hendy, Liu, & Pfaff, 2004), this life zone captures around 258tC/ha. Through the harvesting of NTFP and because of the dependence of SSFESR workers on a healthy ecosystem, we consider all the forest territory used for economic activities as sustainably managed. In order to calculate the captured carbon per hectare, we multiply the total conserved forest territory by the 258tC/ha as proposed by (Kerr et al., 2004). The model is running for the time period between 2017 and 2029.

4.2.4 Scenarios

In this study, we present 10 scenarios. Looking at the model from the policy makers' perspective, we present the model outcomes with three limited maximal investment volumes and three different prices for captured carbon. The first scenario is considered as a base scenario and represents the model outcomes with unlimited investment volume and the carbon price of 50USD/tC.

According to Richards & Stokes (2004), the costs of carbon sequestration in forests and land-use are in the range between 10 and 200USD per captured ton of carbon. For the nine scenarios, we choose three carbon prices options with carbon price 1 (Cp_1) equalling 30USD, carbon price 2 (Cp_2) determining 60USD and carbon price 3 (Cp_3) 100USD.

We limit the funding volumes according to the number of households in the case study region and the average investment volumes per household into social development projects. The total amount of households in the case study region amounts to 380 households. We consider three investment options. One option with an investment of 250USD per household resulting in a maximal investment of 95000USD, one with an investment of 150USD per household and one with 50USD per household with the maximal investment of 19000USD (Table 4-3). These investment volumes are chosen after analyzing the World Bank investments into the social development projects showing e.g. 166USD per household (World Bank, 2014) or International Fund for Agricultural Development presenting investments of e.g. 300-400USD per household (IFAD, 2012).

Maximal Investment	**Cp_1 (30USD)**	**Cp_2 (60USD)**	**Cp_3 (100USD)**
95000USD	Scenario 1	Scenario 2	Scenario 3
57000USD	Scenario 4	Scenario 5	Scenario 6
19000USD	Scenario 7	Scenario 8	Scenario 9

Table 4-3: Map of scenarios

As we not only consider the social factor but also the environmental factor throughout this study; the investment options can be presented as the investment price per conserved hectare of forest. The analyzed investments result in 32USD/ha or 0,12USD/tC for the scenarios 1-3, 19USD/ha or 0,07USD/tC for the scenarios 4-6, and 6USD/ha or 0,02USD/tC for the scenarios 7-9. These investment volumes can be compared to the cash payments of 28-100USD/ha/yr by CONAFOR (Mexican Federal Government through the National Forestry Commission) for avoided deforestation and sustainable forest management (FAO, 2013).
The first scenario with unlimited funding is presented in detail in section 4.3. In section 4.4, we present various scenarios with limited maximal investment volume in regard to the number of involved households.

4.3 Results

We first analyze the model results with unlimited investments' input. Afterward, we regard different scenarios with reduced investments. As a result, we can investigate the profitable scenarios and present the social, environmental and economic benefits of these options.

4.3.1 Investments

The model's optimal solution proposes to invest 286808USD in total, which is 755USD per household or 96USD per hectare for the time period between 2017 and 2029. All of the investments go into the establishment of ten processing centers, three storehouses, one international and one national certificate in the first simulation year 2017 (Figure 4-3). As the processing brings the highest increase in the selling prices for the NTFP compared to other assets, ten processing facilities are suggested for construction.

The construction of three storehouses allows selling the NTFP products outside harvesting seasons for a higher price. Investments in national and international certificates are bringing the enterprise the option of selling their raw and processed products on the national and international markets.

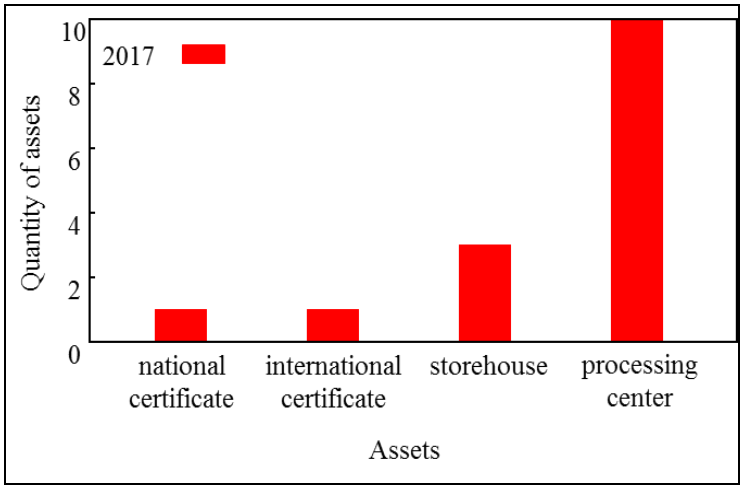

Figure 4-3: Investments allocation into assets

4.3.2 Social benefit

The social benefits include the establishment of new working places after the investments into the SSFESR. Establishment of new working places inside of forest communities may become an incentive to stay living inside the community and may eventually lead to a decrease of migration to metropolitan areas.

The processing of NTFP is mostly undertaken by women. As the result of the establishment of the SSFESR and the interrelated processing facilities, working places for men and mostly for women can be established. With the increasing possibilities in the processing of NTFPs, the number of harvesters as well as the number of persons working in the processing facilities rises. New economic activities inside of forest communities lead to new working places and consequently to poverty alleviation.

Year	Female Working Places	Male Working Places
2019	447	65
2024	445	65
2029	461	68

Table 4-4: Number of established working places for men and women

More than 60 working places are established for men and more than 440 working places for women as the result of the investments in the year 2017 and the construction of ten processing facilities. The number of working places rises with the number of installed processing centers and their capacity. Mostly female workers are affected by the investments into the construction of processing facilities (Table 4-4).

The number of established working places is nearly stable over time as no additional processing or storage facilities are constructed until the year 2029. In the year 2029, the working places for processing reach over 460.

4.3.3 Economic benefit

According to the OIFC model, the sale of the unprocessed NTFP is not profitable. The model suggests selling only the processed amla, shikakai, puchakai, kadukai, and seemar (Figure 4-4).

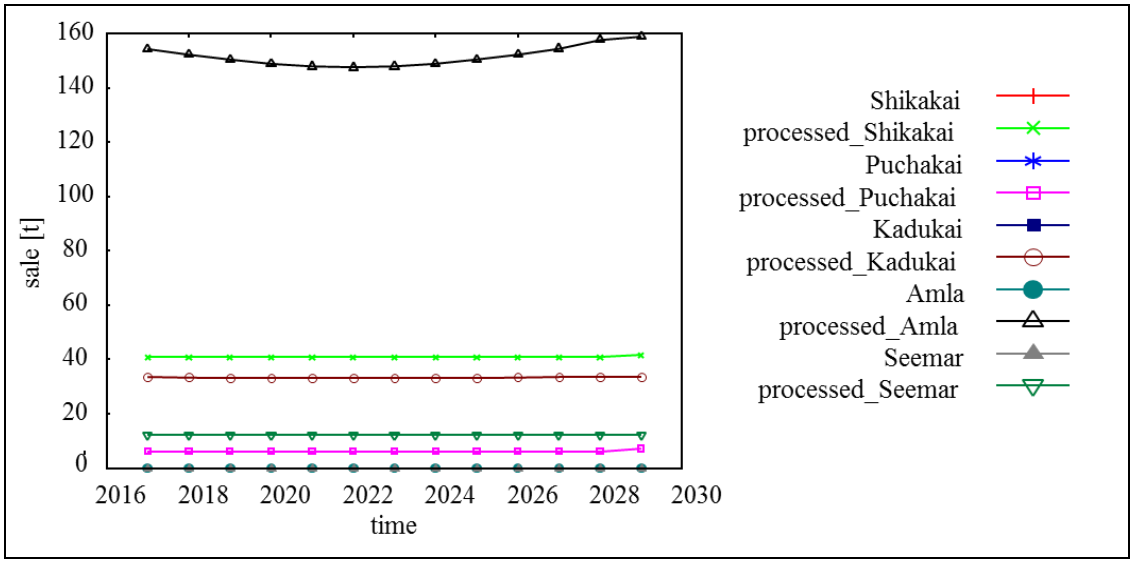

Figure 4-4: Sale of raw and processed NTFP

According to the case study data, there is a comparatively small price difference between harvesting and non-harvesting seasons. That is why the model suggests constructing only

three storage facilities compared to ten processing facilities. Most of the sale is happening during the harvesting season (Figure 4-5).

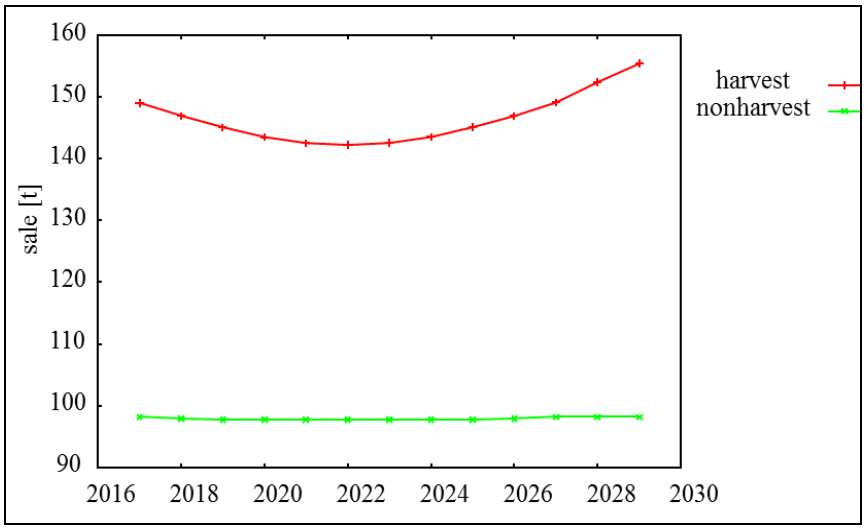

Figure 4-5: Sale of the products during the harvesting and non-harvesting season

Although the investment costs for acquiring an international certificate are high, the model suggests investing into both the national and the international certificate leading to the sales on the national and international markets. Sale to the intermediary is not suggested because of the large price difference with the sale on the local market (Figure 4-6). Sales vary little over time due to no additional investments after the year 2017.

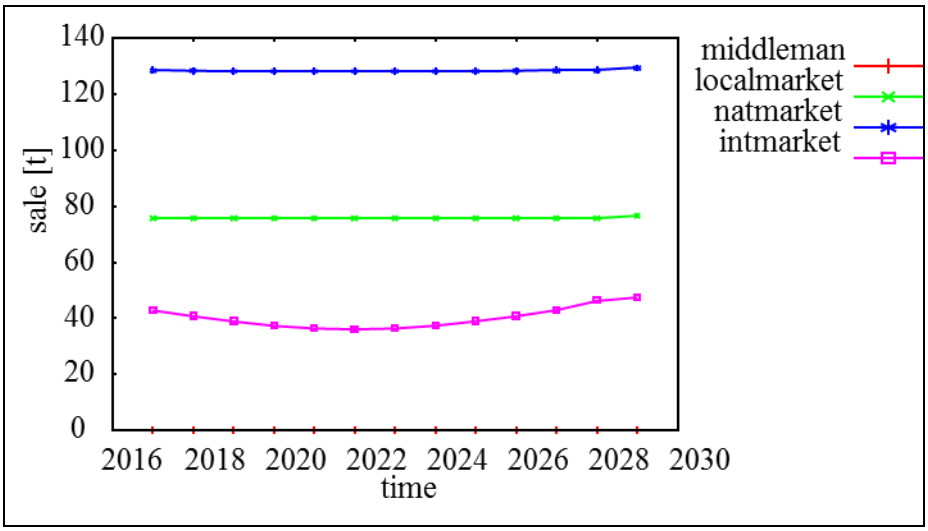

Figure 4-6: Sale of the products depending on the buyer

4.3.4 Environmental benefit

Economic activities of forest community inhabitants are linked to forest conservation. In all assessed scenarios, the harvesters of SSFESR are obliged to collect NTFP sustainably. We

assume that the regular monitoring of the forest territory prevents illegal logging. The more forest territory is covered by the harvesters, the larger is the monitored and conserved forest region.

Year	Forest Conservation [ha]	Avoided Emissions [tC]
2019	3268	843164
2024	3258	840477
2029	3371	869701

Table 4-5: Environmental benefit (forest conservation in [ha], avoided emission in [tC])

The total forest territory which can be conserved as the result of these investments and the total carbon emissions which can be avoided through the activities of the SSFESR are presented in Table 4-5. As the number of harvesters increases, more forest territory is involved in economic activities leading to more forest preservation and fewer carbon emissions. By the year 2029 over 3370ha of forest can be conserved and over 860000 tC emissions can be avoided (Table 4-5).

4.4 Sensitivity analysis

After analyzing the optimal solution with unlimited funding (4.3.1, 4.3.2, 4.3.3, 4.3.4), we explore various scenarios with limited investments. The goal is to investigate which outcomes can evolve with much lower investments than calculated in the base scenario but also to explore the sensitivity of the model with regard to changes in the investment volumes and carbon prices.

4.4.1 Investments

While looking at these three investment scenarios, we see that investments are made very differently regarding the investment limits (Figure 4-7). The carbon prices play a minor role for investment decisions inside the respective scenarios. As also presented in the base scenario (Section 4.3.1), most of the investments are made towards the processing facilities leading to the creation of working places for women and higher income as the selling prices for processed products can become tenfold compared to the unprocessed ones, see Section 4.2.3 for data.

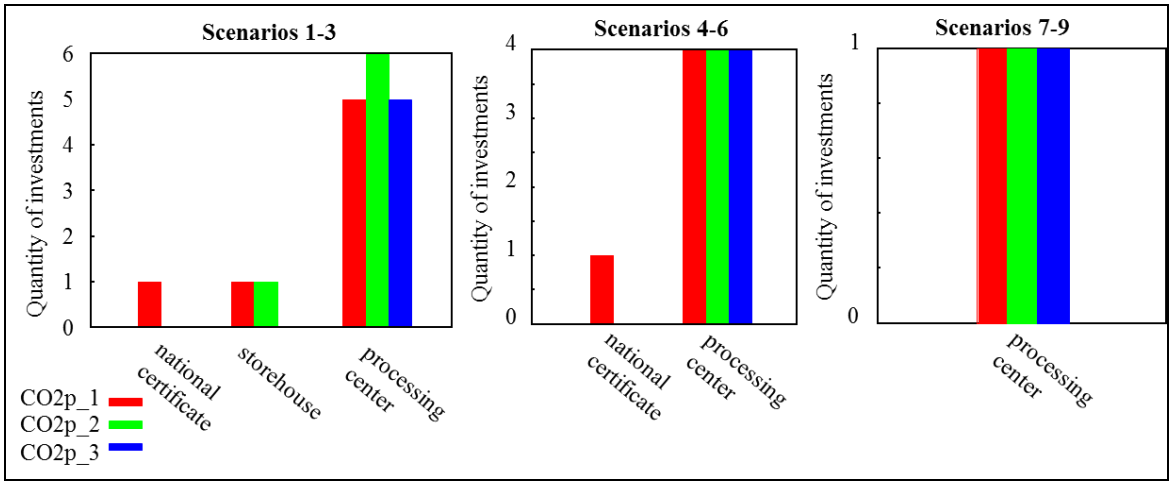

Figure 4-7: Investments allocation into assets according to scenarios and carbon prices

Once the investments are made and the working places established the difference in the social, environmental and economic benefits over time varies minimally. For that reason and in terms of simplicity, we present the model outcomes of the scenarios for the years 2019, 2024, and 2029.

4.4.2 Social benefit

The amount of established working places for women vary for the time frame between 2017 and 2030 in the range between 279 and 324 for women and between 64 and 69 for men for the scenarios 1-3, in the range between 208 and 254 for women and between 64 and 68 for men for the scenarios 4-6 and between 70 and 71 for women and between 63 and 68 for men in the scenarios 7-9 (Figure 4-8). For the scenarios 1-6, the lowest carbon price of 33USD (Cp_1) seems to be the most profitable one establishing around 40 working places more for women inside the processing center compared to the carbon price of 66USD (Cp_2).

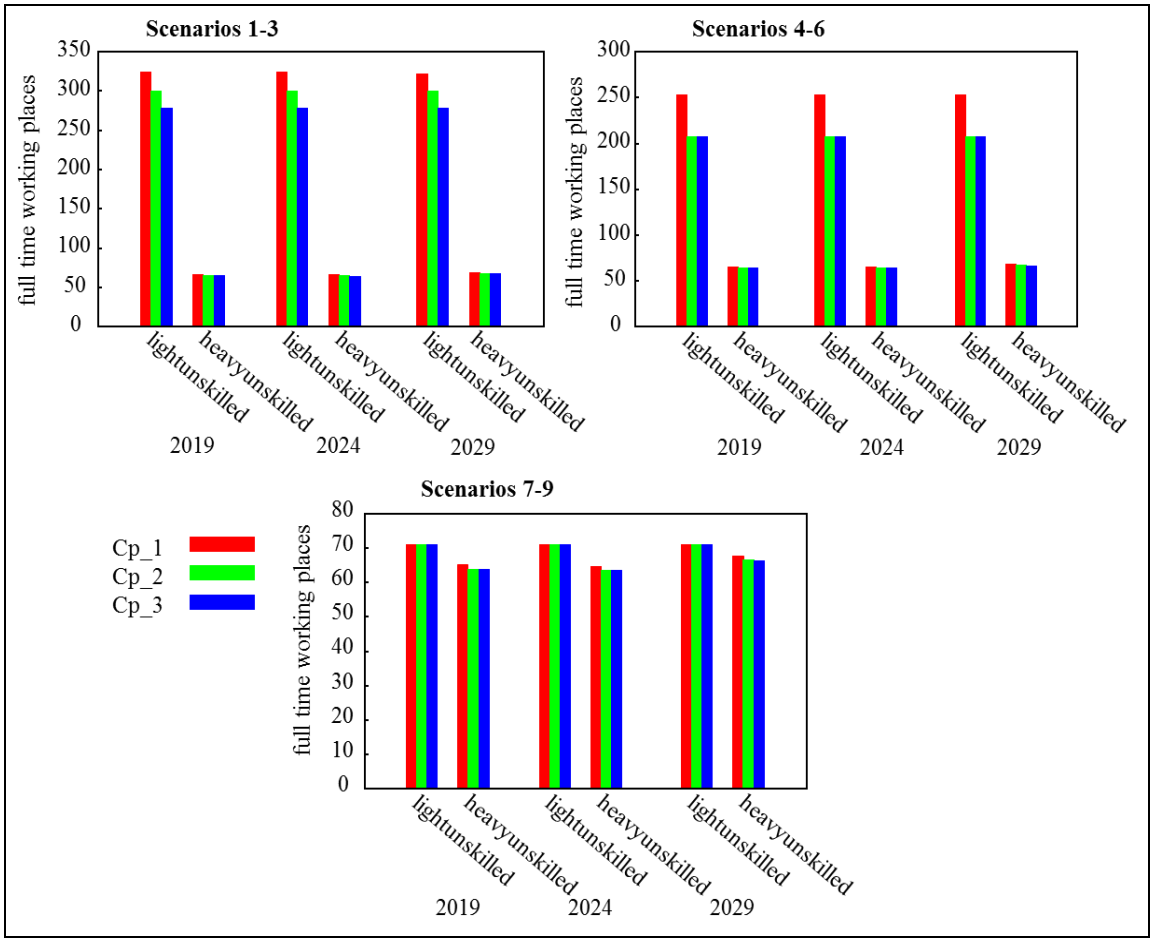

Figure 4-8: Working places according to the funding volume and carbon prices

4.4.3 Economic benefit

As storage room construction is suggested only for the scenarios 1-3, the sale of the products during the non-harvesting season happens exclusively in this scenario (Figure 4-9). The sale quantity varies minimally over time. The carbon price of 66USD/tC induces the highest sales quantity for NTFP.

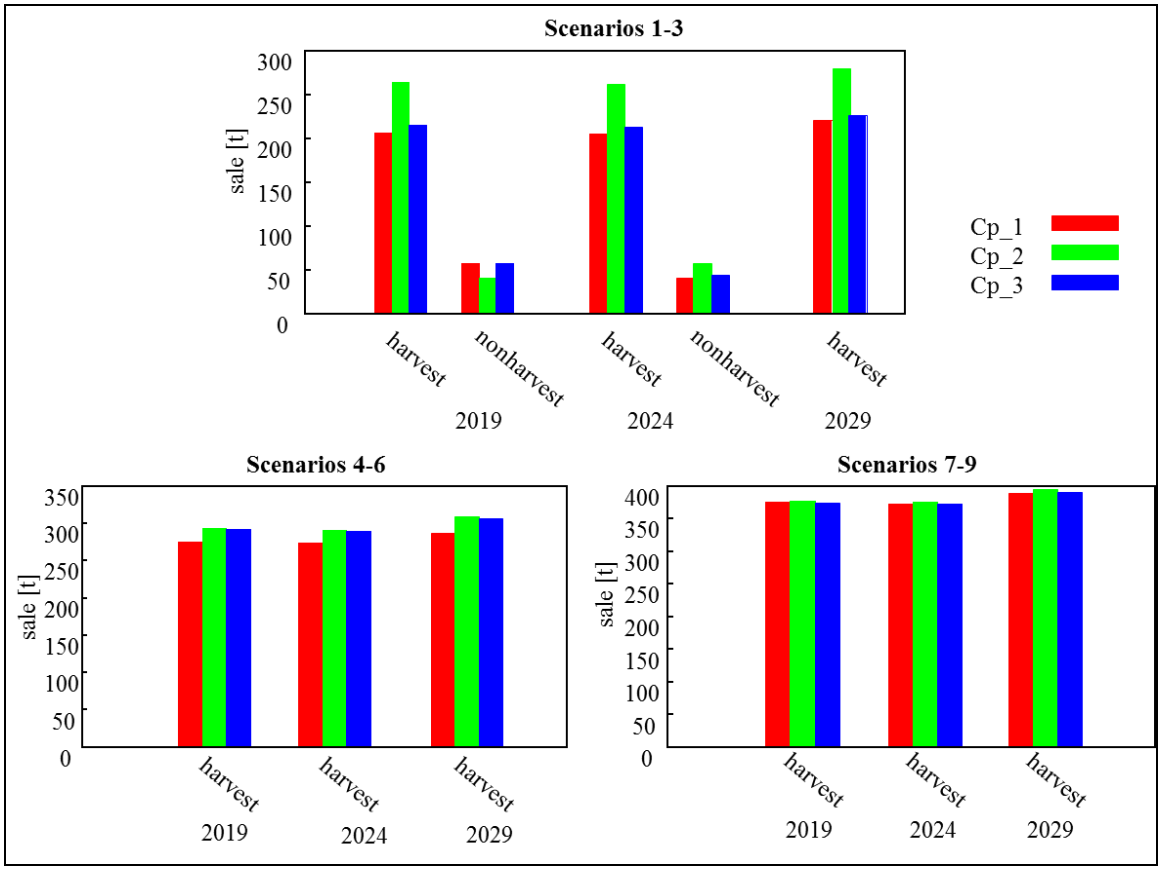

Figure 4-9: Sale quantity according to the harvesting or non-harvesting season

Although there is a serious investment difference between the scenarios 4-6 (57000USD) and 7-9 (19000USD), the amount of sold products exceeds in the scenarios 7-9 the scenarios 4-6 by almost 100t. This is because in the scenarios 7-9 the products are mostly sold unprocessed (Figure 4-10) which requires less working hours also bringing less income to the workers. The lower quantity of the sold products in the scenarios 1-6 lead to a higher income of over 70Mio USD for the scenarios 1-3 and to an income increase of over 30 Mio USD in the scenarios 4-6 over the 13 year period (2017-2030) if compared to the scenarios 7-9. The number of processing facilities, the national certificates, and the possibility to store products in the scenarios 1-3 lead to an essential income increase from the sale of the products.

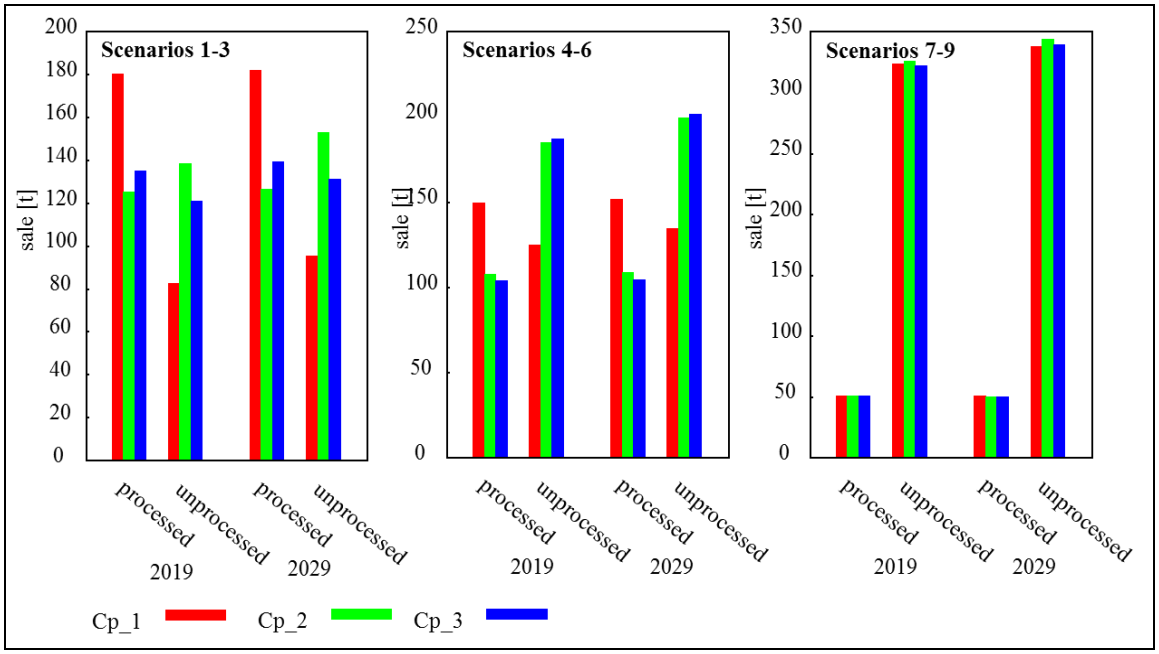

Figure 4-10: Sale of raw and processed products depending on the investments volume and carbon prices

With the higher funding volume, there are more options to choose the market for the produced products as in the case of scenarios 1-6 a certificate for national sales has been made. Despite the availability of the national certificate in the scenarios 1-6, the model suggests the sale of the products mostly to the local market and the middlemen especially after the year 2019 (Figure 4-11). The higher the funding, the more the model decides to sell to other buyers rather than to the middlemen.

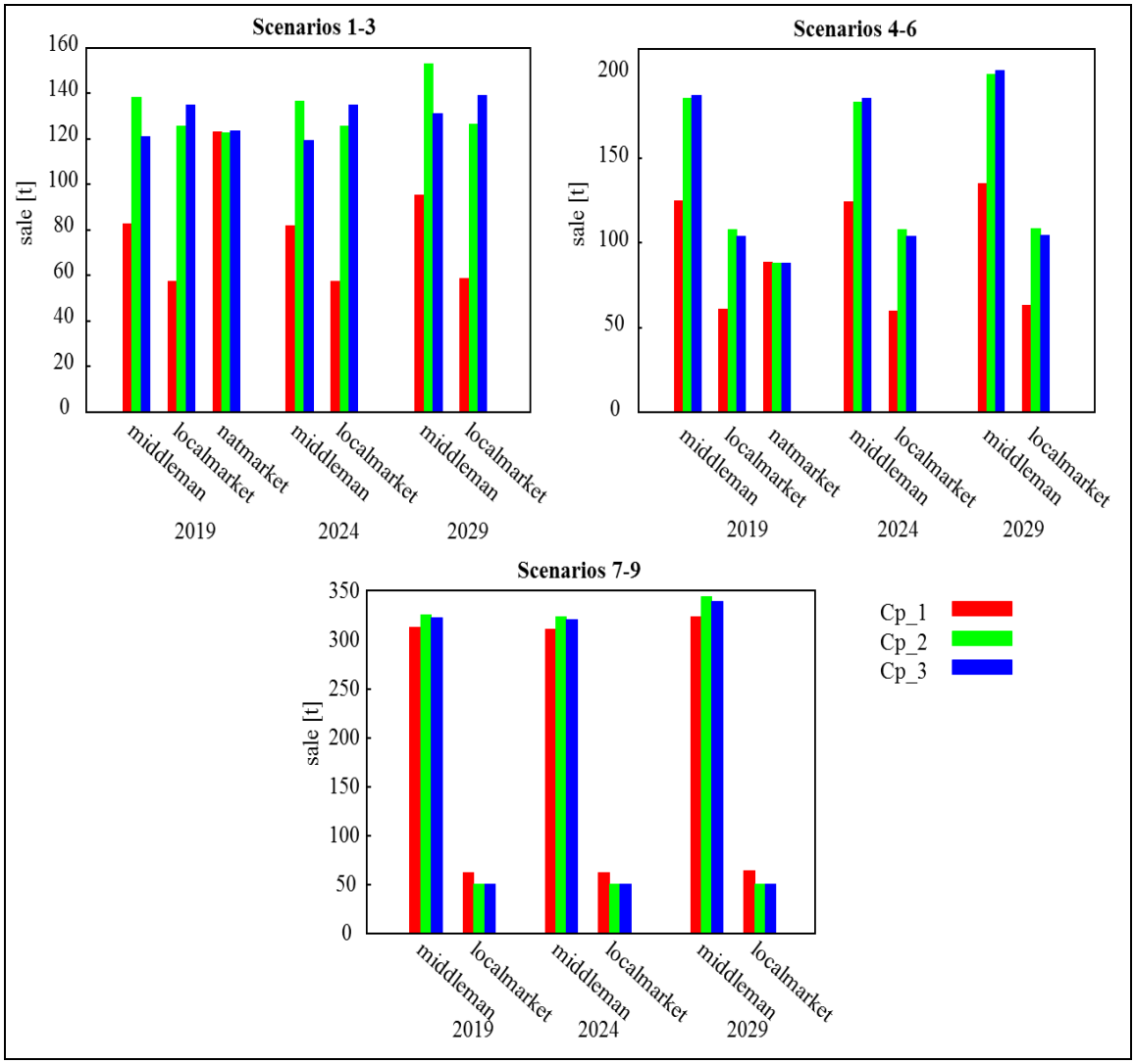

Figure 4-11: Sale of the products according to the buyer: middlemen, local market, and national market (no international sales are present)

4.4.4 Environmental benefit

The environmental benefit varies very little across different scenarios. The carbon price plays a limited role in increasing the avoided emissions in the range between 958400 tC and 1030000 tC for the scenarios 1-3, in the range between 976800 tC and 1032700 tC for scenarios 4-6 and between 982000 tC and 1033700 tC for the scenarios 7-9. The carbon price (Cp_2) of 66USD together with the carbon price (Cp_3) of 100USD leads to the highest amounts of avoided emissions (Figure 4-12).

The small investment within the scenarios 7-9 leads to the highest environmental benefits. The reason is that through the lower availability of processing facilities in the scenarios 7-9, the workers' income is dependent on the harvest and sale of the raw products. The harvesters

are willing to overcome longer distances for the collection of products as their income mostly depends on the sale of raw products.

According to the model, the investment in scenarios 7-9 is sufficient for the motivation of the same amount of harvesters as in the scenarios 1-6.

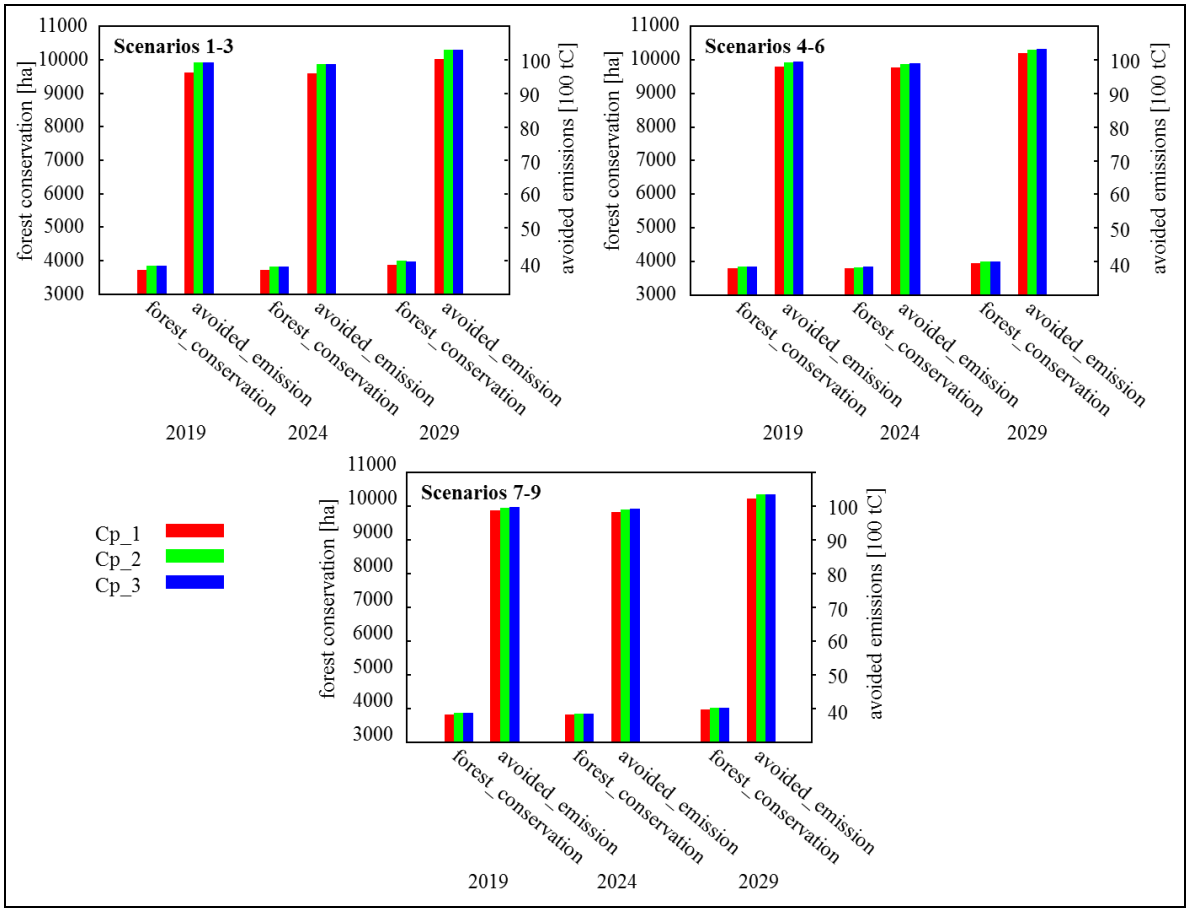

Figure 4-12: Forest conservation and avoided emissions in regard to the scenarios and various carbon prices

4.5 Discussion and conclusion

There is a need to increase the revenue from NTFP, abreast with the revenue from forest products such as wood and carbon in order to sustain the livelihood of forest communities and to make the standing forest competitive to agricultural land (Sutcliffe, Wood, & Meaton, 2012). The establishment of SSFESR and the OIFC model simulations show that investments into the establishment of SSFESR in forest communities lead to the increase in working places and in conserved forest territory. Humphries et al. (2012) and Rahman et al. (2012) show up to 12% rates of return on investments in community-based forest enterprises.

The investments into the presented SSFESR do not pay-off during the 13 years of running the model (2017-2029). The main objectives of the SSFESR are not the economic returns on investments but rather the environmental and social benefits. These non-market benefits are especially important for tropical forest communities. In these regions, community inhabitants often depend on governmental support in the form of various welfare payments. The international community is willing to provide payments for ecosystem services. These causes make the establishment of SSFESR reasonable from the social as well as the environmental perspectives. The SSFESR represent an attractive mitigation option as the costs for carbon sequestration equal to 0,12USD/tC for the scenarios 1-3, 0,07USD/tC for the scenarios 4-6, and 0,02USD/tC for the scenarios 7-9. For comparison, according to IPCC (2014) the mitigation costs to effectively support the 2°C goal vary between 300USD/tC an 400USDUSD/tC (IPCC, 2014a).

Our model results show that depending on the set goals of the policy makers already an investment of 50USD per household leads to the establishment of 65 working places for men and to 75 working places for women. For comparison, the investments of 150USD per household lead to the creation of 253 working places for women but also to 65 working places for men. On the one hand, the investment of 50USD per household is sufficient to conserve the same forest territory as in the scenarios of twice or thrice as high investments. On the other hand, larger investment volumes lead to an essentially higher amount of female working places inside of processing facilities. Investments into the sustainable development of the economic activities of forest communities can increase the income of local inhabitants from the sale of processed NTFP, expand the range of activities, increase the forest area covered through the monitoring, and also create new jobs and decrease the level of poverty. Sustainable economic activity can simultaneously address social, economic and environmental objectives. Once the harvesters and processors are legally registered as the SSFESR workers, they receive a legal status. This legal status provides more rights and possibilities for improving the health care provision, education facilities, infrastructure, etc. inside the community.

The development of SSFESR requires investments and socially oriented assistance. Our model can be a tool for policy-makers on well-founded decisions about allocation of investments into the development of social enterprises inside of forest communities.

5 SUMMARY, CONCLUSIONS AND OUTLOOK

5.1 Summary and conclusions

Tropical forests play an essential role in climate change mitigation. At the same time, there are around 1.2 billion people worldwide who live in poverty, mainly and directly depend on the tropical forests and obtain a significant part of their livelihood from NTFP. The aim of this thesis is to answer the question of how non-destructive forest use and poverty alleviation can be achieved in tropical forest communities simultaneously.

Brazil and India are chosen as the two research sites for this work. Brazil is selected as it has the largest area of tropical forests in the world and experiences one of the highest rates of deforestation. India is chosen as the second research site as it has the largest number of the poor in the world with around 275 million people living in and around forest areas.

The 2nd chapter of this thesis with the title "*Analysis of the Changes in Economic Activities of Brazilian Forest Communities after Methodical Support and Provision of Pre-Financing Capital"* presents the field research results of economic activities in two forest communities of Rondônia, Brazil. In this chapter the results of a longitudinal economic experimental research are described which has been initiated in the year 2008. For this research, the emphasis is made on Brazil Nut as a unique NTFP which is primarily collected from the wild, and which optimal natural regeneration depends on an intact and healthy ecosystem.

A team of Brazil Nut harvesters has been organized and a harvesting strategy has been developed with the provision of pre-financing capital for the stock creation of Brazil Nuts. There were three interventions with the pre-financing capital limits of 2.470USD in the first intervention, 2.200USD in the second, and 11.600USD in the third one.

The analysis of this experiment suggests that through organizational support and pre-financing, Brazil Nut harvesters are able to organize, to increase their income, to manage and conserve the forest territories sustainably, and to rediscover abandoned forest areas. Interdependency can be identified between the external support continuity, the size of pre-financing capital, the number of participants, their income as well as the size of managed forest territory. Clear land tenure as well as technical, organizational and marketing assistance are identified as essential throughout the first years of intervention.

Although the conclusions of these pre-financing interventions are only valid for the described Brazilian forest communities, an aim is to compare the presented results to similar interventions in other tropical forest regions.

In the 3rd chapter with the title *"Requirements for the Sustainable Development of Economic Activities in Tropical Forest Communities"*, the local research results of the two analyzed Brazilian forest communities (Chapter 2) are compared to the research results of the global Poverty and Environment Network (PEN) study organized by the Centre for International Forestry Research (CIFOR) with analyzed 334 forest villages from 24 tropical forest countries of Asia, Latin America and Africa.

The aim is to abstract from the case study of the two presented Brazilian forest communities in Chapter 2 and to develop a global concept of how sustainable development can be applied to the economic activities of tropical forest communities leading to the improvement of the communities' living standard and conservation of tropical forests. After formalizing qualitative causal relations it can be concluded that sustainable development in forest communities cannot be achieved without 1) legal rights for forest management, 2) targeted investments and initial capital for the organization of economic activities with ecological and social responsibility, and 3) organizational, technical, and methodical support.

As the result, the compatibility of the forest communities' realities with the theoretical concept of the sustainable development can be analyzed and the concept of the Small Scale Forest Enterprise with Social and Ecological Responsibility (SSFESR) is introduced. The SSFESR is defined as an enterprise managed and employed by indigenous and other local forest communities, which is aimed at making profit from sustainable harvesting, processing and trade of Non Timber Forest Products (NTFP) and sustainable timber management practices. Social and ecological responsibility within the SSFESR describes the need for conserving tropical forests and for raising the living standards of forest communities' inhabitants. As a consequence of the SSFESR, the following benefits can be achieved: An environmental benefit through the forest conservation and forest monitoring, an economic benefit through the increase of income, and a social benefit through the creation of working places, poverty alleviation, infrastructure development, and the professional training.

In the 4th chapter of this thesis with the title *"Investments in Tropical Forest Community Enterprises for Livelihood Creation and Climate Change Mitigation"*, the aim is to make a quantitative assessment of the ecological, social, and economic returns on investments into the development of the SSFESR. In order to achieve this goal the Optimal Investment Forest

Conservation and Livelihood Creation Model (OIFC) is developed 1) which determines the environmental and social benefits of investments into enterprise development in forest communities and 2) mathematically formalizes the interdependencies between these investments, the forest conservation, and the poverty alleviation. The OIFP is able to estimate the conserved forest area, the required number of workplaces, and the income generated from work inside the enterprise depending on the investments into the SSFESR. The model uses data from a case study of the Indian Banglapadigai region with 380 households with a focus on five NTFP.

It can be concluded that depending on the set goals of the policy makers already an investment of 50USD per household leads to the establishment of 65 working places for men and to 75 working places for women. For comparison, the investments of 150USD per household lead to the creation of 253 working places for women but also to 65 working places for men. On the one hand, the investment of 50USD per household is sufficient to conserve the same forest territory as in the scenarios of twice or thrice as high investments. On the other hand, larger investment volumes lead to essentially higher amount of female working places inside of processing facilities.

Investments into the sustainable development of the economic activities of forest communities can increase the income of local inhabitants from the sale of processed NTFP, expand the range of activities, increase the forest area covered through the monitoring, and also create new jobs and decrease the level of poverty. Sustainable economic activity can simultaneously address social, economic and environmental objectives. The OIFC model can become a tool for policy makers for well-founded decisions on allocation of investments into the development of social enterprises inside of forest communities.

The overall importance of this thesis can be considered from the viewpoint of three Sustainable Development Goals including poverty alleviation, sustainable communities' development, and sustainable forest management. As the result of this research, it is substantiated that investments as well as human and social capital are required for the organization of the sustainable development of economic activities in tropical forest communities. Sustainable economic activities inside of tropical forest communities can solve the environmental, social and economic challenges of the region. Environmental and social benefits of the international community while investing into the development of SSFESR are the conservation of tropical forests for future generations and a contribution to climate and biodiversity stabilization.

5.2 Outlook

Further research is required to present the net benefits and the required investments into the development of SSFESR worldwide in tropical forest regions. This includes the identification of the total required amount of investments, the total possible forest territory which can be conserved with these investments and the number of established working places. Another task is to compare the outcomes of this method with other forest conservation methods such as protected areas etc. in regard with the total amount of investments, total conserved forest territory and working places establishment.

A natural next step is the development of an algorithm for political decisions on allocation of investments into the sustainable economic activities in tropical forest communities on the basis of a mathematical model. For the actual implementation of the proposed concept, a political decision of the upper power echelons and in the field are of essence.

Reducing the tropical forest deforestation and degradation together with the livelihood creation in poor regions is an extremely challenging undertaking. The past research has constantly contributed to the solution development for these challenges. This thesis is one further contribution.

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APPENDICES

Annex 1: Letter from Mr. Pralong Dumrongthai, Director of the Bureau of Community Forest Management from the Royal Forest Department of Thailand

Royal Forest Department
Bureau of Community Forest Management

15th of November 2012 Bangkok, Thailand

Protocol of the scientific meeting

Present were:

Mr. PralongDumrongthai	Director of the Bureau of Community Forest Management, Royal Forest Department
Mrs. NantanaBoonyananta	Director of Community Forestry Development Division,Community Forest ManagementBureau, Royal Forest Department
Mrs. Elena Mechik	Doctoral Candidate, Research Unit Sustainability and Global Change, University of Hamburg, Germany

Presentation by Dipl.-Ing. Elena Mechikto the topic "Economic Incentives for Sustainable Tropical Forest Maintenance"

Short summary of the presentation:

1. Importance of tropical forests in climate stabilization and atmospheric balance maintenance. Role of governments and international organizations in tropical forests' protection.

2. Studies of economic activities in forest communities of the Amazon region, Brazil and of Madhya Pradesh region, India. Studies identified common trends in stimulating tropical forest protection by local inhabitants.

3.Based on her research, Dipl.-Ing. Elena Mechik under supervision of Prof. Dr. Hermann Held and Dr.Uwe Schneider, University of Hamburg, Germany has developed a mathematical model of small scale forest enterprises with social responsibility. Such a model can be used by policy makers for investment decisions into the development of economic activities of forest communities. The result of this model's calculations will forecast the efficiency of investments into community development, forest protection and the creation of new jobs as a step towards poverty alleviation.

4.A complex of economic activitieshas been proposed with the goal of motivatingforest communities' inhabitantsto tropical forest preservation. The conclusion was that solution to the challengeof tropical forest preservationis only possible onthe basis of governmental policydecisionsand international organizations.

5.The possibilitiesof involving the publicto the challenge of tropical forest preservation, the ideaof the environmentalmissionary, and international cooperation were discussed.

Concluding discussion after the presentation:

During the scientific meeting, it was noted that there were trends in the economic activities of forest communities of different world regions and the need in economic incentives for empowering communities' inhabitants in forest protection. The importance of internationalcooperation inthe preservation and maintenance of tropical forests has been mentioned.It was noted that Dipl.Ing.ElenaMechik'sapproach to economic analysisbased onmathematical modeling has a scientific novelty.

Resulting words after the discussion:

Research of Dipl.-Ing.ElenaMechikis considered as relevant and useful, and it isrecommended to continue it.

Director of the Bureau of Community Forest Management

Mr. PralongDumrongthai

Annex 2: Letter from Dr. Barbara Hendricks, the German Federal Minister for the Environment, Nature Conservation and Nuclear Safety

Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

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Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 11055 Berlin

Frau
Dipl.-Ing. Elena Mechik
Forschungsstelle Nachhaltige Umweltentwicklung
Universität Hamburg
Grindelberg 5
20144 Hamburg

Dr. Barbara Hendricks
Bundesministerin
Mitglied des Deutschen Bundestages

TEL +49 3018 305-2000
FAX +49 3018 305-2046

maileingang@bmub.bund.de
www.bmub.bund.de

Berlin, 27. Juli 2016

Sehr geehrte Frau Mechik,

vielen Dank für Ihr Schreiben vom 6. Juli 2016, mit dem Sie an unser Gespräch bei der Eröffnung des Kompetenzzentrums Naturschutz und Energiewende anknüpfen und Ihr interessantes Projekt zum wissenschaftlichen Ökotourismus in Waldgemeinden der Entwicklungsländer vorstellen.

Die Internationale Klimaschutzinitiative (IKI) des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) finanziert Klima- und Biodiversitätsprojekte in Entwicklungs- und Schwellenländern sowie in den Transformationsstaaten. Das BMUB veröffentlicht in der Regel jährlich im Frühjahr einen Aufruf, Projektskizzen (Ideenwettbewerb) einzureichen, sowie die dazugehörigen Förderinformationen (https://www.international-climate-initiative.com/fileadmin/Dokumente/2016/F%C3%B6rderinformation_IKI-Auswahlverfahren_2017.pdf).
Sie können dort sehen, ob und inwieweit Ihre Projektidee generell mit den Förderprioritäten der IKI – etwa im Förderbereich Biodiversität – im Einklang steht. Allerdings lief die Einreichungsfrist für das aktuelle Auswahlverfahren bis Anfang Juni 2016. Daher besteht kurzfristig keine Möglich-

Zustelladresse: Robert-Schuman-Platz 3, 53175 Bonn, Lieferadresse: Stresemannstraße 128-130, 10117 Berlin
Verkehrsanbindung: Potsdamer Platz, S-/U-Bahn: S1, S2, U2, Bus: 200, M41, M48

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keit, diese Idee im Rahmen der IKI aufzugreifen. Die nächste Förderinformation ist für das Frühjahr 2017 geplant, die zusammen mit dem Projektaufruf voraussichtlich im März 2017 veröffentlicht werden wird.

Eventuell kommen für Sie aber auch andere Fördermöglichkeiten in Betracht, etwa über die Angebote des Bundesministeriums für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), das im Rahmen seiner Zuständigkeit für die Entwicklungszusammenarbeit auch Projekte zum nachhaltigen Tourismus in Entwicklungsländern fördert, (https://www.engagement-global.de/vereine-und-organisationen.html) oder des Bundesministeriums für Bildung und Forschung (BMBF).

Für Ihr Projekt und die Organisation des wissenschaftlichen und sozial orientierten Ökotourismus in Waldgemeinden der Entwicklungsländer für deutsche und internationale Universitäten wünsche ich Ihnen viel Erfolg.

Mit freundlichen Grüßen

Rebecca Hendricks

Annex 3: Confirmation letter of the 2nd place in the Seed for Change Competition, South Asia Institute, Harvard University

24 January 2017

To whom it may concern:

The Harvard University South Asia Institute (SAI) engages faculty and students through interdisciplinary programs to advance and deepen the teaching and research on global issues relevant to South Asia. Every year we organize the Seed for Change Competition which aims to develop a vibrant ecosystem for innovation and entrepreneurship in India and Pakistan.

This letter is to confirm that Lena Mechik and Aaron Mendonca participated in the 2016 Seed for Change Competition. Their entry, The Craftsmen, is a small forest enterprise facilitator that creates new value chains, provides year-round employment, and trains communities in sustainable harvesting practices. The Craftsmen placed second and received initial funding of $5000.

If you have any questions, please contact Nora Maginn, the SAI Senior Program Manager, at maginn@fas.harvard.edu.

Best,

Nora Maginn
Senior Program Manager, Harvard South Asia Institute

Harvard South Asia Institute

1730 Cambridge Street, Cambridge MA 02138

EIDESSTATTLICHE VERSICHERUNG

Hiermit erkläre ich an Eides statt, dass ich die vorliegende Dissertationsschrift selbst verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Hamburg, den 01.03.2017 Unterschrift

DECLARATION

Elena Mechik, born in Rostov on Don, Russia, the 16th of March 1985:
I hereby declare my share in the authorship of the chapters 2, 3, and 4 contained in the submitted dissertation, which are respectively published in a scientific journal or in preparation for submission, as follows:

Chapter 2 (first author, 4 authors in total):
Mechik E, von Hauff M, de Moura LHL, Held H. 2017. *Analysis of the Changes in Economic Activities of Brazilian Forest Communities after Methodical Support and Provision of Pre-Financing Capital.* Journal of Tropical Forest Science, 29(2). (Accepted for publication in April 2017)

Task list and degree of involvement by the co-authors:

Development of the topic:	Mechik E. (completely).
Literature review:	Mechik E. (completely).
Data collection:	Mechik E. (predominantly), de Moura L.H.L.
Development of the methods:	Mechik E. (completely).
Design of the experiments:	Mechik E. (predominantly), de Moura L.H.L.
Review of the results:	Mechik E. (predominantly), von Hauff M., de Moura L.H.L., Held H.
Manuscript:	Mechik E. (predominantly), von Hauff M., de Moura L.H.L., Held H.

Chapter 3 (first author, 2 authors in total):
Mechik E, von Hauff M. 2016. *Requirements for the Sustainable Development of Economic Activities in Tropical Forest Communities.* European Journal of Sustainable Development, 5(4), 107–120. https://doi.org/10.14207/ejsd.2016.v5n4p107.

Task list and degree of involvement by the co-authors:

Development of the topic:	Mechik E. (completely).
Literature review:	Mechik E. (completely).
Data collection:	Mechik E. (completely).
Development of the methods:	Mechik E. (completely).
Review of the results:	Mechik E. (predominantly), von Hauff M.
Manuscript:	Mechik E. (predominantly), von Hauff M.

Chapter 4 (first author, 3 authors in total):

Mechik E, Schneider UA, Ramachandran A. *Investments in Tropical Forest Community Enterprises for Livelihood Creation and Climate Change Mitigation.* (In preparation)

Task list and degree of involvement by the co-authors:

Development of the topic:	Mechik E. (completely).
Literature review:	Mechik E. (completely).
Data collection:	Ramachandran A. (predominantly), Mechik E.
Development of the methods:	Mechik E. (completely).
Design of the experiments:	Mechik E. (completely).
Programming:	Schneider U.A. (predominantly), Mechik E.
Review of the results:	Mechik E. (predominantly), Schneider U.A., Ramachandran A.
Manuscript:	Mechik E. (predominantly), Schneider U.A., Ramachandran A.

The other chapters included were completely written by the first author of the thesis.

Hamburg, 01.03.17

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