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ASSESSING THE RESILIENCE OF THE PALM OIL VALUE CHAIN TOWARDS DROUGHT AND FLOODING IN SABAH, MALAYSIA

MASTER THESIS

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Executive Summary

Palm oil is a globally traded cash crop. Its demand is increasing because of its flexible processing characteristics for food and non-food items. Nine percent of the global supply of palm oil is produced in Sabah, one of the thirteen states of Malaysia. The palm oil industry is the third biggest contributor to the economy of Sabah, and 87% of Sabah's agricultural land is cultivated with oil palm. The palm oil industry in Sabah is frequently exposed to shocks and disturbances, for example, flooding events are common and may hinder the harvesting of fresh fruit bunches and transportation of palm oil products. In 2015/2016, the industry experienced a severe drought, which caused the palm oil production to drop by 14% in 2016 compared to the average of the previous ten years. Thus, the question arises to what extent the stakeholders in the industry are able to deal with these shocks.

This study assessed the resilience of the palm oil value chain in Sabah with regards to drought and flooding. The methodological approach of this study is based on the resilience guidelines, which have been developed by the SAE group at ETH Zurich. This method takes a qualitative and holistic approach and sets a strong focus to include stakeholders throughout the research process. Thus, data was collected through literature research, stakeholder interviews and interactive workshops.

Overall, the resilience of the palm oil industry in Sabah is relatively high, whereby the resilience towards flood events is higher compared to drought events. Companies engaged in planting, milling and refining show the highest resilience in the palm oil value chain. One of the main reasons for their high resilience score is that palm oil has been highly profitable; therefore, these actors could invest into management structures, financial capacity and education. Transport companies and input trading companies displayed a lower resilience than plantation and processing companies. For example, they struggled from a decline of sales and orders during the recent drought. This caused lower profits. Smallholder farmers have the lowest resilience because their ability to react and recover from shocks is low. The reason is inadequate management practices, low knowledge levels, insufficient access to information and low financial capital.

To build resilience in the palm oil value chain in Sabah towards drought, industry stakeholders proposed higher investments into soil conservation practices and improved water management practices. Furthermore, industry players, especially smallholder farmers and medium-sized plantations, consider the diversification of their income sources to reduce their dependency on oil palms.

Acknowledgement

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Finally, I owe my deepest gratitude to my family and friends, who continuously encouraged me and believed that I could complete this thesis. I am so thankful for being on the same journey with you.

Initial Proposal

Assessing the resilience of the palm oil value chain in Sabah, Malaysia
25.08.2016

Background

Palm oil is one of the most important vegetable oils globally since it bears relatively high yields per hectare (3.7 t/ha compared to 0.47 t/ha for example soybean oil) with low input costs (Oosterveer, 2015). Due to its flexible processing characteristics, palm oil is used for several purposes such as food, cosmetic items and biodiesel (Oosterveer, 2015). Because of its popularity, the palm oil sector has experienced rapid expansion globally, whereby over 85% of the global production is located in Malaysia and Indonesia (MPOB, 2011; Sabah Forestry Department, 2015). In Malaysia, palm oil has been significantly supported by the Malaysian government and counts as the 4th largest contributor to the national economy (Ludin et al., 2014; Teoh, 2010). One of the prominent palm oil regions is Sabah, a Malaysian state on Borneo island, where around 30% of Malaysian palm oil is produced (Sabah Forestry Department, 2015). Sabah is a partly autonomous state of Malaysia, whereby it is own parliamentary assembly and head of states, hence it can be considered as an own entity in regard to the local palm oil value chain. Palm oil production in Sabah has resulted in higher incomes and secure employment, nonetheless issues about land rights of indigenous communities have been raised (Dayang Norwana et al., 2011). In addition, recurring El Niño events have severely affected the palm oil yields in Malaysia in the past years (Ng Lee Fang, 2015). Furthermore, palm oil has been a controversially discussed topic due to a number of ecological-related issues such as soil erosion (Oosterveer, 2015). Such challenges and trends are likely to disrupt the proper functioning of the palm oil value chain in Sabah and may lead to adverse outcomes. This leads to the ultimate question: "how resilient is the palm oil value chain in Sabah, Malaysia and how can resilience be built up in this value chain"?

By adopting the concept of resilience, and in particular the SAE (Sustainable Agroecosystems Group at ETH Zurich) resilience guidelines, the strength and weaknesses of each value chain process to deal with sudden disruptions (shocks) can be assessed, apart from providing an assessment tool for measuring resilience for each process level within a value chain, the guidelines also offer a structured approach from problem identification, system definition, assessment and building of resilience. Through the active involvement of representatives from all parts of the value chain as well as local experts and governmental stakeholders, the SAE resilience approach is participatory-based and allows for a holistic understanding of how a system, such as the oil palm value chain in Sabah, functions. The strength from each value chain actor is sought to be supportive of developing innovative interventions for building resilience.

Objectives

- To assess the resilience of the oil palm value chain in Sabah, Malaysia
    - Application of the SAE resilience guidelines (problem identification, system definition, resilience assessment, resilience building)

Research Questions

- What is the resilience degree of the palm oil value chain in Sabah, Malaysia?
- Which interventions can increase the resilience of the palm oil value chain in Sabah, Malaysia?

Methodology

- The research will be conducted based on the SAE guidelines to assess and design interventions for food system resilience:
    - Identification and framing of problem
    - Stakeholder analysis
    - Mapping the system (material flow, financial flow, information flows, spatial distribution of value chain)
    - Identification of main drivers
    - Resilience assessment
    - Identification of interventions to build resilience

Expected results

- A fundamental understanding of the resilience of the palm oil value chain in Sabah, Malaysia
- Identification of interventions for resilience building
- Building of resilience of the palm oil value chain through stakeholder interaction
- Strengthened partnership between SAE Group at ETH Zurich and TFT

Work plan

Date	**Place**	**Activity**	**Guideline Step**
01. August – 10. October 2016	Zurich	Literature research, elaborate research proposal, study methodology, planning of field trip	1,2
10. October – Beginning of December 2016	Malaysia	Field trip: Stakeholder interviews, resilience assessment	2,3
Beginning of December 2016	Malaysia	Stakeholder workshop	4
Mid of December – End of February 2016	Zurich	Data analysis, thesis writing	3,4
28. February 2016	Zurich	Submission of thesis	

Declaration of Originality

ETH

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Abbreviation

CPKO	Crude palm kernel oil
CPO	Crude palm oil
DOBI	Deterioration Of Bleachability Index
DOSH	Department of Occupation Safety and Health
EFB	Empty Fruit Bunches
EPD	Environmental Protection Department
EMPA	East Malaysian Planters Association
FFA	Free fatty acid
FFB	Fresh fruit bunches
GST	Goods and Services Tax
ISCC	International Sustainability and Carbon Certification
NGO	Non-governmental organisation
MPOA	Malaysian Palm Oil Association
MPOB	Malaysian Palm Oil Board
POME	Palm oil mill effluent
RM	Malaysian Ringgit
RSPO	Roundtable on Sustainable Palm Oil
SAE	Sustainable Agroecosystem
SES	Socio-ecological system(s)
TFT	The Forest Trust

1 Introduction

1.1 Background

The global population has experienced a rapid increase in the past years, and it is predicted to reach around 9 billion people until 2050. In addition, the per capita consumption of food is rising due to higher income levels of consumers (Godfray et al., 2010; McKenzie & Williams, 2015). Consequently, global food production is required to double to meet the increasing demand until 2050 (Tilman et al., 2002). Despite the challenge that the increase in production poses on food systems, they are increasingly threatened by shocks and disturbances. Pest outbreaks, political crisis as well as climate change are disturbances that put pressure on food systems (Ericksen, 2008; Godfray et al., 2010; Liverman & Kapadia, 2012; Tendall et al., 2015). Hence, human well-being and ecosystem services are adversely affected by these shocks.

The concept of resilience has been seen as an approach to face the emerging risks and uncertainties of food systems (Tendall et al., 2015). According to Folke et al. (2010) resilience is the ability to "cope with uncertainty in all ways". Thus the concept of resilience aims to ensure well-functioning food systems to provide food security and other relevant function such as social welfare despite the disturbing events (Tendall et al., 2015).

One of the most important vegetable oils is palm oil, which accounts for 39% of the global vegetable oil production (MPOB, 2016). In the past 25 years, the consumption of oil palm has quadrupled, caused by the rise in the world population and their global wealth status (Lai et al., 2015). The reason for its successful expansion is found in its general low production cost compared to other vegetable oils and the high yields per hectare. According to Wahid et al. (2005) palm oil yields three to eight times more oil per hectare and year compared to other common tropical oils. The high favourability is also because of its flexible processing characteristics, which provides a broad range of applications from food items to non-food items like detergents and cosmetics as well as biodiesel (Corley, 2009; Lai et al., 2015; Oosterveer, 2015).

Hence, palm oil can be seen as a typical agro-food commodity and profitable cash crop that is being traded all over the world (Martin et al., 2015; Oosterveer, 2015). The largest importers of palm oil are Europe, China and India (MPOB, 2016), whereby 85% of the global palm oil production is located in two countries, namely Malaysia and Indonesia. Indonesia is the number one producer of palm oil with 33.6 million tonnes, followed by Malaysia with a yearly production of 19.96 million tonnes in 2015 (MPOB, 2016). Although Indonesia has the highest production, Malaysia has the lead in refining palm oil (Lai et al., 2015). In Malaysia, palm oil has been significantly supported by the Malaysian government and counts as the fourth largest contributor to the national economy (Ludin et al., 2014; Oosterveer, 2015; Teoh, 2010).

One of the prominent palm oil regions is Sabah, a Malaysian state in the North of Borneo island, where 29% of Malaysian palm oil is produced (MPOB, 2016). Sabah is a partly autonomous state of Malaysia. It has its own parliamentary assembly and ministers and has certain discretion to decide on political issues, including the palm oil industry. Over 1.5 million ha of palm oil plantation cover around 21% of the total land in Sabah and hence has a significant impact on the landscape, ecosystems and local communities (Department of Statistics, Malaysia, 2016). 78% of the palm oil production area is occupied by large-scale estates owned by private or governmental linked companies. The remaining 22% are

cultivated by independent and organised smallholder farmers (MPOB, 2016). Furthermore, the palm oil value chain in Sabah has an established processing and input supply sector.

However, the palm oil industry has been a controversially discussed topic in the past years, because of various social and environmental issues such as rainforest deforestation (Cramb & Curry, 2012; Oosterveer, 2015). The industry has also been facing a number of challenges and disturbances, from labour shortages to extreme climatic variability. The most recent event was the El Niño phenomenon in 2015/2016 that caused a severe drought over Sabah. Consequently, the total palm oil production decreased 14% compared to the previous ten years (MPOB, 2017). The counterpart of El Niño, the so-called La Niña phenomenon, has repeatedly caused excessive rainfall and flooding in various areas of Sabah. For example, a flood event in the year 2000 inundated around 10,000 ha of plantations along one of the largest rivers in Sabah over 20 days (Teoh et al., 2001).

Evidently, the production step of the palm oil value chain in Sabah has been affected by drought and flooding. However, it remains unclear how these disturbances influence the other stakeholders of the palm oil value chain and whether stakeholders have the capacity to overcome drought and flood events. This lead to the ultimate question on "how resilient is the palm oil value chain towards drought and flooding in Sabah, Malaysia?"

1.2 Problem statement

The palm oil industry in Sabah has experienced a severe drought in 2015/2016 and was exposed to several flood events in the past years. Such shocks have affected the different actors of the palm oil value chain in Sabah and lead to adverse economic, social and ecological outcomes.

1.3 Objectives

The objective of this master thesis is to assess the resilience of the palm oil value chain in Sabah, Malaysia, through applying the Sustainable Agroecosystems Resilience (SAE) resilience guidelines. The focus of the resilience assessment is on the resilience towards drought and excessive rainfall and flood events. The study also aims to build resilience actively through involving stakeholders in the research process.

1.4 Research questions

- What is the resilience of the palm oil value chain in Sabah towards drought and flooding?
- Which interventions can increase the resilience of the palm oil value chain in Sabah towards drought?

1.5 Methodology

The research was based on the SAE assessment guidelines to study the resilience of the palm oil value chain in Sabah and to design interventions to build resilience in this industry. The applied guidelines aim to assess the resilience of food systems through a stakeholder-based approach and in consideration of social, economic and environmental aspects. The used methodology is triangular, which combines secondary data from current research literature as well as primary data. The primary data was collected through semi-quantitative interviews with value chain actors and experts from industry associations, government representatives

as well as scientists. Additionally, two workshops were conducted to gather primary data. The first workshop was carried out with experts from The Forest Trust (TFT), a non-profit organisation, at the beginning of the data collection period. The second workshop was at the end of the data collection period and discussed potential interventions with industry stakeholders to build resilience towards drought.

1.6 Expected results

- A fundamental understanding of the resilience of the palm oil value chain in Sabah, Malaysia
- Identification of interventions for resilience building toward drought
- Building of resilience of the palm oil value chain through stakeholder interaction

1.7 Structure of thesis

The thesis is structured in 6 chapters, as outlined below:

Chapter 1 - Introduction	
Chapter 2 - Literature Review	Chapter 2 elaborates the scientific foundation of resilience in food systems
Chapter 3 - Methodology	Chapter 3 explains the applied methodology of this master thesis
Chapter 4 - Results	Chapter 4 states the analysed results of the primary and secondary data.
Section 4.1	Section 4.1 gives a brief overview of the study site.
Section 4.2 - 4.3	Sections 4.2 - 4.3 describe the palm oil value chain in Sabah and the drivers that influence the industry.
Section 4.4	The results of the resilience assessment are presented in section 4.4
Section 4.5	Section 4.5 presents findings of the workshop
Chapter 5 - Discussion	In Chapter 5 the key findings of this research are discussed.

2 Literature Review

2.1 Concept of resilience

The origin of resilience is in the Latin word *resilire*, which stands for rebounding or recoiling (Hoddinott, 2014). Initially, the concept of resilience was developed in the field of ecology in regard to the stability of ecosystems in the 1960s and early 1970s (Folke, 2006). Because of the broad definition of resilience, the concept gained popularity across various disciplines (Brand & Jax, 2007; Folke, 2006; Hoddinott, 2014). Within ecology, the concept of resilience was extended to the active management of ecosystems (Folke, 2006). The influence of humans on the ecosystem has increasingly been recognised as a key driver in the resilience of ecosystems so that today the concept of resilience has a strong conceptual basis in the resilience of socio-ecological systems (SES) (Folke, 2006).

Gallopín (1991) and Steffen et al. (2007) simply describe SES as the interaction between humans and nature. Human societies and economies heavily depend on ecosystem services, so that they can maintain their function and foster growth (Millennium Ecosystem Assessment (MA), 2005). However, the growth of human population and their activities have an increasingly negative impact on ecosystems (Folke et al., 2010; Steffen et al., 2007).To gain a profound understanding of SES, the recognition and study of the close interaction between ecosystems and social systems are essential (Folke et al., 2010). Berkes et al. (2003) and Maleksaeidi & Karami (2013) state that SES are very complex and unbalanced systems that experience periods of sudden and gradual change. A number of shocks and unexpected disturbances may affect the function of SES and consequently it is more complicated to make predictions about the future pathways and occurrences of SES (O'Neill, 1998).

The concept of resilience addresses the complexity of the system and views unpredictable occurrences as an inherent component of SES. Resilience points out that systems are required to develop capacities to handle these disturbances to maintain the function of the system (Berkes et al., 2003; Miller et al., 2010). It is relevant to highlight that resilience is a concept that entails a number of thought patterns, theories and methods rather than a single theory (Brand & Jax, 2007). Hence, Maleksaeidi & Karami (2013) summarise resilience as a "multidimensional and complex concept". Consequently, there are a number of definitions of resilience as well as levels of meanings on how to describe resilience thinking (Carpenter et al., 2001). According to the Resilience Alliance, a research network, resilience is the "capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity" (Walker et al., 2006). This definition implies that despite a shock, the systems can maintain its function and identity (Maleksaeidi & Karami, 2013). By comparison, Tendall et al. (2015) summarise resilience on the basis of the work of Hoddinott (2014) as " the capacity of the system to withstand and/or adapt to disturbances over time".

2.1.1 Specific and general resilience

Folke (2006) emphasises that the concept of resilience includes multiple spatial and temporal levels; from local to global scales and short to long-term time periods. In order to address this challenge of analysing and managing this complexity, some scientists have classified resilience into specific and general resilience (Carpenter et al., 2001; Miller et al., 2010). General resilience implies the resilience of every aspect of SES and takes into consideration that unexpected and novel occurences may disturb SES. Hence, SES are required to deal with all kinds of disturbances (Folke et al., 2010; Resilience Alliance, 2009).

Specific resilience, in contrast to general resilience, is stated as the resilience of “what to what” by Carpenter et al. (2001).The focus lies on a certain shock or disturbance that affects a certain aspect of the system. For example, a woodland experiences a specific shock such as a fire, which has an adverse impact on the food provision of the surrounding communities. It is relevant to make such specifications since the resilience can be highly context-dependent; it varies according to the time period and the spatial scale (Carpenter et al., 2001). Cabell & Oelofse (2012) note that a SES might be considered as resilient in the present; however in 50 years it may not be resilient anymore since the system continuously experiences change. In conclusion, it can be said, that higher resilience of a certain period paradoxically compromised the resilience of the following time period (Carpenter et al. 2001).

The same principle applies to the spatial scale. A particular region of a country might be affected by a natural disaster such as a pest outbreak affecting agricultural production. Presumably, this event decreases the resilience of the affected region. However, by looking at the whole country, the pest outbreak may not affect its resilience significantly. This leads to the conclusion that the spatial scale is relevant to define when looking at the resilience of what to what.

Nonetheless, a high resilience of a lower scale of the system may compromise the resilience at a bigger scale. Consequently, both general and specific, resilience are essential to gain a profound understanding of the studied system. Therefore, it is vital to take the general resilience of a SES into regard, when analysing or managing a specific aspect of the system, in order to increase the resilience of the overall system (Folke et al., 2010).

2.1.2 Persistence, adaptability and transformation

Furthermore, resilience can be described by three major characteristics; namely persistence, adaptability and transformation (Folke et al., 2010). Particularly in the pioneering work on resilience, a great emphasis was put on persistence, since it is the ability of the system to withstand disturbances (Folke, 2006). If a SES exhibits a robust character, it will be able to endure a certain turbulence and still maintain its function (Folke 2006).

Adaptability characterizes resilience as the "capacity of actors in a system to influence resilience" as claimed by Walker et al. (2004). This statement reveals that resilience is not a pre-existing characteristic of a system to endure disturbance, but an ability of the system to change itself to become more resilient (Folke et al., 2010). An adaptive system has the capacity to be equipped for disturbances in advance and to react towards upcoming changes (Engle, 2011). People are the main adaptive force of a system, who have an active influence on the resilience of the system. Their adaptive capacity includes learning from past occurrences and accordingly reorganizing the system to respond better to future changes (Berkes et al., 2003; Maleksaeidi & Karami, 2013).Therefore, persistence and adaptability go hand in hand to maintain the current system and to develop it towards a higher resilience level (Folke, 2006).

Transformability, on the contrary, implies a profound transformation of the system into a new state. A transformed system is fundamentally changed in ecological, political, economic and social key areas (Walker et al., 2004; Folke, 2006). In the view of transformability, shocks and disturbances are seen as an opportunity for redirecting the present pathway of the SES. Walker et al. (2004) describe transformability as the movement from an "undesirable to a

desirable state". For this purpose, a renewal of perceptions and values of the main actors in a system, as well as a transition of governance and network configurations are essential.

2.1.3 Resilience and sustainability

When talking about the concept of resilience, the question arises how resilience and sustainability are related to each other. In principle the different scientific views can be divided into two broad categories. Either resilience is seen as the equivalent of sustainability or resilience and sustainability are two complementary concepts that are connected to each other (Maleksaeidi & Karami, 2013). According to Maleksaeidi & Karami (2013), authors that view resilience and sustainability as equal, argue that sustainable system needs to be resilient. However, Carpenter et al. (2001) point out that resilience can be undesirable in specific cases. He gives the example of a dictatorship in a country that can show high resilience in the point of view of its persistence. On the contrary, the most prominent goal of sustainability is to have a system that is desirable, hence equating resilience and sustainability triggers certain conflicts of interest (Carpenter et al. 2001).

Figure 1: Resilience and sustainability as complementary concepts (Tendall et al., 2015)

As Derissen et al. (2011) describe resilience and sustainability as two complex concepts with various definitions and facets. UN (1987) defines sustainability as addressing the needs of the current generation without compromising the capacity of future generations to meet their needs. Resilience, on the contrary, can broadly be summarised as the capacity of the system to function despite of disturbances and shocks (Tendall et al., 2015).

Maleksaeidi & Karami (2013) conclude that resilience is a precondition of sustainability since a system can only continue to function in the future, if it can recover from the disturbances and shocks (Figure 1). Therefore, resilience can ensure sustainability in the future and is thus an important criterion to achieve sustainability (Maleksaeidi & Karami, 2013). However, in specific circumstances, resilience requires letting go of sustainability standards to preserve the function of the system. Folke (2006) concludes that one of the greatest challenges that humanity is facing is to withstand current disturbances, but also to transform our path towards a sustainable future.

2.2 Resilience in food systems

Due to increasing shocks and disturbances affecting food systems, the concept of resilience has been applied to food systems, which can be seen as the SES (Tendall et al., 2015).

2.2.1 Food systems

Ericksen et al. (2012) describe food systems according to Figure 2. Food system activities are the core of the food system. Ericksen (2008) argues that it makes the most sense to see food system activities as a chain of activities, from the production to the consumption of food. The key actors within value chains are producers, processors, packagers, distributors, retailers and consumers; whereby there can be further actors depending on the complexity of the system (Ericksen, 2008). In former times, agricultural production was the core activity of a food system, but there has been a continuous shift of the main economic activities towards processing, packing and retailing (Ericksen et al., 2012; Ericksen, 2008). Furthermore, it should be noted that globalisation has also influenced food systems, whereas value chains have expanded over the whole globe and long transport routes of foods have become more common (Ericksen et al., 2012).

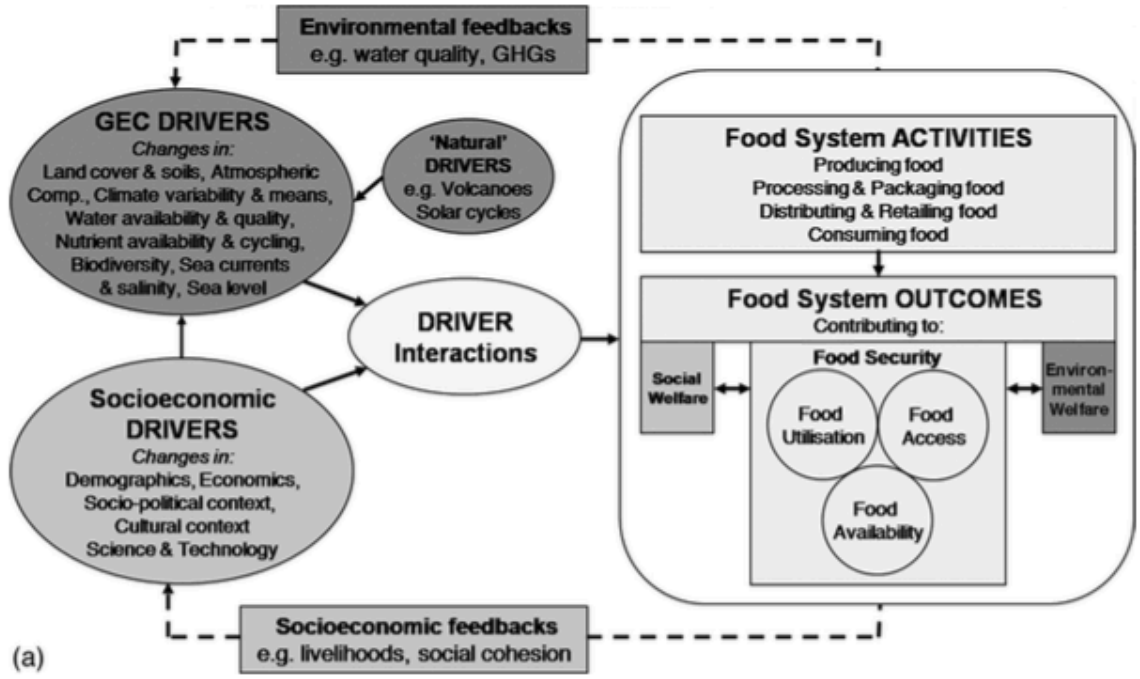


Figure 2: Food systems, their drivers and feedback (Ericksen et al., 2012)

Besides the value chain actors, food systems are influenced and governed by civil and state actors (Newton et al., 2013). State actors are positioned at different levels, from the local to national level. The civil society involves non-governmental organisations (NGO) as well as commodity roundtables. A further category of actors are research bodies, which are often funded by the state, but that remain relatively autonomous (Newton et al., 2013).

The main outcome of a food system is food security, whereby social and ecological welfare are further food system outcomes. The activities of a food system have clear and often major impact on the ecosystem services as well as on the natural capital of the system (Ericksen et

al., 2012). Social welfare outcomes include economic and social elements such as income generation and health status (Ericksen et al., 2012). Ericksen (2008) claims that in the short-term there is a trade-off between the above-mentioned outcomes, however in the long-term outcomes should be balanced.

Food systems are increasingly under pressure by major socio-economic or environmental drivers. Socio-economic changes include political crisis, market failure and urbanisation as well as population growth. Environmental changes involve among others, climate change, land changes, decreasing water quality and availability and biodiversity loss (Ericksen, 2008; Liverman & Kapadia, 2012; Tendall et al., 2015). All the drivers, activities and outcomes are closely linked together and are connected through feedback loops (Ericksen et al., 2012).

2.2.2 Concept of resilience in food systems

Tendall et al. (2015) discuss the concept of resilience in food systems and defines it as: "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances." In Figure 3, the fundamental principles of resilience in food systems are displayed. As discussed previously, a food system provides a certain outcome such as food security or income, which is being analysed as a function of time (x-axis) (Tendall et al., 2015). At a certain point in time a disturbance or shock disrupts the system. These shocks can be of an "internal, external, cyclic, structural, sudden, gradual, natural , political, social, economic" nature (Tendall et al., 2015). The development of the function over time is being described by four components; namely robustness, redundancy, flexibility and rapidity (Tendall et al., 2015).

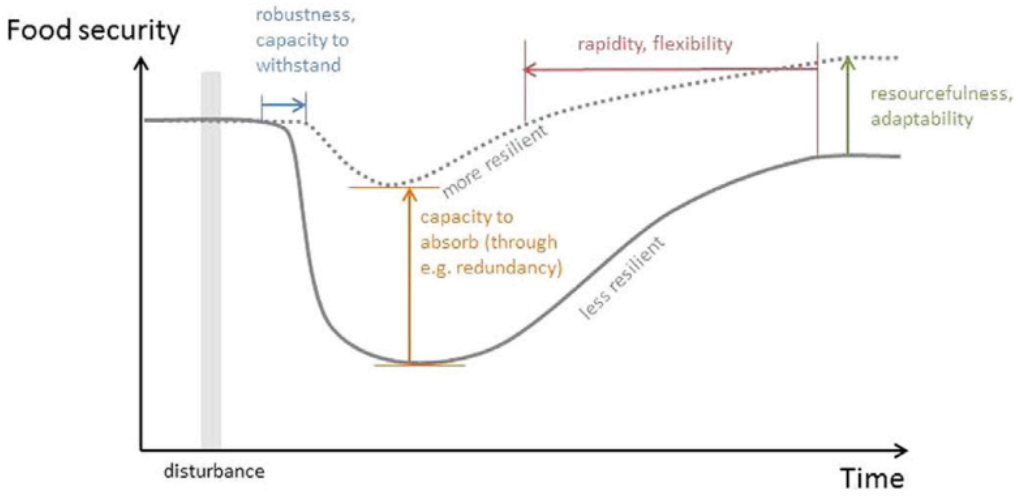


Figure 3: Concept of resilience in food systems(Tendall et al., 2015)

2.2.3 Resilience attributes

Tendall et al. (2015) point out the need for a framework to analyse the resilience of a food system. Various authors have developed attributes to assess the resilience of SES further. The following attributes that were developed by the SAE group and implemented in this research, are briefly described.

Exposure to pressure

Exposure to pressure describes how a food system was affected by a shock and it also entails the time of recovery after a shock event has happened (IISD, 2013). Cabell & Oelofse (2012) argue that small disruptions can increase the resilience of a system since it is an opportunity to reorganise and to get prepared for bigger disturbances.

Modularity

The term modularity can be described as high diversity within the system. It addresses the need for a great variety of elements such as species, landscapes or actors (Biggs et al., 2012; Cabell & Oelofse, 2012). In the case of failure of a particular element, another element could provide the same function and maintain the overall system function (Biggs et al., 2012). It also involves the spatial distribution of services and resources, in case a specific region is affected by a shock (IISD, 2013). Furthermore, modularity requests that stakeholders in the system are able to display diverse opinions and perspectives (Biggs et al., 2012; Gupta et al., 2010).

Buffering capacity

Buffering capacity can be expressed as the spare capacity of resources and services as well as storage capacities. Cabell & Oelofse (2012) describe spare capacities as the duplication of crucial components. It includes financial, technical, social or infrastructural capacities, which allow stakeholders to overcome disruptions and fluctuations better (IISD, 2013). Spare capacity, on the other hand, indicates the storage of resources. For example, storage of water will support an actor to overcome a time of drought (IISD, 2013).

Environmental capital

Natural capital and ecosystem services are essential for the functioning of food system resilience (Cabell & Oelofse, 2012; IISD, 2013). Therefore, environmental capital includes the condition of hydrological cycles, soil condition, biodiversity and other environmental resources. Furthermore, it also considers the condition of built resources as transport infrastructure or energy supplies (IISD, 2013).

Governance capacity

Governance capacity assesses the governance of the system, either from a governmental or entrepreneurial point of view (Gupta et al., 2010). For this attribute, the leadership of the system is essential, as well as decision-making processes being fair and transparent (Gupta et al., 2010; IISD, 2013). It also includes the identification and anticipation of problems, so that measures can be taken against them (IISD, 2013). The question is how governing actors respond during times of shock and if they have sufficient resources to maintain and re-establish the function of the system (Gupta et al., 2010; IISD, 2013).

Profitability and financial capital

Cabell & Oelofse (2012) indicate that profitability is the generation of wealth in the system. It creates the opportunity for investment, that can increase the capacity to react towards shocks (Cabell & Oelofse, 2012). Actors should be able to maintain their livelihood, without depending on external support such as subsidies (Cabell & Oelofse, 2012; Choptiany et al., 2014).

Information and learning

This attribute describes the learning capacity of a system. Biggs et al. (2012) define learning as "the process of modifying existing or acquiring new knowledge, behaviours, skills, values or preferences". Furthermore, information and learning include extension and advisory services, research and development and collaboration between universities and other actors, as important indicators to enhance the resilience of the system(Cabell & Oelofse, 2012). Biggs et al. (2012) also mention the monitoring of natural resources and system processes as relevant for basic information on the system. A further criterion of information and learning is the trust among actors (Gupta et al., 2010).

Transformability

Transformability can be described the process of learning from past experiences and failures, and to foster change in the desired direction (Cabell & Oelofse, 2012). For this reason, the openness of stakeholders and their values are crucial in making changes (IISD, 2013; Milman & Short, 2008). Furthermore, experimentation and innovation are essential to modify the current system (IISD, 2013).

2.2.4 Building resilience in food systems

The resilience of a food system needs to be actively managed to sustain humanity and to obtain desirable outcomes. As discussed above, the governance of the system is essential and has the power to influence the resilience of the system (Folke, 2006; Maleksaeidi & Karami, 2013; Miller et al., 2010). Biermann et al. (2009) state that governance is the institutions, organisations and authorities that take the leadership in regulating the system. Governance not only includes the official governmental bodies, but non-governmental stakeholders such as the private sector and civil society. Governance plays a critical role in regulating the relationship of humanity with their surrounding nature as well as preparing for disturbances (Kopainsky et al., 2013; Maleksaeidi & Karami, 2013). Folke (2006) argues that governance plays an essential role in innovation, generation of knowledge, self-organisation, shaping of values and mind-sets, so that the SES can lead into the desired direction.

The proper management of food systems poses an enormous challenge, since food systems as SES dynamics encompass social, economic, environmental as well as political processes and feedback loops on different scales (temporal, spatial,...) and various interactions (Ericksen et al., 2012; Kopainsky et al., 2013). Hence, Folke (2006) proposes that the first vital step in responsibly managing SES is by gaining a profound understanding of the SES dynamics. The awareness of gaining a better understanding of food systems has become more prominent within the research as well as policy-maker communities. However, studies on food systems have often focused only on one factor or value chain step, such as agricultural production instead of providing a holistic view of the food system and its challenges (Ingram et al. 2012). In addition, Ericksen & Liverman (2012) note that there is a lack of empirical work on food systems. Thus, the research community has the responsibility to develop a research approach that analyses resilience in food systems in a holistic manner.

Different authors have pointed out several criteria that research approaches should meet to build resilience in food systems (Ingram et al., 2012; Kopainsky et al., 2013; Miller et al., 2010; Tendall et al., 2015). One aspect is that the research approach should have a systemic approach that takes into consideration the complexity of a food system (Ingram et al., 2012;

Kopainsky et al., 2013; Miller et al., 2010). Hence, a holistic approach is required which incorporates numerous system components and their interactions.

Furthermore, Tendall et al. (2015) raise the issue of including stakeholders within the research, since their knowledge is of great value, in particular when there is a lack of data for the analysis. Since the actors of the food system are governing the system, their inclusion in the research project is relevant, so that they can implement the gained understanding. In addition, Miller et al. (2010) and Kopainsky et al. (2013) argue that resilience research would be much more efficient and improve the food system outcomes, if specific interventions are an output of the conducted research.

2.3 Transdisciplinary research

One research approach that suits the mentioned criteria for successful studies on food system resilience is transdisciplinary research. Transdisciplinary is a research approach that on the one hand includes multiple disciplines and one the other hand involves non-scientific actors in the research process. The inclusion of interdisciplinary as well as the cooperation of science and society aims to address complex questions that arise when analysing a system. One goal of transdisciplinary research is to address so-called “real-world problems” and to provide solutions for these challenges. It can also be explained as demand-driven research, that analyses prominent issues that our society is facing (Jahn et al., 2012). Jahn et al. (2012) also explain that transdisciplinary research is at the interface of solving these socio-ecological problems and of answering scientific questions. In other words, this approach searches for practical solutions and at the same time meets the scientific goals of generating novel knowledge, methods and theories (Jahn et al., 2012).

The strong emphasis on the inclusion of non-scientific stakeholders is essential for the science community to understand what the real-world problems are. Furthermore, since empirical work on certain systems, such as food systems, is missing, non-scientific stakeholders are essential in providing knowledge on their challenges and experience, so that the science community can benefit from their knowledge. Jahn et al. (2012) speak of mutual learning between scientists and stakeholders from society and points out that the knowledge of both is equally important and useful.

Furthermore, it is essential to include stakeholders, since they have the responsibility to implement the gained knowledge. In cooperating with stakeholders throughout the research process, an opportunity is provided for the stakeholders to reflect and learn more (Miller et al., 2010). As a result, adaptive capacity of stakeholders is built within the research process itself. However, learning about system dynamics and implementing new interventions is an iterative process. Therefore Miller et al. (2010) state in their work that research on resilience of systems is supposed to be process-oriented instead of focusing only on the output.

In summary, transdisciplinary research can be described as "a reflexive research approach that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extra-scientific actors; its aim is to enable mutual learning processes between science and society; integration is the main cognitive challenge of the research process” (Jahn et al., 2012). Hence, transdisciplinary approach meets the proposed requirement for analysing and building resilience in food systems.

3 Methodology

The SAE Resilience assessment guidelines developed by the SAE Group of Swiss Federal Institute of Technology ETH Zurich served as the basic methodological approach. It is a transdisciplinary approach that aims to assess the resilience of food systems in a holistic manner and build resilience throughout the process. Secondary data was obtained through literature research. Interviews and workshops were conducted to collect primary data. This triangular approach is used to capture different dimensions and aspects of the system under observation. The guidelines have been structured into four main stages, which will be explained in the following.

3.1 Stage 1: Problem identification

At the beginning of the research, the system under observation was defined and clear research goals were set. This stage also included planning the research process. These activities were done in close collaboration with the main project partner, TFT. The planning of the research was divided into two months of preparation by reading literature and defining the system, followed by a ten-week field work in Sabah and another two months of secondary data collection, analysis and thesis writing. Due to time limitation of the study, the SAE guidelines were reduced to the most relevant steps. Furthermore, the level of analysis of the system was determined; hence the focus was set on the palm oil industry in one state of Malaysia. Because of organisational reasons, most of the interviews were conducted with stakeholders in Beluran, Sandakan, Kinabatangan and Lahad Datu district.

3.2 Stage 2: Definition of the system

In the second stage, the aim was to define the system by analysing the major stakeholder and by mapping the system. Besides literature research, a workshop with experts from TFT was conducted to gain a better understanding of the system in the beginning of the field work. The participants were asked to identify the major stakeholders in the system and categorise them according to their perceived power and interest dynamics in the industry. Furthermore, the participants mapped the challenges of drought and flooding for the main value chain steps. Hence, the data from the workshop also provide information for the resilience assessment. Besides that, the second stage contained the mapping of the studied system. The basic system map with the different value chain steps was designed and then evaluated by the experts. Due to inaccessibility of quantitative data on the palm oil value chain in Sabah, the system was only pictured in a qualitative manner and no material flow analysis was done.

3.3 Stage 3: Resilience assessment

3.3.1 Resilience indicators and developed questionnaires

In the third stage, the resilience assessment of the palm oil value chain was conducted. The assessment is guided by eight resilience attributes. Each attribute has a set of indicators, which describe them more clearly (Table 1). For each indicator, there is one or more guiding questions that were developed by the SAE guidelines to assess the system. By these guiding questions, adapted semi-quantitative questionnaires were elaborated for the six major stakeholder groups within the palm oil value chain in Sabah. The stakeholder groups were divided into input suppliers (mainly input trading companies and nurseries), independent smallholder farmers, estates, mills, refineries and transportation companies. The questionnaires were adjusted to the activity and situation of each group. The value chain

steps, retailing and consumption, were deliberately not assessed, since local selling of edible palm oil had been highly government controlled until November 2016. Hence retailers and consumers were not significantly affected by flooding and drought events.

Interview partners were mainly identified through a snowball sampling approach (cf. [(Reed et al., 2009)]). For companies, managers or owners of companies, and in some cases company appointed staff were interviewed. In total, 50 semi-quantitative interviews were conducted and seven qualitative expert interviews were held. The experts included a government officer from Malaysian Palm Oil Board (MPOB), academics from University Malaysia Sabah and association representatives from East Malaysian Planters Association (EMPA) as well as Malaysian Palm Oil Association (MPOA).

Table 1: Description of resilience attributes and indicators (adapted from SAE guidelines)

ATTRIBUTES	INDICATORS
Exposure to pressure	• Past experience of shocks • Recovery from shocks
Modularity	• Diversity of inputs • Dependency on other stakeholders (number of suppliers, …) • Diversity of farms, landscapes, crops and varieties • Diverse activities for income generation • Spatial distribution of the value chain steps and competition • Expression of diverse opinion
Buffering capacity	• Spare financial capacity • Spar capacity of natural and built resources • Storage capacities and stocks within the system • Access to disaster risk management
Environmental capital	• Condition and protection of natural resources • Condition of built resources (transport, energy and communication infrastructure, buildings and machinery) • Accessibility, affordability and availability of natural inputs • Internal nutrient sources • Nutrient depletion • Emissions and waste cycles • Effects of management practices on the environment • Adaptation of crop variety to the socio-ecological system • Cost-effective vs environmental thinking
Governance capacity	• Health status of actors and access to healthcare • Living standard of actors • Transparency, legitimacy, accountability and acceptance of governance • Stability of the government • Collaboration between government units • Long-term planning (policies, strategies, …) • Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …) • Equality of stakeholders

	• Fair rights, laws and policies • Autonomy and management skills of actors • Investment in rural infrastructure • Land access and tenure • Self-organisation and networking of actors enabled • Governmental support in times of shock
Profitability and financial capital	• Insurance coverage • Permanent financial flows • Funds for investment, maintenance and expansion • Exposure to financial risk • Viability of the process (subsidies, …) • Profitability (business as usual) • Profitability (times of shock) • Current labour market and its adaptation to fluctuation
Information and learning	• Reliability of communication channels (market prices, weather information, …) • Access to early warning systems • Knowledge base • Education level • Level of experience • Access advisory and extension services • Access and investment into knowledge and education • Collaboration with universities, private sector and governmental departments • Monitoring and record keeping of quality and environmental factors • Trust and respect between actors
Transformability	• Openness to change (values and behaviours of actors) • Learnt lessons from previous shocks • Opportunity for experimentation and innovation

3.3.2 Data analysis

The collected primary and secondary data was analysed for each value chain group. Since the majority of data is qualitative, the analysis followed a qualitative measurement. All the collected data was assigned to the relating indicators of the attributes for each analysed value chain step (see Appendix I). It should be noted that the amount of data varies for the different attributes, depending on the interview answers and whether literature could be found on the topic. Each indicator was rated with a five-tier scale resilience score (Figure 4), which gave the general resilience score of the given information. The scoring of indicators was then weighted regarding its importance for the specific shock. A zero meant that this indicator is irrelevant to overcome the shock; a score of one indicated a low importance; a score of two a medium importance and a score of three a high importance. By multiplying the importance with the general score number, the shock related resilience score was obtained. The sum of the shock related score was divided by the sum of the importance score, which gave the final resilience score of the attributes.

Resilience	Very low resilience	Low resilience	Medium resilience	High resilience	Very high resilience
Score	- -	-	/	+	+ +

General resilience score	Importance of question (specific shock)	Shock related resilience score
-2 to +2	0 to 3	-6 to 6

Figure 4: Rating scale for the resilience attributes

3.4 Stage 4: Interventions for building resilience

The fourth step of the resilience assessment focused on identifying interventions to enhance the resilience of the studied system. This step was implemented by a one-day workshop with various stakeholders of the palm oil value chain. The objective of the workshop was to discuss the resilience of the palm oil value chain towards drought. In total twenty-one people participated in the workshop. The participating group consisted of fifteen participants from the private sector, one participant from an association, three government representatives and two staff from TFT. The participants were formed into four groups, namely: smallholders, plantation and input supply, milling and a group that represented the government. The participants representing the input supply and plantation actors were put together in one group due to organisational reasons. In the first session, each group discussed and demonstrated the major challenges and effects of drought on their activities. After that, they discussed and rated potential interventions to be better prepared for a prospective drought. At the end of the workshop, each group presented their discussion points and their proposed interventions.

Figure 6: TFT expert discussion during the first workshop

Figure 5: TFT experts map interactions of the value chain during the first workshop

Figure 8: Group discussion during the first workshop

Figure 7: Poster discussion during first workshop

4 Results

4.1 Profile of Sabah

Sabah is one of the thirteen state of Malaysia and is located in the North of Borneo. Hills and mountains characterise its landscape. The climate condition is mainly shaped by the North-East Monsoon from November to February and the South-West Monsoon from May to August (Osman et al., 2012). The annual rainfall variability ranges from 1700 to 5100 mm.

The population of Sabah counts over 3.2 million people, whereby 61% belong to indigenous ethnic groups such as Bajau or Duzun; the biggest indigenous groups in Sabah. Another 9% of the population are Chinese citizens and 6% Malays, which are the biggest ethnic group in Malaysia. 27% of the population are foreigners, which mainly come from Indonesia and Philippines (Department of Statistics, Malaysia 2016; Martin et al., 2015).

From 1888 on, Sabah was a British protectorate. During the Second World War, Sabah was invaded by the Japanese, but after their liberation from the Japanese occupation, Sabah entered a period of transition as British crown colony and finally joined the Federation of Malaysia in 1963 (Oxford Business Group, 2011). Due to the so-called 20-point agreement that was elaborated as a condition of unifying Sabah with Federal Malaysia, Sabah maintained partial autonomy in its governance. On account of this agreement, Sabah has an own parliamentary assembly, an own head of state and own constitution. Therefore, Sabah has different laws on the regulation of immigration and land tenure than Peninsular Malaysia (Oxford Business Group, 2011).

The main contributor to the economy of Sabah is the service sector (wholesales, retail trade, communication and information), which contributes 40.5% to the GPD of Sabah. Mining and quarrying sector is the second biggest contributor with 25.7%, followed by the agricultural sector of 22.5% (Department of Statistics, Malaysia, 2016). However, 35.3% of total workforce in Sabah is employed in the agricultural sector. The main crops are dry and wet paddy, coconut, cocoa, rubber and oil palm. The most important crop in Sabah is oil palm since 87% of agricultural land is cultivated with it (Department of Statistics, Malaysia, 2016).

4.2 Palm oil industry in Sabah

4.2.1 Stakeholder in the palm oil value chain

In Table 2, general information on the total capacity of the palm oil industry is given. The palm oil value chain can be divided into four main steps, namely: input supply, production, processing and distribution (Figure 9). In the following section, each value chain step and the necessary background information are given.

Table 2: Overview of palm oil industry in Sabah 2015

TYPE	NUMBER
Plantation (ha)	1,544,223
Mills	129
Kernel crushing plants	12
Refineries	13
Annual CPO[a] production (tonnes)	5,722,967
Annual CPKO[b] production (tonnes)	1,274,029

[a] Crude Palm Oil [b]Crude Palm Kernel Oil

4.2.1.1 Input supply

The main input supply activities in Sabah are fertiliser manufacturers, input trading companies and nurseries. Fertiliser manufacturers import minerals, blend, mix and store them locally. They either sell their fertilisers directly to plantation companies or via input trading companies. Besides locally produced fertiliser, input trading companies receive their products (fertilisers, pesticides, …) from Malaysian and international suppliers. They own shops in cities such as Sandakan or Lahad Datu for direct sales and they also do deliveries for bigger orders. Oil palm seedlings are raised by company own or external nurseries. The interviewed nurseries have around 50,000 up to 300,000 seedlings. They mainly obtain seeds from private or government-linked companies that have their own breeding program and seeds production, such as Sime Darby or Felda. Oil palm seedlings are cultivated in polybags for approximately nine to twelve months before being replanted into the plantation fields.

4.2.1.2 Production

The plantations in Sabah can be divided into four categories (Figure 10). Smallholder farmers are either independent or bound to a government-introduced scheme, such as FELDA and FELCRA (Majid Cooke, 2012). Independent smallholders are autonomous farmers that are self-organized in their finances and their farm management. In contrast, smallholder farmers, who are bound to a scheme, have a contract with the given organisation and are strictly supervised by them. Due to organisational reasons, only independent smallholder farmers were interviewed in this study. The majority of big estates, which range from 100s to 1000's of hectares, are owned by private companies. Many companies focus on oil palm as their core business, but especially bigger companies have also diversified their business into other sectors such as property development (Teoh et al., 2001). Government-linked companies cultivate 6% of the oil palm planted area. Usually, the government is the major shareholder of these companies; they appoint the senior management and are able to make major decisions for the companies.

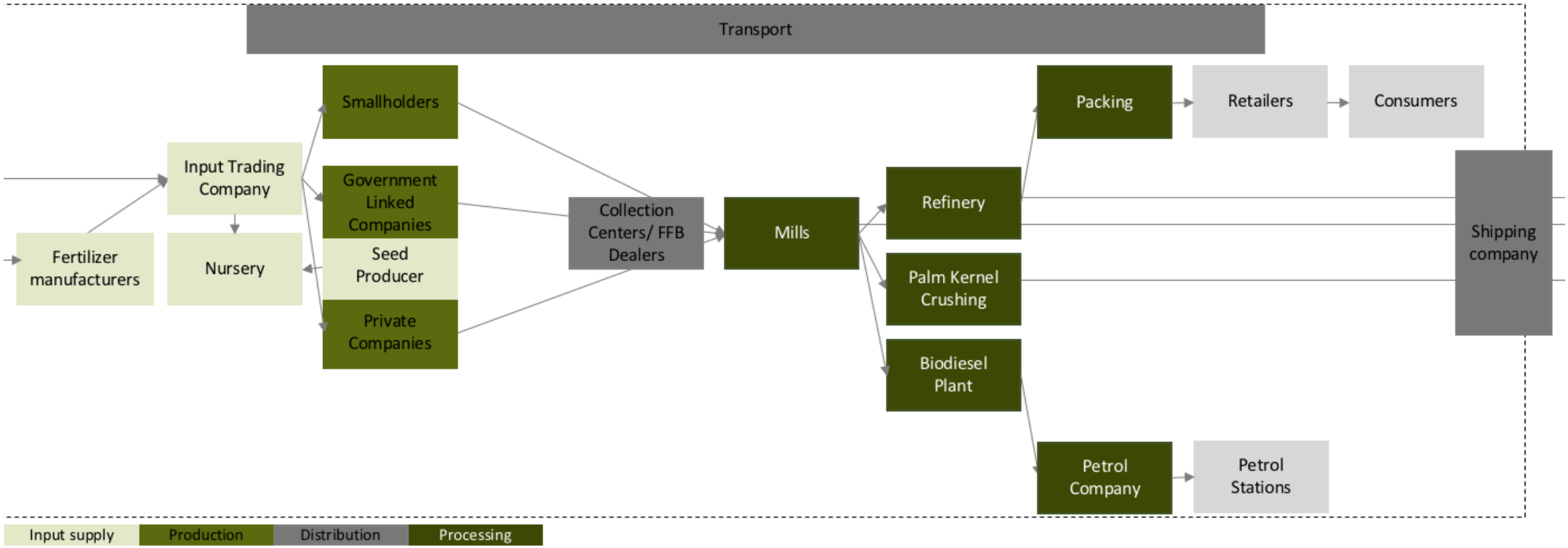


Figure 9: Map of palm oil value chain in Sabah

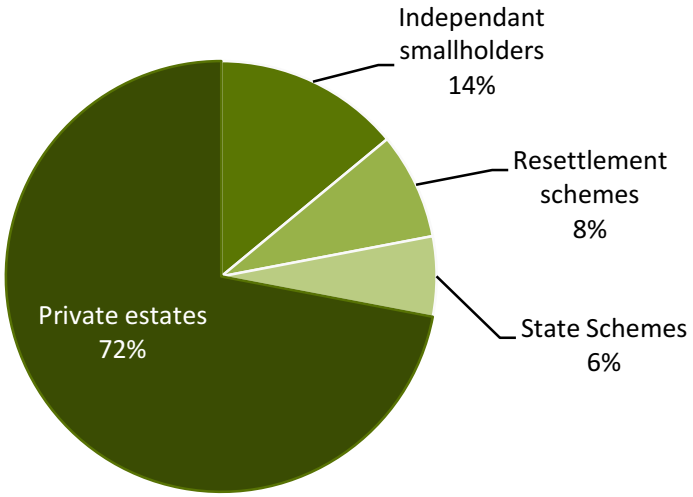


Figure 10: Distribution of oil palm area by category (MPOB, 2016)

4.2.1.2.1 Oil palm

In this section, palm oil and its cultivation are briefly described as a basis to understand the resilience assessment results of this value chain step.

The commercial variety *Elaeis guineensis* grows best in tropical rainforest conditions with annual precipitation of around 1750 to 3000 mm (Sutarta et al., 2016). In general, oil palms are cultivated in monoculture for 20 to 30 years. The first FFB can be harvested after two to three years, whereas the most productive years are between nine to fifteen years (Basiron, 2007; Woittiez et al., 2017). The global average palm oil yield is 3 t/ha/year, whereas the highest yield achievements are 12 t/ha/year (Woittiez et al., 2017). In Sabah, the average oil yields are 4.3 t/ha/year (MPOB, 2016). Harvesting is heavily labour-intense and requires approximately one worker per 15 hectares (Government of Malaysia, 2010). Planters stated that oil palm is a relatively robust plant towards climatic variability and disease compared to other crops. Oil palm depends mainly on a single species of weevil for its pollination, namely *Elaeidobius kamerunicus* (Foster et al., 2011). However, the pollination by the weevil becomes less efficient in dry weather conditions as well as excessive rainfall (Sutarta et al., 2016).

Furthermore, it should be noted that current environmental conditions and management practices have short-, mid- and long-term effects on the fruit development of oil palms and hence on the FFB yields (Figure 11). In the short-term, effects induced by environmental conditions and management practices influence the number of flowers and bunch weight, whereas mid-term effects (13 - 25 months) alter the ratio of female and male flowers. In unfavourable conditions such as insufficient rainfall, the ratio of male flowers is higher and consequently less FFB are developed. Undesirable environmental conditions will cause floral abortion or even bunch failure in the long-term (25 - 40 months). In conclusion, inadequate management practices (insufficient nutrient supply, disease attacks,…) and adverse climate conditions, have an effect on the FFB production on the prospective three years (Sutarta et al., 2016).

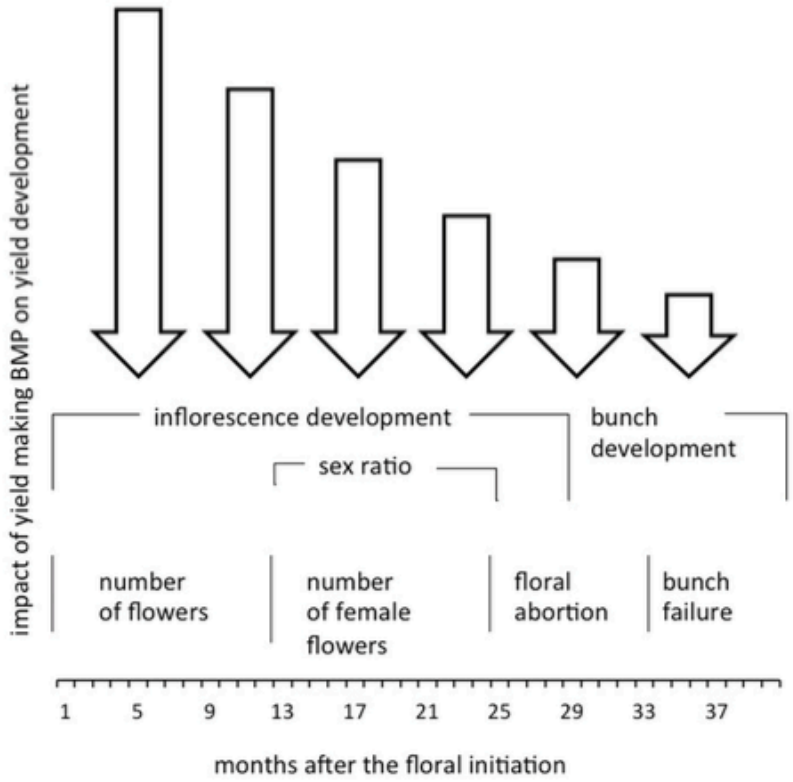


Figure 11: Fruit development cycle of oil palm (Oberthür et al. 2012)

4.2.1.3 Processing

Crude palm oil (CPO) is processed from the outer mesocarp of the fruitlets and their endosperm is processed into crude palm kernel oil (CPKO). CPO is mainly used for food-items, whereas CPKO is processed into non-food items such as cosmetics or plastics. In order to achieve high-quality oil, it is essential to harvest the FBB at the right maturity and to processes them within 48 hours after harvesting. Therefore, mills, which process FFB into CPO, are located close to the plantation sites. This process obtains following by-products; fibre and shell that is mainly used as fuel for the boiler, empty fruit bunches (EFB) that can be used as mulch on the plantation fields and palm oil mill effluent (POME), which may lead to environmental problems if being discharged into the river. However, POME can be used as an electricity source from its biogas emission or it can be used as liquid fertiliser (Abdullah et al., 2015). CPKO is processed in 12 kernel crushing plants in Sabah, which are either combined with a mill or located close by a bulking station (MPOB, 2016).

The second processing step is implemented by refineries that processed CPO and CPKO into a wide range of products from biodiesel, oleochemicals and detergents (Corley, 2009). In Sabah CPO and CPKO is exported to Malaysia or international markets. The remaining CPO is processed in the 13 refineries that are located close to the sea and often have their own bulking station. The largest proportion of CPO is processed to refined, bleached and deodorised palm oil, palm oil olein, palm oil stearin as well as palm fatty acid distillate (MPOB, 2016). The government of Malaysia introduced a mandatory biodiesel blend of 10% palm oil into petroleum (Chow, 2016; Potter, 2015). Three refineries in Sabah also have a biodiesel

plant that produces biodiesel, which is then sold to petrol companies that blend the oil. The government regulates the palm oil prices for biodiesel.

4.2.1.4 Distribution

FFB are either transported directly to the mill by the company-own transportation or by external transport companies. Especially smallholder farmers depend on transportation businesses. In cases, where the mills are located further away, FFB are sold to collection centres that are owned by the mills or third parties. CPO is mainly transported by external companies, either by boats on the river or via tanker trucks. Mills usually have one to three years contract with a transportation company.

4.2.1.5 Governmental agencies

Several governmental agencies have an influence on palm oil industry. In the following, the most relevant ones are described.

MPOB

MPOB is the premier regulatory agency of the palm oil industry in Malaysia. This agency has the responsibility to provide licenses for the whole palm oil value chain, to do research and development as well as to provide training and technical services for the industry. MPOB is governed by the federal government and has branch offices in every district in Sabah. Their board consists of representatives from the federal government, industry associations and Sarawak and Sabah state government officials (MPOB 2016; Wahid et al., 2005).

DOSH

Department of Occupation Safety and Health (DOSH) aims to prevent industrial accidents and diseases. Mills and refineries mentioned that they are required to comply with the regulations of DOSH and that this agency is monitoring them.

EPD

The Environmental Protection Department (EPD) in Sabah is responsible for environmental planning, assessment and enforcement. Hence, their function is to control if, plantations, mills and refineries are following the environmental regulations.

Disaster Risk Management Organisation

The National Security Council has the responsibility for the required disaster risk management policies. The National Disaster Management and Relief Committee is the appointed body for the coordination of disaster relief, which includes several governmental agencies and social organisations to provide shelter, food aid and rescue during disasters (CFE-DM, 2016; Chan, 2015). Furthermore, disaster risk management is structured in three levels; national, state and district level, whereas each level has its own responsibilities (CFE-DM, 2016; Chan, 2015). However, Malaysia is currently of changing its current disaster management system and will set up a new National Disaster Management Agency (cf. [CFE-DM, 2016]).

4.2.1.6 Associations

The interest of the private sector is represented by various associations (Table 3).

Table 3: Relevant industry organisations

FOCUS OF ASSOCIATION	NAME OF ASSOCIATION
Plantation	Malaysian Palm Oil Association (MPOA)
Plantation	East Malaysian Planter Association (EMPA)
Palm oil refiners	Palm Oil Refiners Association of Malaysia (PORAM)
Planters	The Incorporated Society of Planter (ISP)
Smallholders	National Association of Smallholders (NASH)
Independent palm oil millers	Palm Oil Millers' Association of Malaysia (POMA)

4.2.1.7 Stakeholder categorisation

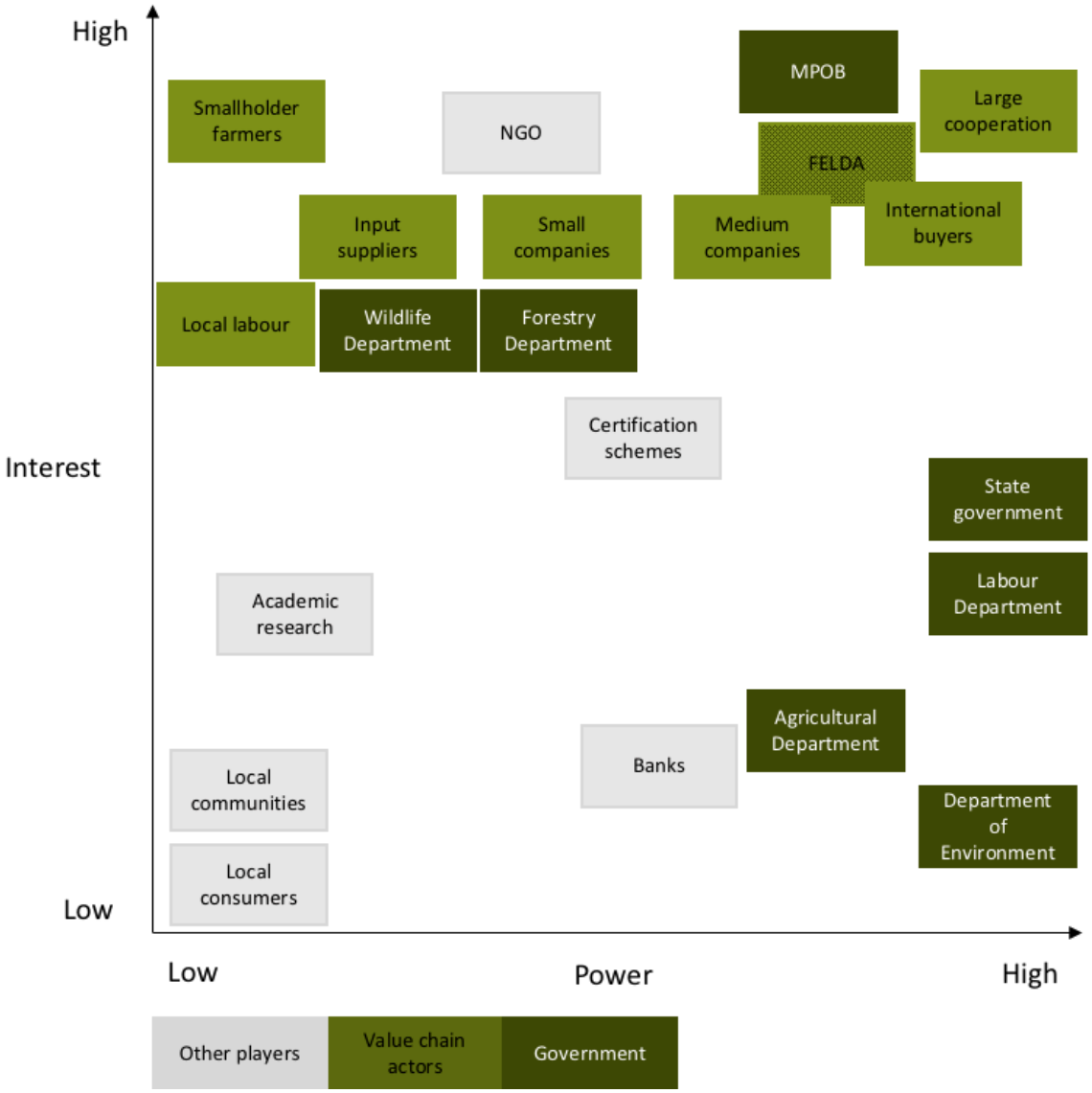
In Figure 12, the palm oil industry actors in Sabah are categorised according to their power and interest levels. The power axis characterises which players have the power to control the system, to make decisions and to facilitate the implementation of new interventions. Their power may be direct (e.g. budget) or indirect (e.g. ability to coerce or persuade others). The interest axis reveals a high dependency of the actors on the palm oil industry and their benefits from the industry. It should be noted that the diagram is a summary of the first workshop. Therefore, it indicates understanding and interpretation, which the TFT experts had of the industry dynamics.

The interest and power distribution in the palm oil value chain reveals that the interest for all the players is high since the industry is their primary source of income generation. The power distribution, on the other hand, displays vast differences within the industry. Smallholder farmers and industry labourers appear to be the weakest players regarding their power to change the system. All the experts agreed that the bigger the company, the higher their influence on the industry. Large cooperations, as IOI or Wilmar, have the highest power. International palm oil buyers, for example Néstle, also have a crucial influence on the local palm oil industry in Malaysia.

Several governmental agencies are involved in the industry and vary in their interest and power levels. MPOB is clearly the most important governmental agency. Other departments as the Department of Agriculture and Labour Department have a high influence on the industry, but almost no interest.

Several non-governmental players are indirectly connected with the industry. Academic research, for instance the University Malaysia Sabah as a major player, is rated with a low interest in the industry and low power to foster change. Roundtable on Sustainable Palm Oil (RSPO), on the other hand, indicates a higher level of influence and dependency on the industry (see Section 4.2.3.5 for further information on RSPO). There are also several NGOs that deal with palm oil industry in Sabah. They are very interested in moving the industry into their desired direction, but they often lack the power to do so. The lowest interest and power score were given to local consumers as well as local communities that are influenced by the palm oil industry.

Figure 12: Power/Interest categorisation of stakeholder elaborated at the first expert workshop



4.2.2 Spatial distribution

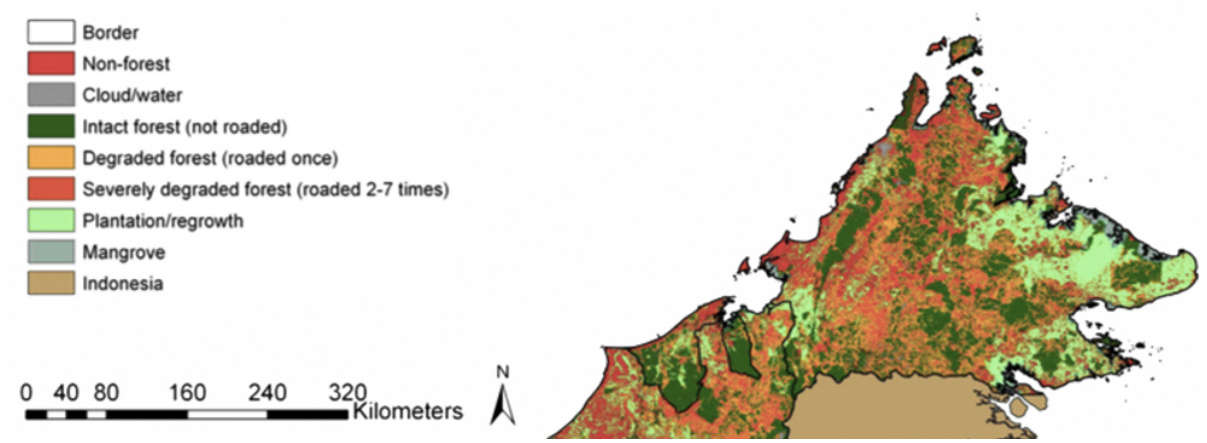


Figure 13: Spatial distribution of plantation area in Sabah (adapted from [Bryan et al., 2013])

The entire palm oil industry in Sabah is mainly located in the eastern part of Sabah (Figure 13). According to Department of Statistics, Malaysia (2016), 52.6 % of plantations are located in the Sandakan Division, and another 39.9 % are in the Tawau Division. A small proportion of plantations is in the interior and western coast of Sabah. The distribution of the mills is approximately congruent with the distribution of plantations (Interviews). In general, there is only one main road that connects mills with the major cities, where the refineries and ports are located. Therefore, most of the transports pass through the same road (Figure 14). The refineries are located in the industrial cluster of Sandakan, Lahad Datu and Kunak, where it is further processed or shipped directly. A further port that deals with the shipment of oil palm products is located in Tawau.

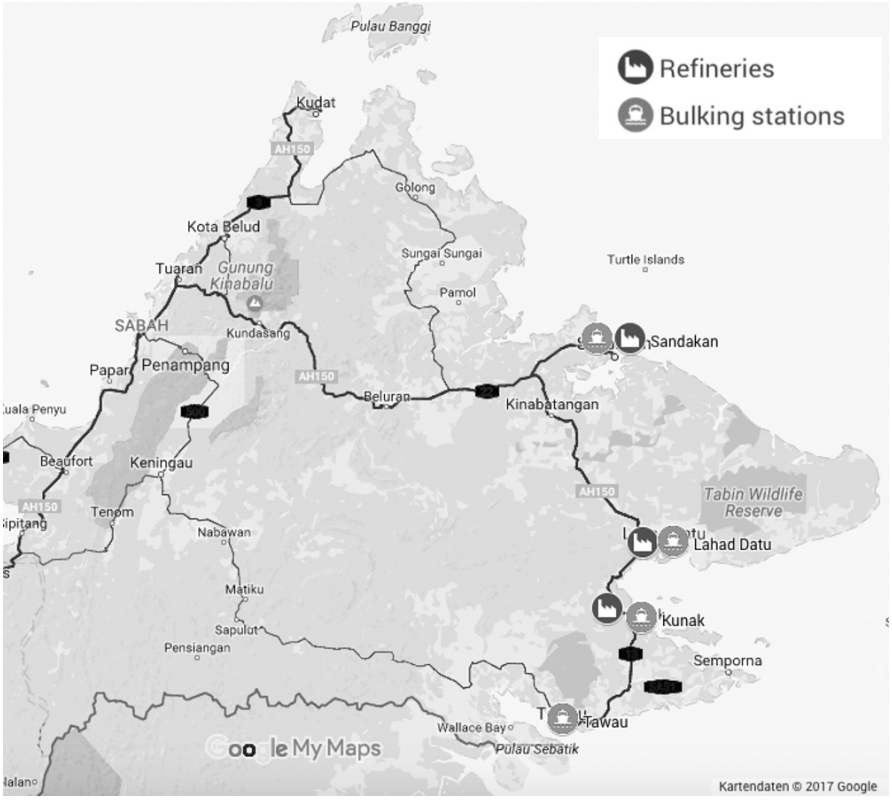


Figure 14: Industry relevant infrastructure in Sabah (adapted from [Google 2017])

4.2.3 Drivers of change

4.2.3.1 Climate variability

The usual weather patterns in Southeast Asia are occasionally disturbed by the so-called El Niño Southern Oscillation, which is a phenomenon that appears every two to seven years. During El Niño years, the sea surface temperature in the central and eastern Pacific raises above average. This leads to a change of the trade winds and the sea level pressure over the Pacific. As a result, there is a decrease in precipitation and the temperatures rise in South East Asia. El Niño years are often followed by the reversed cycle called La Niña. La Niña phenomenon appears during a cooling of the sea surface temperature and therefore rainfall increases and in some regions, it causes floods. Usually El Niño and La Niña develop over a period of 9 to 12 months and experience their peak between December to April. The severity of El Niño and La Niña depend on the measure of change in sea surface temperature and its duration. According to Climate Prediction Center (2016), the last three severest El Niño events appeared in 1982/83, 1997/98 and 2015/16 and the severest La Niña years in 1973/74, 1975/76 and 1988/89. Moderate El Niño years occurred in 2002/03 and 2009/10 and moderate La Niña years in 07/08 and 10/11 and 98/99. Malaysian Meteorological Department (2009) confirms that the driest years in Malaysia appeared during El Niño years and the wettest years correlated with La Niña years.

El Niño years notably affect the FFB production in Sabah. The El Niño event in 2015 lasted for 19 months and led to reduced rainfall, less rainy days and higher temperature. Hence, the palm oil industry was significantly affected by this shock. The CPO production in Sabah decreased by 30% in February and 14% over the whole year compared to the average of 2007 until 2015 (Figure 15).

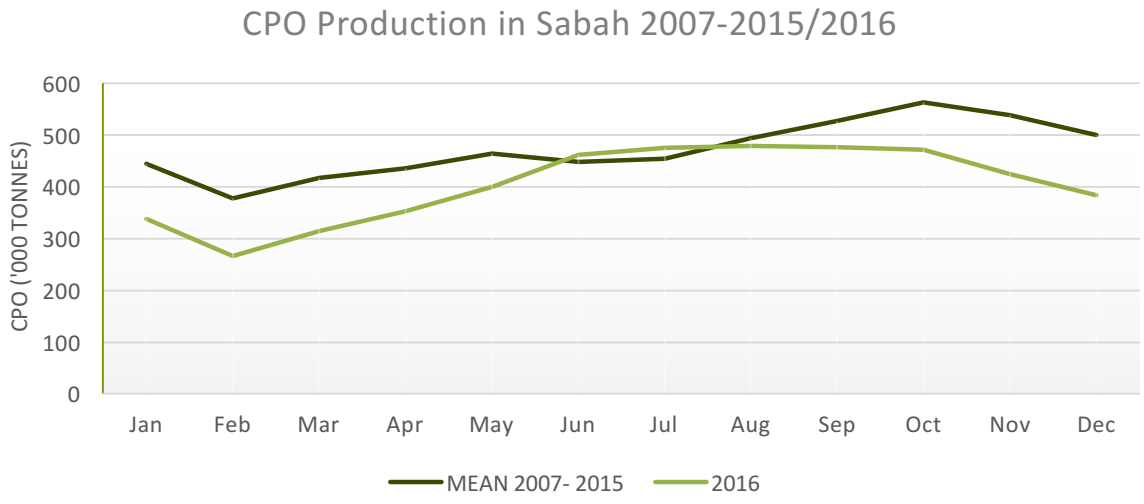


Figure 15: Decrease in annual CPO production in 2016 (MPOB, 2016)

La Niña years have often led to flood events all over Malaysia. Flooding is the disaster with the highest frequency in Malaysia (CFE-DM, 2016; Chan, 2015). There are annual floods due to the seasonal monsoon from November until March, to which the population has adapted well, for example by the traditional houses on stilts. However, there are also major flood events, which cause high losses in life and damage to infrastructure, properties and crops. Governmental support is essential in such events because people are often required to be evacuated (Chan, 2015). Smaller annual and unexpected major flood events have an influence on the palm oil

industry. For example, harvesting activities are hindered and roads become impassable for the transportation of FFB or CPO. In Sabah, a highly flood-prone area is the Kinabatangan river, which is surrounded by hundreds of hectares of palm oil plantations. Teoh et al. (2001) explain that in 2000, a major flood event covered over 10'000 ha of palm oil plantations (Figure 16) and caused losses of approximately RM 10 million (2.25 million USD), due to the destruction of immature oil palm seedlings.

Figure 16: Major flood along Kinabatangan river in 2000 (Teoh et al., 2001)

4.2.3.2 The economy of palm oil in Sabah

The Malaysian government views the palm oil industry as a key sector for the economy in Malaysia. In 1960, the government recognised the potential of oil palm and began to invest in this industry; as a result, oil palm became their leading agricultural commodity in the 1980s (Rasiah & Shahrin, 2005). Further policies such as the fiscal measures in the form of export duties and incentives, boosted the processing sector in Malaysia (Lai et al., 2015; Rasiah & Shahrin, 2005). The government further invested in infrastructure as well as in research and development and committed to promoting the industry in the global oil and fats market (Cramb & Curry, 2012; Lai et al., 2015; Rasiah & Shahrin, 2005). The current Economic Transformation Plan states the still present objectives of the Malaysian government to boost the palm oil industry as a measure of economic development in order to become a developed country in 2020 (Government of Malaysia, 2010; Potter, 2015).

In Sabah, the economy is highly depending on oil palm. Palm oil products account for 36.7% of the export value, besides petroleum that accounts for 40.2%. Hanim (2016) states that the current production cost per tonne of CPO is on average around RM 1800 (405 USD). Unlike other commodities, CPO prices have steadily been rising over the past decades. The price has more than doubled between 1980 and 2015 (Figure 17) (MPOB, 2016). Many of the interviewed plantation owners have pointed out that the industry has been highly profitable in the past years.

Since oil palm products are mainly traded on the global market, various factors influence the price development. One the one hand, the prices are closely related to the global vegetable prices, since different oils can be used as substitutes. On the other hand, since more than 85% of oil palm is produced in Southeast Asia, the El Niño phenomenon affect supply significantly, and consequently the demand and prices increased during and after the El Niño event. Since the Malaysian government has initiated a minimum blend of palm oil as biodiesel, the prices

have also been linked to the global petroleum prices (Interviews). The trading currency of CPO is USD; consequently, the currency exchange rate of RM and USD is an important factor for the profitability of the palm oil industry.

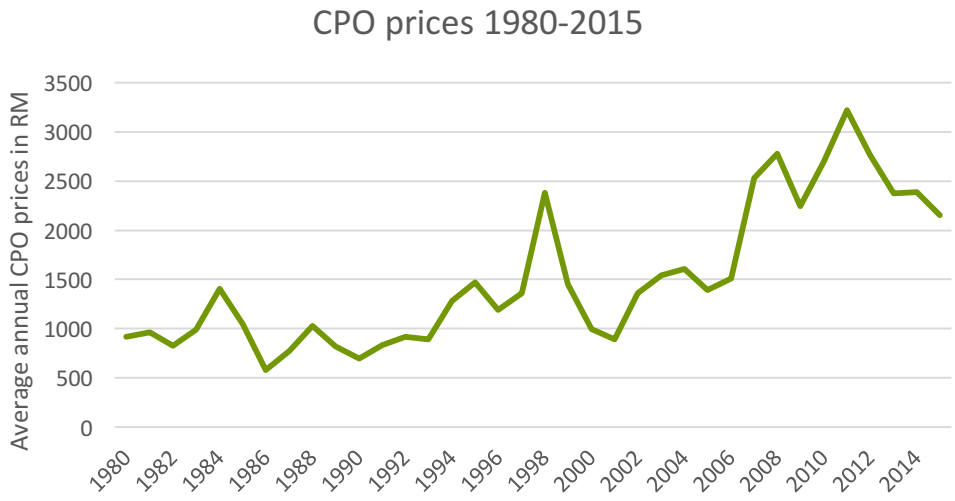


Figure 17: Development of CPO prices (MPOB, 2016)

4.2.3.3 Labour shortage

The palm oil industry, especially the plantation activities are heavily labour-intense. Activities such as harvesting of FFB, the collection of fruits or recycling of crop residues has been difficult to mechanise; therefore the demand for workers has been very high. Since plantation work is physically exhausting and the wage rates are relatively low compared to other jobs, Malaysians do not desire to work on a plantation. Consequently, the palm oil industry in Sabah depends on foreign labour, which is mainly from Indonesia and the Philippines (Corley & Tinker, 2015; Sayed Mahadi, 2014).

However, the industry has experienced a shortage of labour in the recent years. Apparently, plantations in Sabah lack over 35'000 workers (Azman, 2012). The consequence of the insufficient labour force is that the productivity of plantations decreases notably. FFB rot and are not delivered to the mills within the required time span of 48 hours. Some interviewees also acknowledged that certain management practices, such as applying EFB on the fields as natural fertiliser and mulch, are not done, due to the insufficient labour force.

One of the main reason for the recent shortage is the expansion of the palm oil industry in Indonesia and the increase of Indonesian salaries in their oil palm plantations. Indonesian workers are preferred by the Malaysian companies since they are considered to have a better working mentality, and they are able to communicate in the local language (Alam et al., 2015). Nonetheless, due to the closing gap between salary offers in the two countries, Indonesian workers are encouraged to return to their home country.

Besides the economic dimension, the labour issue is related to social and legal matters. Foreign workers are often being discriminated by the local authorities as well as by the media and the local population (Majid, 2009). In addition, it is relevant to note, that a high number of the workers are illegally in Sabah (according to [Sayed Mahadi, 2014] actual numbers are difficult to estimate) and legalisation of workers are complicated and costly. Although these

issues could be elaborated further, it would be out of the scope of this study. However, the issue of labour shortage is relevant to bear in mind, since it has an influence on the resilience of the whole palm oil value chain in particular matters.

4.2.3.4 Land titles

In Sabah, agricultural development counted as one of the major drivers of deforestation (Osman et al., 2012). Between 1990 and 2008, Sabah lost more than half of their intact forests, which is around 1.85 million ha (Osman et al., 2012). The government of Sabah has acknowledged this issue and has designated specific areas in Sabah as protected area (Bryan et al., 2013). Because of these forest conservation policies, opportunities for extensive plantations is becoming limited in Sabah (Government of Malaysia, 2010). Therefore many plantation companies seek to expand their palm oil business in Indonesia (Interviews; Government of Malaysia 2010).

A further issue in the palm oil industry is the land tenure system in particular for smallholder farmers (Martin et al., 2015). The majority of the interviewed smallholder farmers did not have ownership of their land (Majid Cooke, 2012). According to the Sabah Land Ordinance 1930, native people have the right to apply for a native title for 8 ha. If no application of land is made, the land belongs to the State of Sabah (Lunkapis, 2013; Majid Cooke, 2012). However, obtaining a land title as a smallholder is very challenging and often requires several years (Interviews, Majid Cooke 2012). The reason for this is that the process is hindered by high bureaucracy and inefficient processes (Interviews). Apparently, several departments are required to give their approval for the land title, but their collaboration has been stated as marginal (Interviews). Furthermore, some interviewees raised the concern of corruption that prolongs and biases the process.

Consequently, untitled land, even though it may be customary land and smallholders cultivate it, the land belongs to the state of Sabah and is vulnerable to the discretion of the state and land use change (Cooke, 2013). In the study of Martin et al. (2015), several farmers were aware of cases of land grabbing, since smallholder farmers did not have any acknowledged legal claim on their land. The uneven power distribution between native communities and the government, make smallholders highly insecure about their land rights and submit vast areas of land under governmental control (Majid Cooke, 2012). The current regulations have led to the promotion of large scale estates instead of protecting customary land (Cooke, 2013; Nesadurai, 2013; Interviews). Consequently, opportunists may take advantage of unresolved land titles situations (Lunkapis, 2013). However, native communities are fairly limited in raising their concerns before the government (Lunkapis, 2013).

4.2.3.5 Demand for sustainable palm oil

In the recent years, the palm oil industry has been highly criticised about the deforestation of rainforest and further environmental and social issues on the ground. Hence, western consumers and NGOs have increasingly demanded sustainably produced palm oil (Martin et al., 2015; Oosterveer, 2015). Private companies and governmental stakeholders have started to acknowledge these issues and have taken the initiative to address them (Choong & McKay, 2014; Oosterveer, 2015). The most known and influential sustainability initiative in the global palm oil industry, as well as in Sabah, is RSPO (Oosterveer, 2015). RSPO was founded in 2004 by different global stakeholders such as planters, processors, retailers and NGOs and is a voluntary membership association with over 3000 members (Oosterveer, 2015; RSPO, 2017).

Several criteria and principles were developed in order to address the key sustainability issues in the global palm oil industry. Certified companies are required to fulfil the given criteria. Today western markets increasingly demand palm oil that is certified by RSPO (Oosterveer, 2015).

The issue of sustainability, as well as RSPO certification, is a well-known and commonly discussed topic by industry stakeholders in Sabah. Several interviewees pointed out the benefits of complying with RSPO standards and the positive impact it is having on the companies' operations and the environment. One mill manager, for example, pointed out the positive improvements in their operations regarding safety and health issues. Nonetheless, RSPO initiative has increasingly been criticised to be ineffective in achieving sustainability on the ground and that it imposes western standards on local producers (Oosterveer, 2015; Sheil et al., 2009; Teoh, 2010). Furthermore, several companies imply that the certification process is too costly and too complicated to comply with (Basiron & Yew, 2016; Interviews). Whether certified or not, stakeholders in the palm oil industry are increasingly aware of the topic of sustainability and cumulatively improve their operation of their companies.

4.3 Resilience assessment

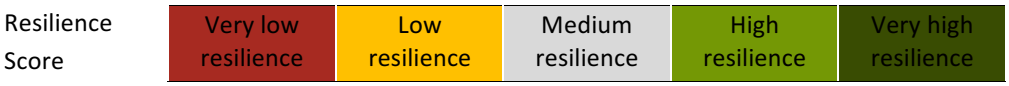


Figure 18: Resilience scale for Table 4 to 10

4.3.1 Whole value chain

This section assesses data and challenges that address the whole palm oil value chain in Sabah. The presented factors point out the general resilience of the palm oil industry that influences the resilience of the system towards drought and flooding directly or indirectly.

Table 4: Resilience score for whole value chain

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

The drought in 2015/16 affected all stakeholders in operational or financial aspects. The recovery will take at least three years, because of effects of insufficient rainfall on oil palm yields (see Section 4.2.1.2.1). In general, the various actors were able to endure the shock and have been on the trajectory of recovery. Since flooding is an issue that occurs more frequently in the palm oil industry and only in specific areas, the palm oil industry has adapted better to this shock and therefore recovers faster.

Modularity

In every value chain step, there are sufficient suppliers and buyers available without evident monopolies. A critical issue regarding the whole palm oil value chain is the uniformity of the landscape since vast areas are covered with oil palm mono-cropping. The genetic variability is further reduced, as most of the plantations cultivate the same variety, namely *Tenera.* Furthermore, since oil palm is one of the major contributors to the economy, a depression of the oil palm industry will affect the whole economy in Sabah. For instance, palm oil companies implement cost-cutting measures during times of drought, such as reducing their orders for spare parts or not investing in new machinery. As a result, companies like hardware stores and mechanic stores experience a high decrease in their profits. Therefore, it can be stated that a disturbance in the palm oil industry affects the economy in Sabah to a large degree.

Buffering capacity

Due to the decrease in rainfall in 2015/16, water scarcity was an issue for the palm oil industry and the local communities. No interviewee received support from the government to overcome this issue. One of the refinery managers also mentioned that especially in Lahad

Datu sufficient water supply from the pipeline is not always guaranteed. Therefore, they were required to buy water from other local sources, which increased their production cost.

Regarding flooding, the disaster management organisations are essential to overcome major flood events. The reaction towards flooding by the government has improved over the past years, and evacuation and relief aid appear to function considerably well. Chan (2015) acknowledges the Malaysian flood mitigation policy as commendable when he takes into consideration that Malaysia is still a developing country. Today the budget allocates 1.17 billion USD for flood mitigation measures, which is a 256-fold increase in budget since the first Malaysian plan in 1971 (Chan, 2015). Interviewed smallholders said that their communities received adequate support when floods hit them. They were evacuated, if needed, and provided with shelter and food aid. However, the main focus of the disaster risk management organisation is on flooding, and none of the interviewees received any support during the recent drought.

Environmental capital

As explained in Section 4.2.3.4, vast areas of forest have been logged in the previous decades. However, the government of Sabah has recognised the importance of conserving forest area for biodiversity and wildlife conservation. Hence 10,415km^2 (14%) of the area of Sabah has been declared as protected area (Bryan et al., 2013).

Nonetheless, it is criticised that for instance the Kinabatangan area should have been protected under forest reserve and not been released for private companies to establish plantations (Interviews). It is debated that the plantations along the Kinabatangan river are severely flooded in certain years, because of logging and clearance of land for plantations (Teoh et al., 2001). Hence, the destruction of the natural ecosystem and planting in a flood-prone area has caused negative impacts on the plantations themselves.

The previous logging of forests and planting oil palms has also had an adverse impact on biodiversity (Fitzherbert et al., 2008). However, the advantage of oil palms is that its long lifespan enables the development of a stable ecosystem compared to other annual oil crops (Alam et al., 2015).

Although profitability has the highest priority in the industry, the thinking of the industry about environmental protection has gradually been changing in the past years. As a result, management practices in plantations and processing companies have become more environmental-friendly. Several interviewees also stated that the EPD has become stricter in its enforcement in recent months. Hence, the environmental capital and its importance have become more important in Sabah.

Governance capacity

Malaysia is seen as a politically and economically stable country with reliable policies. As a result, Malaysia has experienced economic development, which is reflected in a steady annual GDP growth of 6.5% between 1957 and 2005 (Amran & Devi, 2008; Hagenmeier, 2015). The GDP of the country is predicted to grow further between 5 to 6 % per year, and Malaysia aims to become a developed country in 2020 (Mutalib, 2017). However, the development of the

country is questioned, due to its ethnical division and corruption in the political system (Haque, 2003; Mutalib, 2017).

The population in Malaysia has a complex ethnical structure that is divided into several groups with their own religions, languages and cultures. Due to historical reasons, the ethnic majority, so-called Bumiputras or Malays have received special privileges and rights that influence most domains of society including politics, business and education (Haque, 2003). For instance, Malays may receive business incentives, and a certain proportion of study places at universities are reserved for Bumiputras. The preference of the Bumiputras affects the society as a whole, whereas Non-Bumiputras feel neglected and often leave the country (Haque, 2003). A few of the Chinese interviewees confirmed that they are disaffected with the current political situation. Nonetheless, it was difficult to assess to what extent the ethnical division affects the palm oil industry. Except that many well-educated people leave the country, which reduces the pool of human resources in the industry and that neglected ethnicities dislike making further investments into the palm oil industry.

The transparency of the political system is also questioned, due to cronyism and corruption issues (Hagenmeier, 2015; Mutalib, 2017). According to the Corruption Perception Index in 2016, Malaysia scores 49 out of 100 points, which clearly indicates that corruption occurs. In Sabah, a major corruption scandal has been revealed by the Malaysian Anti-Corruption Commission. Governmental officials of the irrigation and drainage department in Sabah are accused of having evaded RM 3.3 billion (470 million USD) from state accounts; money that was allocated to water projects in Sabah (Berita Daily, 2016; Borneo Today, 2016). This corruption case directly influences the resilience of the palm oil industry by reducing the construction of water harvesting and water protection schemes in rural areas (Borneo Today, 2016). Furthermore, in side notes, interviewees often touched on the topic of corruption cases between the government and palm oil industry.

Regarding MPOB, the private sector acknowledges it as the leading governmental agency in the industry, but most of the interviewees held back their opinion about the credibility of MPOB. Private sector stakeholders often mentioned that MPOB is strong in certain areas such as licencing, research and advisory. However, in certain subliminal remarks, they criticised certain outputs of this agency. According to them, the research done by MPOB is not aligned with the needs on the ground. Furthermore, there is no long-term vision in governing the industry. It was also said that EMPA, for example, is an association that is able to coordinate well with MPOB and can raise relevant issues to them. A MPOB officer also claimed that MPOB does not coordinate well with other governmental departments. This collaboration would be relevant to respond to certain issues such as rapid processing of land title applications.

Furthermore, the Malaysian healthcare system is regarded as relatively strong and well accessible for the whole society (CFE-DM, 2016). In principle, health care is affordable, accessible and seen as supportive in times of shock. For example, some smallholder farmers explained that they were informed about certain disease problems that appear during drought periods and they were given advice on how to prevent them.

Financial capital and profitability

In Malaysia, all employers are obliged to contribute to SOCSO, the Social Security Organisation, which provides social security protection for all workers. Employees are

provided with free medical care and financial assistance in case of accidents or disease. According to Chan (2015), other insurance such as flood insurances are insufficiently elaborated to support flood victims.

The palm oil industry does not receive any subsidies, except for replanting plantations. Because of the high profitability, the oil palm industry actors are imposed with high taxations. The taxes compromise of a corporate tax of 25%, a recently introduced Goods and Services Tax (GST) of 6% and a sales tax of 7.5%. If the oil palm prices increase, there is a so-called windfall profit levy of 7.5% or even 15% depending on the oil palm price. In addition, a fee of RM 13 (2.9 USD) per tonne of CPO is ascribed to MPOB. Other payments towards the government include CPO export duty, licencing and inspections fees and import duties on agricultural machinery (Hanim, 2016). In the article of Hanim (2016), it is estimated that the total taxes and fees of the palm oil industry contribute approximately RM 5.46 billion (1.23 billion USD) to the state coffers.

Information and learning

Several interventions increase the knowledge development in the industry. Most of the company managers have studied at a university in Malaysia or abroad. Palm oil specific knowledge is distributed through several industry journals, conference and events organised by the private sector or governmental agencies. Bigger companies invest money in their own research and development. The government-supported research is monopolised by MPOB, whereas the Faculty of Sustainable Agriculture at the University Malaysia Sabah have a small stake in research on oil palm.

Regarding records, MPOB keeps data on yields, stocks, prices and exports. However, further statistics is often not available, for instance, the applied management practices in the industry. MPOB also sets certain standards in the FFB and CPO quality that the industry needs to comply with.

Furthermore, access to information has improved in recent years through internet access. The quality, pricing and access to internet in Malaysia are rated as very good (Freedom House, 2015). Even the interviewed smallholder farmers had cell phones with internet access. Early warning systems and flood forecasts have been put into place all over Malaysia. There are 217 flood sirens, 84 flood warning boards, various systems on the dissemination of warnings through mass media broadcastings systems, public announcements as well as a hotline for disaster reporting (CFE-DM, 2016; Chan, 2015). The meteorological department records the weather changes all over Malaysia and informs about upcoming El Niño and La Niña appearances.

Transformability

It is difficult to assess the entire palm oil industry and the institutional and societal framework it is embedded in regard to its transformability. Therefore, only following indications can be noted.

The government has adapted to flood events by investing more funding in disaster risk management. Chan (2015) argues that the disaster risk management is on the right path, but there are still various improvements required. For example, the present approach should be

changed from a top-down to a rather horizontal approach that can increasingly empower the local communities.

Currently, the government has not given significant support to the victims of the recent drought by El Niño. Hence, the transformability score is lower for drought than for flood events.

4.3.2 Input supply

Table 5: Resilience score for the input supply sector

Stakeholder	Input trading companies		Nurseries	
Attribute	Drought	Flooding	Drought	Flooding
Exposure to pressure				
Modularity				
Buffering capacity				
Environmental capital				
Governance capacity				
Profitability & fin. cap.				
Information & learning				
Transformability				

Exposure to pressure

The main consequences of El Niño phenomenon on the input suppliers was a decrease in product sales. Weeds are growing slower with less rainfall; therefore, companies apply less herbicide. Depending on the planting company's policy or the farmer's opinion, less fertilisers are applied and bought. Furthermore, plantations do not transplant seedlings during the dry season, so that sales of seedlings decrease during the drought event. However, all the interviewed businesses were able to endure this time of drought.

In contrast to El Niño, all the input suppliers mentioned that flooding had not been a relevant shock for them since their nursery or shops are in flood-proof areas. Flooding sometimes hinders the delivery of products for a few days; however, their sales are usually not affected.

Modularity

The interviewed inputs suppliers mentioned that especially in Sandakan, there is a high competition between trading companies. Nurseries, in contrast, are rather scarce in Sabah. All the input suppliers mentioned that they have several buyers for inputs; from smallholders up to big-scale plantations. In addition, trading companies also have a high variety of products, which they buy from many different national and international suppliers. Nurseries by contrast only sell oil palm seedlings as a product. This is a greater risk for their business in case their seedling production fails. However, nursery owners often have another income apart from their seedling selling business, such as their own plantation.

Buffering capacity

Spare financial capital is the most important buffering capacity for input suppliers. Most of the companies have own savings to overcome uncertain times. However, input suppliers mentioned that bank loans would be accessible, but the interest rate is so high compared to their margins that it is not worthwhile having a bank loan. In the case of nurseries, despite financial capacity, the most important spare capacity is water. Therefore, most of the nurseries have built ponds to store water, and most of them have installed irrigation schemes. Such infrastructure is a crucial asset in times of drought. Input traders also mentioned that they have sufficient storage capacity. However, none of the interviewees stated it as an exceedingly important asset to overcome a drought or flood event.

For nurseries, a limiting factor, especially during times of drought, is the availability of land, so that all the growing seedlings can be stored if they are not sold. One of the nursery owners stated to have made a significant financial loss since they needed to throw away a large number of seedlings due to insufficient space. However, most of the nurseries have sufficient land for their production.

Environmental capital

As mentioned above, water is one of the most important factors of running a nursery during times of drought. All the interviewed nurseries had an irrigation scheme. However, only half of the interviewed nurseries applied mulching on the polybags to preserve water and minimise weed growth. Nurseries apply various synthetic fertilisers and herbicides to increase their production. They mentioned that organic fertiliser is relatively expensive compared to synthetic fertiliser. Input trading companies mostly sell non-organic products, since the demand for organic products has been low. Nonetheless, there are some pioneers that promote organic inputs.

Governance capacity

Input suppliers are self-reliant businesses that are able to make a fair living out of their activities. All interviewed input companies could endure and recover from drought and flood events. However, most of the interviewees expressed underlying criticism against the government since the government is not investing sufficiently in the palm oil industry and did not offer any support during their challenging time.

Financial capital and profitability

Input trading companies explained that in general, they had been able to make a profit. However, the past few months have been very challenging financially, due to the introduction of GST, the raise of the minimum wage and the recent El Niño event. They said that GST reduced the purchasing power of customers; therefore, they had fewer sales. The rise of salaries increased their management costs. Some of the input suppliers indicated that their sales decreased by 20% to 60% during 2016, because of the above-mentioned reasons. However, most of them acknowledged El Niño as a significant contributor to the high decrease in sales.

One of the main issues in the input business are low margins; especially for fertilisers, which are around 3 to 5%, sometimes up to 10% depending on the product. The margins can further be pressured by the high variability in the product prices on the market. Some input suppliers mention that they buy "fast-moving" products that sell quickly, to reduce their risk. In

addition, most of the interviewees said that bank loans are accessible, but the interest rates are compared to their margins so high, that it is not profitable to have a loan. Hence, companies only depend on their own savings during times of shock.

In principle, trading companies have insurances that cover buildings and stocks against fire and theft; they contribute to the governmental SOCSO fund for their employees, and they have insurance for their transport vehicles. Nurseries only have SOCSO for their employees.

Information and learning

In principle, input suppliers stated that their relationship with their customers is satisfying. They give free advice to their clients on how to use their products properly or how to do transplant seedlings. They also mentioned that the communication between them works very well and that the input delivery can be postponed without any complications in the case of flooding. Furthermore, it can be said that managers of input companies have a relatively high education standard.

For nurseries, the quality of seedlings is essential since it affects their customers for the next 20 years. Hence, nurseries actively monitor the quality of their seedlings and cull them frequently. However, it was noticed that nursery owners were not very well informed about the different hybrids on the market.

Transformability

It was observed that within the industry the focus is strongly on common products instead of experimenting with new products. Nonetheless, some pioneers evaluated and tested new products, for example, the inoculation of soil with mycorrhiza. Therefore, it can be stated that there is room for experimentation and innovation. However, it is still difficult to convince the majority of input suppliers to invest in new products.

Furthermore, it could be observed that trading companies often did not modify their company management, although drought had a significant influence on their sales. The managers of trading companies often replied that they do not know what to improve to be better prepared for a next drought or flood event. Nursery owners, on the contrary, think about how to prepare for a next drought. For example, they aim to sell more seedlings by pre-orders, so that they can plan their seedling production better and reduce their risk of not having any buyers during drought periods.

4.3.3 Smallholders

Table 6: Resilience score for smallholder farmers

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

The drought in 2015/2016 severely affected the interviewed smallholder farmers. They stated that their yields dropped immensely; depending on the smallholders, from 3 to 1 t FFB/month, 3 to 2 t FFB/month or even 12 to 2 t FFB/month. However, since most of the farmers do not keep records, it is difficult to state an accurate number of yield reduction. For smallholder farmers that were in the replanting stage, beetle attacks were the severest issue. Besides the high yield reduction, some of the farmers faced water shortage for their household consumption. Some even mentioned a case of cholera in their community, due to contaminated drinking water.

Depending on the area, some of the smallholder farmers have been exposed to flooding. Some mentioned floods that only last for one day, however in some areas flooding lasted for two to three weeks. Most of the farmhouses are built on posts to inhibit flooding of their houses. During a flood, FFB cannot be harvested; therefore, they lose one or two cropping cycles of the 24 cycles in a year. Besides flooding, excessive rainfall makes harvesting more difficult, and roads are muddy so that they often could not pass through with their trucks.

Modularity

Smallholder farmers have a high modularity regarding their number of suppliers and buyers. Depending on the location of their farm, they are able to deliver to more than one mill, which benefits them in case mills closes temporarily. However, mill managers also mentioned farmers that have a more than 50km to the closest mill.

Smallholder farmers primarily depend on oil palm for their farm income and have some fruits and chickens for home consumption. Some farmers sell their fruits and vegetables on the market. Other smallholder farmers have an additional income source such as a governmental pension. The most relevant source of money is the support of children that have a job outside of the farm and that still support their parents.

Buffering capacity

As stated above, water access was a major problem for farmers during times of drought. Although some of them have water tanks and ponds for water harvesting, their water supply was often not sufficient to meet the household needs. One of the reasons is that the government has not built water pipelines in certain areas to provide fresh drinking water to the local communities.

Most interviewed smallholder farmers could sustain their basic living needs in times of drought or flooding, because of additional income or support from a family member. If their housing area was flooded, the government supported them with boats, shelter and food aid. Most of the farmers were content with the given rescue support from the government.

Environmental capital

Palm oil as explained in Section 4.2.1.2, is compared to other crops very resilient towards drought and flooding. However, there is a big difference between the proposed best management practices by big industry players and the management practices that smallholder farmers implement. Hence, the average yields of smallholder farmers in Malaysia are around 17 t FFB/ha/year compared to the national average of 21 t FFB /ha/year (Government of Malaysia 2010). The reason, therefore, is that most of the smallholder

farmers do not have a scheduled fertilisation plan, pruning is often not done as required, no cover crops are sown, and most of them do not apply EFB. Consequently, yields are lower, erosion increases during higher rainfall and the moisture retention in the soil is lower compared to bigger estates.

Governance capacity

Smallholder farmers have a decent living standard, which means that they are able to provide sufficient food for their families, they have an acceptable housing standard, and their children can go to school. Some smallholders even earn enough money to lease a four-wheel car, so that they can transport FFB to the mills themselves. However, the communities pointed out the lacking support of the government concerning road system or the water supply for their households. As discussed in Section 4.2.3.4, one of the biggest issues for smallholders is their access to land titles. Many farmers stated that the government support in processing their land titles is minimal and that it costs them lots of money to go through the application process. Furthermore, interviewees revealed that smallholder farmers often do not plan their next business step or prepare for an anticipated shock, since they often lack the financial capacity or the knowledge to improve their farming system.

Financial capital and profitability

Smallholders are usually not insured, except for the leased cars, which are required to have insurance. Palm oil production has increased in popularity over the past years since it is a very profitable crop. Many farmers have stated that they used to cultivate rubber or paddy, but since oil palm gives a higher revenue, they changed their farming system. Smallholders receive a monthly payment from the mills. Since the drought event lasted for several months, the income of the smallholders was highly decreased, although the higher market prices in this period absorbed a share of their loss. Nonetheless, most of the interviewed farmers could maintain their basic living needs during the drought period. The smallholder farmers also stated that it is challenging to find sufficient farm workers (see Section 4.2.3.3). However, they have a clear advantage in terms of their flexibility in hiring and dismissing workers compared to big plantations; thus they often do not hire any workers in times of shock.

Information and Learning

A visible difference in the knowledge of palm oil production and the management skills could be observed between smallholder farmers and plantations. Smallholder farmers often learned about oil palm growing from their neighbours or by having worked in plantation themselves. Only a few have received training from the government when venturing into palm oil cultivation. Furthermore, most smallholders have mentioned that they do not receive any or very little support from extension officers. Consequently, access to knowledge on better management practices is low. Nonetheless, smallholder farmers have gained much experience in growing oil palm, since they have been in palm oil production for several years. Smallholder farmers stated to have access to weather information through their television; however, the weather broadcasts only inform on the regional and not the local weather. Most of the smallholder farmers also do not keep records of their yields, their fertiliser and herbicide application. The majority of the interviewed smallholder stated to have a good relationship with the mill and once a year they receive training on fertiliser application or grading of the FFB quality.

Transformability

Most of the interviewed smallholder farmers did not change anything about their farming system after the drought or flooding period. Their ability to improve their system is constrained by their lack of knowledge and their lack of financial capital to adapt the system towards shocks. However, the farmers at the workshop were keen to listen to other stakeholders and how they adapted their plantation to weather-related shocks.

4.3.4 Plantation

Table 7: Resilience score for plantations

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

All the plantation companies stated clearly that El Niño phenomenon event 2015/2016 affected their yields severely in the short-term. Some specified that their yield loss was around 15% to 30% and some stated a loss of 50% in some month at the beginning of 2016. Some of the well-informed interviewees referred to the mid- and long-term effects of lower precipitation on yields as described in Section 4.2.1.2. For this reason, the recovery from the experienced drought will require around three years.

The actors that experienced flooding several times said that flooding mostly lasts between one day up to one week, whereas some major flood events lasted for two to three weeks. The inaccessibility of roads and planted areas is one of the major issues of flooding. Consequently, harvesting of FFB is hindered and yields decrease. Additionally, FFB quality is usually lower, because of the higher water content of fruitlets and their contamination with dirt. The transportation of FFB is also more difficult for plantations. However, plantations are well-prepared for flood events and are usually able to recover within a few days.

Modularity

Plantations have the option to sell their produce to several mills. However, they mostly sell to the nearest mill, so that they can save transportation costs. In the North-East of Sabah, there are only a few mills; therefore plantation owners in this area are constrained in their choice.

A positive factor in regard to modularity is that plantation owners can buy inputs from various input suppliers. Natural inputs such as mulching are from internal sources, whereas synthetic fertilisers are purchased from different companies. The most critical issue is that plantation companies heavily depend on oil palm cultivation as a source of income. Nonetheless, some companies have diversified into other business sectors as well.

Buffering capacity

Most of the interviewed plantation managers reported that the recent drought affected their business, but they were able to overcome this time since they have sufficient savings as a financial buffer. Another relevant buffering capacity is water. All the plantations mentioned that they could provide sufficient drinking water for their workers. However, the high water requirement of oil palms could not be met during drought. Plantations do not have any irrigation schemes installed since the investment is too high.

Concerning flood events, plantations that are in a flood-prone area have boats to harvest or rescue people. Some of the bigger companies also mentioned that they support the surrounding communities in times of flooding with rescue boats, shelter and food provision.

Environmental capital

There is a tangible difference in the management practices of plantations. Nonetheless, in the recent years through the demand for sustainable palm oil, plantations have started to improve their management practices in being more environmental-friendly.

Mulching with pruned palm fronds is a common practice that enhances soil structure and the water retention in the soil. Furthermore, it is common for plantations to plant leguminous cover crops during the replanting stage to reduce soil erosion, to fix additional nitrogen and to contain more moisture in the soil. Some companies add EFB, whereas other companies stated that they do not have sufficient workers to recycle EFB. Plantations heavily depend on external nutrient inputs to achieve higher yields. Fertiliser applications are applied four times a year according to the requirements in the given season.

Moreover, the environmental standards for plantations have developed in the past years. For example, plantations are required to leave a certain distance between the river and the plantation to inhibit fertiliser run-off into the river. Another example is that no palm oil cultivation is allowed in steep slopes to prevent soil erosion.

Governance capacity

All the plantation companies are facing the issue of labour shortage. On the one hand, this negatively affects the FFB yield, since there are not enough workers to harvest or to manage plots properly. On the other hand, it has a positive effect for the workers, since companies are committed to improve their living conditions and working environment. The interviewed plantation managers mentioned that they provide housing, electricity as well as water for their workers. In bigger companies, they also provide a small clinic for basic health needs and schools for the children of their workers.

During El Niño period, workers were still given work, but since a lot of work is payed piece-rated bases; the income of workers decreased. However, companies compensate this income loss by paying at least the minimum wage of RM 920 (207 USD). A relevant factor is the management of the company; big plantations are often very well-organised and structured. However, one of the association members of EMPA argued that big cooperations have three main levels of management: shareholders, company management and plantation management, whereas smaller companies only have one management level. Consequently, one-management-level companies are more flexible to reorganise and adapt to upcoming

disturbances. Concerning droughts and flooding, plantation companies are aware of the related risks and have developed several emergency practices to adjust to these situations.

Financial capital and profitability

In general, plantation companies stated that oil palm plantation is a very profitable business compared to other crops such as rubber or cocoa since the market is less volatile and the prices are high. Plantation are still able to make very high profits in successful years, despite the heavy taxations (see Section 4.3.1). Plantation owners reported that there is no substantial risks, especially if the land was acquired in the previous decades when the land prices were comparatively low. Most of the interviewed plantation owners said that they could generate savings and hence, they were able to overcome the profit losses caused by drought. The profit losses caused by flood events are even smaller since the yields effects are much lower.

Information and learning

The indicator of information and learning displays a relatively high resilience for plantation companies. Mostly plantation managers have a university degree or they have several years of experience in managing plantations. Interestingly many plantation owners do not have a professional background in agriculture, but they learned about the relevant practices and the industry dynamics over the years. Most of the owners showed broad knowledge on agronomical management and palm oil markets. There are also several seminars and conference by MPOB, NGOs or companies themselves. Besides that, further knowledge is accessible through various newspapers, journals and brochures. Furthermore, plantations can call an expert, if they need advice. Bigger cooperation employed their own agronomists. Usually, plantations have a strict record keeping on rainfall, FFB production, fertiliser and pesticide applications and further factors such as soil fertility. In addition, they also do yield estimations for the coming weeks.

Transformability

Many interviewees had a very constructive thinking and recognised the various challenges of the industry well. As discussed in Section 4.2.3.5, one of the main topics in the industry is sustainable development. Especially big cooperations have realised that their image is increasingly depending on the display of sustainable activities; hence they have started to change their practices. Consequently, there has been a change of thinking on environmental issues within the whole industry. Many of the interviewees were aware of the environmental challenges such as soil erosion, deforestation and excessive fertiliser application.

Regarding El Niño, most of the plantation managers have adapted to drought in the short-term, by applying less fertiliser or herbicides and by changing their work scheduling. Some planters pointed soil and water conservation practices such as closing the drainage canals, building silt pits and terraces, planting cover crops and applying mulch. In addition, some plantation managers mentioned that financial management (savings expenses, cash-flow management,…) is of great importance to overcome a drought period. Nonetheless, it was difficult to assess if plantations generally are well-prepared for a future drought. In comparison to drought, plantations that are in flood-prone areas, showed a high adaptive capacity towards flood events.

4.3.5 Mills

Table 8: Resilience score for mills

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

Most of the mills were affected by the El Niño phenomenon in 2015/2016 since their FFB supply was significantly lower. As a result, mills had a lower running capacity and shut down their mills for one or two days a week. The additional time was used to do maintenance work, but some of the mill managers expressed it as a challenge not to have sufficient work for their workers. One or two of the interviewed mills did not experience any negative effects since the supplying plantations had been in the process of replanting and therefore their supply had already been low in the months before. All the interviewed mills explained that they were able to recover from the drought impacts.

In contrast to drought, the majority of the mills have not been affected by flooding. The main reason is that since the establishment of a mill is a high investment, the position of the mill is planned in flood-free areas. Nonetheless, some mills experienced a reduction in their FFB supply, if the surrounding plantation area was flooded. In addition, their road access can be blocked, so that no delivery of CPO or FFB is possible. The most serious effect of higher rainfall is the effects on the FFB quality and thus on the CPO quality. Mill managers pointed out that FFB have a higher free fatty acid (FFA) content, a higher moisture content and the collected crops are dirtier so that the impurity of CPO is higher when there is higher rainfall.

Modularity

In general, since the distribution of mills in Sandakan division is relatively compact, the higher competition for FFB supply may negatively affect a mill. On the reverse side, if a mill has a break-down or is not able to process all the supply, there are sufficient options to divert the crops. A further positive aspect is that mills depend on several farmers; some mentioned 50 to 200 farmers for their FFB deliverance. Mills also spread their risk in hiring at least two transportation companies, in case one transport companies fails to take their order. One of the weaknesses of mills is that they only depend on CPO production in their activities. However, it remains uncertain how many companies have ventured into other business activities to balance this risk.

Buffering capacity

One of the major restrictions of mills is that they cannot store FFB longer than 48 hours. CPO, on the other hand, can be stored in tanks. Thus, mills have storage tanks between 1500 tonnes to 7000 tonnes, which is around 3 to 10% of their annual production depending on the mills

capacity and policy. Storage tanks are a major benefit in times of flooding when the road system is blocked and no transportation is possible. In addition, mills are required to pay a penalty, if their FFA concentration is higher than 5%. To handle this issue, they store CPO with a very low FFA content, so that they can blend it in if the FFA content is too high of newly produced CPO.

Furthermore, the interviewed milling companies have the most critical spare parts of their machinery in storage, so that a break-down can be remedied as fast as possible and the operations are not interrupted for long. Regarding drought, the major issue is water scarcity. Most mills have ponds for water-harvesting; nevertheless, the harvested water was not sufficient for all the mills. Therefore some needed to buy water and transport it to the mill site. However, all the mills that mentioned to have had water scarcity, have already built more ponds.

Environmental capital

Depending on the policy and finances of the mills, maintenance of the road infrastructure as well as of their machinery appears to be good. Mills even have their own electricity supply through a boiler and a spare generator-set as a back-up. Mills have advanced in recycling their waste by using fibre and shell for their boiler and they are sending the EFB back to the plantations. POME used to be released into the river, which led to severe water pollution in several rivers. However, through the new government regulation, the mills effluent is required to be below 20 parts per million. Hence, mills were obliged to change their management practice and invest into new technologies. However, the production of methane gas from the POME treating ponds is still a concern. Therefore, the government has launched an initiative, that all mills are compelled to install a biogas plant to reduce greenhouse gas emissions until 2020 (Government of Malaysia, 2010).

Governance capacity

Especially mills that need to comply with a certificate, such as International Sustainability and Carbon Certification (ISCC), are required to improve the living conditions of their workers. Mills usually provide housing, a small health clinic, clean water supply and electricity for their workers. However, there are still huge disparities between mills, whereby some of them are deficient in their care for the living conditions and the security of their workers. Furthermore, it can be stated that mills are mostly well-organised in their management and their activities. The interviewed mill managers stood out in their ability to anticipate problems and find a solution for them. Mills also do not depend on government support during times of shock but have the capability to overcome the challenges themselves.

Financial capital and profitability

Mills are in general well covered by insurance of their workers and their machinery. Compared to plantations, mills usually have sufficient workers for their operations. The interviewed mill managers stated that milling is a not very risky investment except investments into biogas plants. As mentioned the government pressures mills to establish biogas plants until 2020, but the cost of such a plant reaches up to RM 10 million (2.25 million USD). It was stated as a high investment especially for smaller milling companies. The profitability of mills is highly dependent on the global market price of CPO (see Section 4.2.3.2). Therefore, companies mostly have high financial capital, which supports them to endure and recover from shocks.

Mills have a financial scope in selling their CPO; either they sell on “spot” or by the so-called "MPOB pricing". MPOB pricing means that mills announce the quantity of CPO that they will sell at the end of the month, and then MPOB releases the average monthly price at which the declared CPO will be sold. Whereas selling on spot aims to sell CPO when the prices peak. Hence companies speculate to reach the ideal moment to sell their produce. The upside of the recent drought is that the prices on the market increased. Hence the high production cost could be buffered to a certain extent. One company mentioned that during the time of drought, they were losing money since they could not meet the declared quantity. Thus, they were obliged to buy CPO on the spot market, where the prices were significantly higher than the average monthly price.

Information and learning

Information and learning scored a high resilience level, because of the high knowledge and experience level of the actors as well as good access to information and advice. All the interviewed mill managers have studied engineering, and most of them were very experienced in dealing with issues on the ground since they gained much experience through their milling career. Besides that, companies have training funds for their employees. Workers receive different internal training for example on safety operations and the mill managers obtain new information from conferences or technical training from consultants. Companies that are certified have a prescribed number of training days that employees need to receive. Mills also record the obtained quantity and quality (Deterioration of Bleachability Index [DOBI], FFA, moisture and impurities content) and they also grade the FFB before processing.

Transformability

As mentioned already, mill managers have a very constructive thinking and are eager to improve their processes as much as possible. Furthermore, mill manager said that the compliance with certifications, such as RSPO or ISCC, have improved their safety and health standards and their emission control. Stricter enforcement and unexpected spot checks of governmental agencies such as DOSH and EPD have also advanced the mill operations and standards.

Moreover, mills have already learnt their lesson from the recent drought event and have already improved their water management by building new ponds or recycling water more diligently. The same transformability pattern can be observed with flooding, mills have adapted well to the recurring event by increasing their storage capacities for CPO, diesel and spare parts as well as preparing for the shock early. In conclusion, mills have a high capability of facing weather-related shocks.

4.3.6 Refineries

Table 9: Resilience score for refineries

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

The interviewed refinery employees stated that the main issue during the drought season was a decline in CPO supply. Consequently, the running capacity of the whole refineries was lower and processing cost per unit increased. One the other hand, CPO quality is better during dry weather conditions compared to normal circumstances. The higher CPO quality is characterised by lower impurities levels, lower FFA concentrations and higher DOBI scores.

These parameters are opposite during excessive rainfall. Therefore, refineries have higher processing cost for degumming and bleaching of CPO. During times of flooding, some of the mills are hindered in delivering their CPO, which prolongs the storage period and therefore the quality decreases as well. However, none of the refineries experienced any flooding events on their processing sites, which makes them more resilient towards this shock. All the interviewees claimed that they were able to recover well from drought and flood events.

Modularity

In the recent years, the number of refineries in Sabah has increased to eleven; consequently the proportional share of CPO supply per refinery has decreased. This high competition especially affects the refineries during drought periods, when the total CPO supply in Sabah is lower.

Refineries receive their CPO supply from several mills (around 15 to 40). Hence, the risk of not receiving CPO supply on time is spread over several suppliers. Refineries also have several buyers all over the world, but in regard to resilience towards drought and flooding this fact is negligible.

Buffering capacity

Financially, most of the refineries have sufficient buffer capacity since they are often large corporations with enough funds to overcome a disturbing time. However, some of the refineries did not have sufficient water for steaming. Nonetheless, refineries can buy water outside of their company and transport it with tankers. Therefore, they will not run out of water, but as a consequence their processing cost increases.

Refineries recognise the importance of having sufficient storage capacities. The interviewed refineries claimed to have between 85,000 to 175,000 metric tonnes of storage capacity for CPO and processed products, which enables them to store products for several weeks.

Particularly during seasons of high precipitation, additional storage capacity is needed when the CPO production increases or if the shipment is delayed due to a stormy sea. Refineries also store the most critical spare parts for their processing plants in case of a break-down. Besides that, refineries also have an own gen-set in the event of electricity cut-downs.

Environmental capital

The most relevant environmental capital factors concerning flooding are the condition of infrastructure such as buildings and roads, electricity supply and communication infrastructure. Many interviewees had the opinion that the current communication system and electricity system in Sabah, requires improvement, whereas company properties such as the plants or access roads are in good condition.

Most of the refineries are ISCC certified. However, it remains unclear, what the influence of this certification is on the resilience towards drought or flooding. Water is the most critical aspect regarding environmental capital. Hence, refineries increasingly address this issue by recycling water within the plant.

Governance capacity

In times of shock, refineries rely on company measures and do not receive any additional governmental support. Refineries are characterised by high leadership skills. Most of these enterprises do long-term planning, and company employees revealed a good understanding of the effects of drought and flooding. They were also able to mention the required interventions to overcome such a shock. Companies usually have the necessary skills and knowledge to implement them. Hence, the governance capacity can be rated as very high towards drought and flooding.

Financial capital and profitability

The resilience score of financial capital and profitability for both shocks is high. One factor is that refineries have sufficient labour force to conduct the process and they developed towards more automated processes. Furthermore, refineries are well covered with insurance towards work accidents, machine breakdowns, infrastructural damage and product transports. Another factor is the profitability of refineries in Sabah. An interviewed refinery manager claimed that older refineries in Sabah have a higher profitability compared to newly constructed ones. New refineries have higher financial risks since they have higher investment costs to pay off.

One interviewee also said that the market price is more relevant than the given CPO supply in regard to their profitability. In times of drought, the prices have been relatively high; therefore the supply shortage was balanced out by increased market prices. Interviewees stated that flooding only affected their processing cost, but the effect on the total profit was insignificant for them.

Information and learning

The interviewed managers demonstrated a high level of knowledge about the processes and challenges within the industry and had several years of experience. Companies also invest in training their staff through internal as well as external training by the government, certification schemes or other relevant actors. Refineries also attribute high importance to record keeping and quality control. For example, from every entered tanker, a sample is taken

to measure FFA content, DOBI, moisture and impurities content. Besides that, refineries have started to recognise the importance of trustworthy relationships to mills, so that they can maintain and gain a greater share of CPO supply in Sabah. In general trust between mills and refineries was rated as high.

Transformability

It could be observed that refineries are open-minded to improve their practices in order to be better prepared for a future drought or flooding events. As soon as the companies' profitability is at risk, companies are willing to modify their management. However, not many interventions were mentioned by the interviewees to enhance the resilience of their companies. The reason might be that the overall resilience of refineries appears to be relatively high compared to other value chain actors. One supply chain manager pointed out the importance of better water management through water catchment ponds, water conservation and recycling practices. Another employee said that the company aims to improve their marketing strategies, so that they can increase their CPO supply.

4.3.7 Transportation

Table 10: Resilience score for transport companies

Attribute	Drought	Flooding
Exposure to pressure		
Modularity		
Buffering capacity		
Environmental capital		
Governance capacity		
Profitability & fin. cap.		
Information & learning		
Transformability		

Exposure to pressure

Most of the transportation businesses were severely affected by the El Niño phenomenon. All the interrogated transportation companies claimed that the numbers of orders for CPO transportation decreased massively in 2016. Some stated a reduction of 20 to 30% in their orders, whereas others experienced a decrease of 50 to 60 %. Nonetheless, most of the companies said that they were able to endure the drought period and recover steadily from it.

In contrast to drought, transport managers indicated that flooding had not been a relevant challenge for them in the past years. Although at certain sites yearly flooding occur, the companies have adapted well to this disturbance. Transporters explained that mills call them if access roads are impassable, so that they can delay the transport. One challenge is that the road conditions are worse during rainy seasons, especially if the mills do not maintain their access road properly.

A major problem in the management of transportation companies are frequent accidents and truck breakdowns. The reason therefore are poor road conditions, inadequate maintenance of trucks and dangerous driving style of the truck drivers. One transport manager

unexpectedly pointed out that accidents happen more often during dry periods than during rainy seasons since car and truck drivers speed more often.

Modularity

Interviewees in Sandakan replied that the competition between transport companies is relatively high. They mentioned that most of the mills have two or three hired transportation companies as measure of diversifying their risk. This may negatively affect transportation businesses in times of drought when demand for transport services are lower. However, transportation companies also have several mills as customers. The interviewed transport companies often had another source of income, such as oil palm plantation or timber logging business.

Buffering capacity

Companies that have been in the business for numerous years mentioned that they were able to overcome a drought better due to their savings. A further relevant buffering capacity includes the storage or access to spare part, to react rapidly if there is a truck breakdown. Some companies store spare parts and others do not. In Sabah, the access to basic spare parts has improved in the past years since there are more hardware stores. However, more specific components are often ordered from the Peninsular with a long delivery time of around one month or very high transportation cost, when transported by plane. In addition, transporters stated that they have at least one spare truck, in the case of a breakdown.

Environmental capital

For transportation companies, the environmental capital in regard to the resilience towards drought and flooding focuses on the condition of their built resources. One major concern of transporters is the poor road infrastructure in Sabah that significantly affects their activity. Due to the bad road performance, transport companies experience frequent truck breakdowns, tires need to be changed often, and the probability of accidents is high. Consequently, transport owners bear increased costs. A further factor is the condition of trucks, which heavily depends on the company's policy and management. Although there are some companies claim to invest much effort in maintaining trucks in good conditions, there are many trucks that are not maintained well.

Governance capacity

Transportation companies provide a fair living standard for their owners and workers. Since accidents and breakdowns are very common, some transport companies put greater emphasis on security measures. Most of the companies are also prepared to send out a mechanic team or a replacement truck in the case of a breakdown. However, due to economic reasons and the reduced number of orders, transport owners are challenged to sustain their companies through the current disturbances. However, it is hard to evaluate how well they can recover from it.

Financial capital and profitability

Flooding is only an organisational issue, since the timing of transport shifts, but does not affect them significantly income-wise, whereas the recent drought has affected their profit highly. Most of the companies could only cover their expenses or were in the red.

Although the business of transportation is not risky, the interviewed transport companies pointed out that because of the high competition and the low margins for transportation, they would not invest into the transportation business anymore. Companies had sufficient savings to overcome the current economic challenges such as lower orders, the rise of minimum salary and the introduction of GST. However, transportation companies are uncertain how stable their business will be in the future. Therefore, companies depend on their own savings, except for buying a new truck, they sometimes take loans from the bank.

All the interviewed managers claimed to have insurance for their trucks, their drivers as well as for the CPO in case of a breakdown. However, health insurance for drivers is mostly not provided, due to high cost. Concerning the labour market, transporters stated that they face difficulty in finding well-trained mechanics and drivers. Due to the high seasonal variability of supply, some transport companies employ their drivers temporarily, whereas others give them an extended holiday during the low season.

Information and learning

The knowledge and experience level of the company managers depended on the size of the companies. The investment into education is minimal; companies only do internal training concerning safety issues for drivers. They also claimed that mechanics usually do not have a mechanical education, but only developed their skills by working. Besides that, transportation companies claimed to have a good relationship with their customers and that their communication usually works well.

Transformability

The well-educated transport company owners indicated how to improve a future shock by keeping tight stocks, good cash-flow management and reducing their debt. Furthermore, they also emphasised the importance of their company image in regard to security measures and reliability. Concluding it can be stated that companies are open for change since they see it as a necessity to sustain their business in the future.

4.3.8 Comparison of resilience towards drought and flooding

Table 11: Summary of resilience score towards drought of the whole value chain

Value chain step / Attribute	Input supply		Production		Processing		Distribution	Whole value chain
	Input Traders	Nurseries	Smallholders	Estates	Mills	Refineries	Transporters	
Exposure to pressure								
Modularity								
Buffering capacity								
Environmental capital								
Governance capacity								
Profitability & financial capital								
Information & learning								
Transformability								

Table 12: Summary of resilience score towards flooding of the whole value chain

Value chain step / Attribute	Input supply		Production		Processing		Distribution	Whole value chain
	Input Traders	Nurseries	Smallholders	Estates	Mills	Refineries	Transporters	
Exposure to pressure								
Modularity								
Buffering capacity								
Environmental capital								
Governance capacity								
Profitability & financial capital								
Information & learning								
Transformability								

Resilience Score	Very low resilience	Low resilience	Medium resilience	High resilience	Very high resilience

Exposure to pressure

All the stakeholders have a high to very high resilience score in exposure to pressure concerning flooding, whereas the scores for drought are low to very low. This vast difference indicates that drought has severely affected the operations of the various actor in the palm oil value chain compared to flood events. The variation can also be ascribed to the long recovery period of drought compared to flooding and that some of the stakeholders have not been significantly affected by floods.

Modularity

The resilience level of modularity for flood and drought events is in general medium. However, for certain stakeholders such as input suppliers, transport companies and refineries the resilience level is higher for flood events. The reason, therefore, is that the competition between these actors is greater during times of drought and in times of flooding a larger number of suppliers is of greater importance.

Buffering capacity

In summary, the buffering capacity is higher for flooding compared to drought. For drought, low availability of water, which many stakeholders struggled with, is a major indicator for the lower buffering capacity score. Furthermore, the lower impact of flooding on the financial capital of the various stakeholders also increases the buffering capacity score in regard to floods.

Environmental capital

Environmental scores are similar for all the value chain steps for drought and flooding. The relevance of built resources is higher for flood compared to drought events. Natural resources, on the other hand, are crucial for both shocks. For drought events, the availability of water and water conservation practices in the soil are essential. For flooding, on the other hand, practices to reduce soil erosion and nutrient leakage are of great importance. Various practices such as cover crops increase the environmental capital scores for flooding and drought.

Governance capacity

Governance capacity scored the same resilience level for both shocks. The explanation, therefore, is that attributes as long-term planning, management skills and the ability to self-organize are crucial in overcoming both shocks and are hence shock independent.

Information and learning

All the value chain actors have the same level of resilience concerning information and learning by comparing the two shocks. The reason, therefore, is that the various attributes (knowledge and experience level, trust between actors, …) are equally relevant for both shocks. Plantations, mills and refineries have a very high resilience level, smallholders, in contrast, have a low score.

Profitability and financial capital

Financial capital and profitability indicator appears to be shock-independent. Although drought affected the profits during the shock, assets such as sufficient labour or savings are relevant to endure and recover from drought and flooding.

Transformability

In general, transformability scores tend to be higher for flood compared to drought events. The major difference is that most value chain steps have adapted their operations more towards flooding over the past years.

Summary

In summary, the resilience of the palm oil value chain is higher towards flooding than towards drought. The resilience scores for governance capacity, information and learning, profitability and financial capital are relatively similar comparing drought and flooding. By contrast, exposure to pressure clearly reveals the highest difference of resilience scores. Buffering capacity, modularity, environmental capital and transformability tend to be in the same range of resilience but differ for certain actors.

4.4 Building resilience in the palm oil value chain in Sabah

4.4.1 Stakeholder workshop

The results of this section were elaborated during the stakeholder workshop (see Section 3.4). The participants of the workshop discussed, which interventions are most important for their activity to overcome a prospective drought. The government group discussed interventions for the whole value chain.

Table 13: Summary of proposed interventions against drought of workshop participants

Process / Intervention	Smallholders	Estates/ Input supply	Mills	Whole value chain
Water management	2	2	1	1
Soil conservation		2		1
Trust between actors			3	
Savings				3
Income diversification	1	5		2
Self-organization/Management		1	2	4
Governmental support	3	4		5
Quality of input sources		3		

Smallholders

Smallholder farmers pointed out two key areas for improvement. One of the biggest issues for the smallholders is their insufficient access to water during drought. Hence, they proposed various interventions to improve the availability of water for their households and farms. They argued that the government should provide water pipelines so that they have access to clean drinking water. Furthermore, they discussed that they could harvest and store water by building ponds and setting up water tanks. The other key intervention addresses their high dependency on oil palm production. Smallholder farmers suggested diversifying their income, for example by planting vegetables as an additional income source.

Input supply & estates

This group included nursery owners, trading company managers and plantation owners, hence their interventions address the input supply and plantations. These participants clearly put emphasis on the importance of governing their businesses properly and being proactive in their management. They argued that companies need to be able to have independent decision-making power as well as the ability to adapt their practices towards a shock event. Plantations and input supplier are required to come up with new ideas to adapt their activities to the new challenges.

The second most important measures should focus on soil and conservation. This group argued plantations should build pits and terraces for water retention as well as building and adapting their drainage system to retain additional water. Moreover, plantations require harvesting reservoirs, so that workers and surrounding communities can be supplied with clean drinking water.

The third intervention focuses on improving quality inputs. Input trading companies should focus on adapting their product range towards more drought suitable products.

All of them agreed that the government is required to improve the water availability by constructing dams and water pipelines. Apart from this, the government is responsible for adequate firefighting and maintaining the road system well, so that in the case of fires, fire engines would reach the emergency area faster.

Lastly, these participants debated about increasing the modularity of their activities. In the case of plantations, they could diversify their crops to reduce their dependency on oil palm, whereas input suppliers should expand their customer portfolio.

Mills

This group consisted of mill managers, which were very determined and very particular about their interventions. Firstly, they stated that it is necessary to improve the water management. Mills should increase the water availability by expanding their water catchment areas as well as by increasing the efficiency of their machinery. They stated that the boiler and turbine have the highest water consumption; therefore they needed to regulate them more diligently.

The second intervention that the mill managers agreed on is the adequate management of their operations. They pointed out the importance of controlling their processes tightly during times of drought, to ensure high quality, reduce loss, achieve a high extraction rate and to reduce the processing cost.

Thirdly, they argued that the communication between the estates and the mills be essential so that mills receive FFB with high quality and are able to plan their operations. Therefore, efforts need to be made to building trust between mills and their suppliers.

Whole value chain

This group consisted of two government officials of the department of agriculture, an association representative of MPOA and staff from TFT that collaborate closely with smallholder farmers. Hence, this group discussed how the entire palm oil industry in Sabah

could build its resilience towards drought. However, their discussions were focused mainly on the plantation activities.

This group rated soil and water conservation practices as the most relevant area of improvement. They argued that more water catchment areas be required as well as to improve the management practices in the plantations. Secondly, planting fruit trees and keeping livestock were proposed as a measure of diversifying the income of farmers. They rated having sufficient savings to overcome times of drought as the third most important intervention. Furthermore, they stated that self-organization of farmers into cooperation or by joining an association as an appropriate step to address the challenges of drought collectively. This group also discussed how the government should support the industry. The critical point in their point of view was that the government should find the right balance in advising the industry versus enforcing certain measures to overcome a time of shock.

Workshop summary

According to the overall workshop discussions, three key areas of intervention were emphasised. Due to water scarcity, each activity needs to improve their water management by collecting, storing and recycling water. Furthermore, production systems are advised to improve their soil management practices to improve water retention in the soil. Furthermore, the various groups argued that management skills and self-organization be essential to prepare and endure for a future drought. In particular for smallholders and medium-size plantations, the diversification of their crops and incomes was debated as a necessary intervention, to reduce the dependency on oil palm and the related risks in times of drought.

Figure 19: Participants of second workshop

4.4.2 Summary of interventions

In Table 14, the key weaknesses of each value chain step are pointed out and potential interventions are listed that were mentioned during the second workshop and interviews.

Table 14: Summary of weakness in resilience and potential interventions

VALUE CHAIN STEP	WEAKNESSES IN RESILIENCE	POTENTIAL INTERVENTION
Input trading companies	• Low profitability • No modification of activities	• Product diversification → drought-suitable products • Expand customer portfolio • Encourage pro-active management
Nurseries	• Uncertainty of sales → loss of seedlings • Water availability	• Increase number of pre-orders • Water harvesting techniques • Water conservation practices
Smallholder farmers	• Water availability • Low productivity • Low financial capital • High dependency on oil palm • Low knowledge levels • Weak management skills • Land insecurity	• Water harvesting techniques • Water pipelines for clean drinking water • Soil and water conservation practices • Accumulate more savings • Income diversification • Improve extension and advisory services • Change land title procedures
Estates	• Water availability • High dependency on oil palm	• Water and soil conservation practices • Income diversification • Encourage pro-active management
Mills	• Lower water supply • Lower FFB supply	• Water harvesting techniques, water recycling • Strict process control, encourage pro-active management • Communication between plantations and mills
Refineries	• Lower water supply • Low CPO supply – high competition	• Water harvesting techniques, water recycling • Invest in the relationship with suppliers/ better marketing strategies
Transport companies	• Low profitability • Accidents	• Cash-flow management, debt reduction • Income diversification • Improved safety measures

Figure 21: Presentation of posters during the second workshop

Figure 20: Discussions during the stakeholder workshop

5 Discussion

5.1 Resilience of the cash crop value chain

The overall resilience of the palm oil value chain in Sabah is medium to high. The primary driver for the high resilience level has been the high profitability of this cash crop.

The high profitability of palm oil and its rising demand on the global market has stimulated investments of companies into various industry-relevant assets. Since palm oil companies were able to generate high profits in the past years, they were able to invest substantially into the development of their businesses. Companies spent money to increase their human capital such as hiring well-educated staff and making investments into their infrastructure, such as constructing good roads. Big companies such as Sime Darby or IOI established their own departments for research and development is another such example. Hence, it can be concluded that the high financial outputs of companies have increased the resilience in various key areas.

Due to the high profitability of palm oil, the government has also invested in the industry to promote economic development. The promotion of research, training and conferences by MPOB have increased the knowledge levels in the industry (Cramb & Curry, 2012; Lai et al., 2015; Rasiah & Shahrin, 2005). Further investments into rural road infrastructure and industrial clusters have supported the establishment of processing activities in Sabah. In the past years specific fiscal measures have also boosted exports of processed palm oil products (Lai et al., 2015; Rasiah & Shahrin, 2005). All of these interventions strengthened the palm oil industry in Sabah so that a relatively high resilience can be observed.

The palm oil industry has also been an essential driver for the alleviation of poverty in Malaysia (Lai et al., 2015; Rasiah & Shahrin, 2005; Teoh, 2010). It has become evident through interviews with smallholder farmers who cultivate oil palms, that they recognised that palm oil enables them to generate higher incomes compared to planting other crops. Consequently, their living standard has increased in the past years. Furthermore, the distribution of the palm oil industry has brought development to the rural areas. For example, the establishment of mills in remote areas enhances the infrastructural development and living standard of local communities. Hence, infrastructure such as access to electricity and road systems is improved and job opportunities are created. All these developments can be seen as positive food system outcomes and indicate a relatively high resilience of the system.

5.2 Resilience towards drought and flooding

This study has revealed that the palm oil industry is more resilient towards flooding than drought events. The comparison of these two climate-related shocks enables us to gain a better understanding of resilience, in regard to the different resilience indicators and the resilience of the stakeholder groups in the palm oil industry.

The significant difference in the resilience level of the indicator "exposure to pressure“ indicates that its resilience level is highly dependent on the type and characteristics of a shock. The impacts of flooding were less severe for the various stakeholders and the recovery time was shorter compared to the impacts of droughts. One crucial factor is the duration of the shock. Flood events only last for a few days, sometimes for a few weeks, but droughts last

several months. The higher resilience level towards flooding can also be explained by the higher occurrence of floods compared to droughts (CFE-DM, 2016). Consequently, actors have developed a greater capacity to react to flood events. For example, the disaster risk agencies are mainly specialised on managing flood events, whereas according to the interviewees the support during drought has been minimal. Cabell & Oelofse (2012) also argue that systems, which experience minor shock events, evoke the system to adapt and increase the resilience level in regard to exposure to pressure. Nonetheless, it should also be pointed out that the resilience score regarding drought and flooding might contain a certain bias. This study was conducted only a few months after a drought occurred and the stakeholders were still recovering from the disturbing event, whereas the last major flood event was years ago. Consequently, the stakeholders' awareness of drought effects was much higher during the study process than the awareness of flooding and thus, interview answers may have varied accordingly.

A comparison of the drought and flood-related results (Table 11 & Table 12) revealed that certain resilience attributes have shock-independent resilience scores. Governance capacity, information and learning as well as financial capital had the same resilience score for drought and flooding. Information and learning and governance capacity highly influence the ability of the stakeholders to manage their activities and react towards shocks. This ability is essential for any type of shock. High financial capital enables stakeholders to buffer income losses and to invest into needed capacities to overcome any shock. Other indicators show a higher dependency on the given shock. For example, a high buffering capacity to overcome droughts is storage of water, whereas this intervention is not as useful for flood events. Thus, it can be concluded that certain indicators contribute to the general resilience of the system, whereas other indicators have a higher shock-dependency.

The overall resilience score within stakeholder groups reveal similar patterns for both shocks. The most explicit difference is between the high resilience score of plantation, milling and refining companies compared to smallholder farmers. These companies are characterised by owning a high level of autonomy, well-developed management, strong financial capacity and high experience and knowledge levels, whereas smallholders in comparison show large deficits in all of these areas. As shown in (Figure 12), the palm oil companies are international players that also reveal the highest power in the industry, whereas smallholder farmers have little power. All of these results indicate that the industry has not been able to include smallholder farmers sufficiently in the positive developments of the industry.

5.3 Building resilience towards drought

Workshop participants pointed out that water management and soil conservation practices are the most needed interventions. Particularly, in the production and processing activities, water scarcity has been a relevant issue during drought; hence this intervention addresses a crucial problem. It is feasible for companies to address water harvesting techniques, since they have the required financial capacity and knowledge for the implementation. For smallholders, external support would be required to supply them with fresh drinking water or provide them with information on better management practices. Sutarta et al. (2016) confirm that debated water and soil conservation issues such as silt pits, bench terraces or pruning of palm fronds as essential strategies to face future droughts. Sutarta et al. (2016) also emphasise that adaptation strategies are available and that it is important to disseminate information on these practices. For plantation companies the access to such information

exists, whereas smallholder farmers have limited access to such knowledge (Azmi & Nagiah, 2013; Sutarta et al., 2016). This affirms the demand for improved knowledge access for farmers via governmental extension services or other supporting actors. However, the current extension services have not been able to meet these requirements, as most smallholder interviewees did not receive any or minimal extension support (Azmi & Nagiah, 2013; interviewees). In the Economic Transformation Programme, the government recognises this issue and states the objective to increase the ratio of extension officers from a current ratio of 1:950 to 1:250 officers per smallholders by 2020 (Government of Malaysia, 2010).

Diversification of income is a further intervention for smallholder farmers up to medium-size plantations that was rated as important by the workshop participants. This strategy aims to increase the modularity of the system and therefore distributes the risk of an insufficient income from several sources. Income sources could be diversified by the cultivation of other crops or by finding external farm income sources. Intercropping is a potential intervention, which would also increase the diversity of the vegetation and therefore strengthen the ecological resilience of the system (Corley & Tinker, 2015). One option is to plant crops such as maize or peanuts during the replanting stage. This intervention has already been promoted by MPOB to support the income of smallholder farmers. The implementation of intercropping with perennial crops has not been practised on a large scale in Sabah. The biggest challenge of intercropping schemes is to achieve the same profitability as with oil palm monocultures. The integration of livestock is a further option that promises a higher profitability (Corley & Tinker, 2015). A few pioneers in Sabah already include livestock on their plantations and MPOB also promotes livestock integration. Further research and experiments of the industry could reveal profitable options for diversifying farming systems.

The resilience of smallholder farmers can be improved by addressing the issue of land insecurity in Sabah. Tenaw et al. (2009) argue that their ownership of land highly influences the decision-making of smallholders. If their access to land is insecure, the risk of expropriation is higher and hence, farmers are less likely to make long-term investments (Martin et al., 2015; Tenaw et al., 2009). Therefore, farmers aim to maximise their productivity in the short-term, which hinders sustainable management of natural resources in the long-term (Landesa, 2012; Tenaw et al., 2009). Another aspect is that the access to credit is usually better with secure land ownership since it serves as a security for the money lenders (Tenaw et al., 2009). Furthermore, only smallholders with a land title are allowed to receive extension services from MPOB (interviewees). All of these arguments point out the need for change of the current land tenure procedures to increase the resilience of smallholder farmers.

5.4 Way forward

The agricultural sector in Sabah is highly dominated by the palm oil value chain, given that 87% of the agricultural land is covered with palm oil. Another 9 % is planted with other cash crops, namely rubber, coconut and cocoa. Only 4% of the land area is cultivated with paddy, the main stable crop, along with other food crops (Department of Statistics, Malaysia, 2016). Due to the high focus on cash crops, the food self-sufficiency level in Sabah was only 46% in 2010 (Suzuki et al. , 2015). Furthermore, 66% of the sold rice was imported in 2015 (Department of Statistics, Malaysia, 2016). Although the agricultural sector has a high resilience with regard to income generation, it is questionable, if Sabah can maintain its food security when facing shocks and disturbances. Therefore, further research on the food security aspect of the whole food system in Sabah is needed.

6 References

Abdullah, I., Hasrulnizzam Wan Mahomood, W., Hafidz Fazli Md Faudi, M., Nizam Ab Rahman, M., & Ahmad, F. (2015). Sustainability in Malaysian Palm Oil: A Review on Manufacturing Perspective. *Pol. J. Environ. Stud.*, *24*, 1463–1475. https://doi.org/10.15244/pjoes/37888

Alam, A. S. A. F., Er, A. C., & Begum, H. (2015). Malaysian oil palm industry: Prospect and problem. *Journal of Food, Agriculture & Environment*, *13*(22), 143–148.

Amran, A., & Devi, S. (2008). The impact of government and foreign affiliate influence on corporate social reporting: The case of Malaysia. *Managerial Auditing Journal*, *23*(4), 386–404. https://doi.org/10.1108/02686900810864327

Azmi, R., & Nagiah, C. (2013). A review of smallholder oil palm production: challenges and opportunities for enhancing sustainability - a Malaysian perspective. *Journal of Oil Palm, Environment and Health (JOPEH)*, *3*. Retrieved from http://jopeh.com.my/index.php/jopecommon/article/view/58

Basiron, Y. (2007). Palm oil production through sustainable plantations. *European Journal of Lipid Science and Technology*, *109*(4), 289–295. https://doi.org/10.1002/ejlt.200600223

Basiron, Y., & Yew, F.K. (2016). The burden of RSPO certification cost on malaysian palm oil industry and national economy. *Journal of Oil Palm, Environment & Health*, *7*, 19–27. https://doi.org/10.5366/jope.2016.02

Berita Daily. (2016, November 6). MACC seeks international help in Sabah corruption case. *Berita Daily*. Retrieved from https://www.beritadaily.com/macc-seeks-international-help-in-sabah-corruption-case/

Berkes, F., Colding, J., & Folke, C. (2003). Navigating social-ecological systems: building resilience for complexity and change. Cambridge, UK: Cambridge University Press. Retrieved from: http://www.cambridge.org/ch/academic/subjects/life-sciences/ecology-and-conservation/navigating-social-ecological-systems-building-resilience-complexity-and change?format=PB&isbn=9780521061841

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., Burnsilver, S., Cundill, G., … West, P. C. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources*, *37*, 421–448. https://doi.org/10.1146/annurev-environ-051211-123836

Borneo Today. (2016, November 6). Musa owes it to Sabahans to ensure corrupt-free GLCs, Accountability. Retrieved from http://www.borneotoday.net/musa-owes-it-to-sabahans-to-ensure-corrupt-free-glcs-with-accountability/

Brand, F. S., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and Society*, *12*(1), 23.

Bryan, J. E., Shearman, P. L., Asner, G. P., Knapp, D. E., Aoro, G., & Lokes, B. (2013). Extreme Differences in Forest Degradation in Borneo: Comparing Practices in Sarawak, Sabah, and Brunei. *PLOS ONE*, *8*(7), e69679. https://doi.org/10.1371/journal.pone.0069679

Cabell, J. F., & Oelofse, M. (2012). An Indicator Framework for Assessing Agroecosystem Resilience. *Ecology and Society*, *17*(1), 18. https://doi.org/10.5751/ES-04666-170118

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems*, *4*(8), 765–781.

CFE-DM. (2016). Malaysia: Disaster Management Reference Handbook 2016. Center for Excellence in Disaster Management and Humanitarian Assistance. Retrieved from http://reliefweb.int/report/malaysia/malaysia-disaster-management-reference-handbook-2016

Chan, N. W. (2015). Impacts of disasters and disaster risk management in malaysia: The case of floods. In *Resilience and Recovery in Asian Disasters* (pp. 239–265). Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-4-431-55022-8_12

Choong, C. G., & McKay, A. (2014). Sustainability in the Malaysian palm oil industry. *Special Volume: Making Progress Towards More Sustainable Societies through Lean and Green Initiatives*, *85*, 258–264. https://doi.org/10.1016/j.jclepro.2013.12.009

Choptiany, J., Graup, J., Dixon, J., & Phillips, S. (2014). Self-evaluation and holistic assessment of climate resilience of farmers and pastoralists (SHARP). FAO. Rome, Italy.

Chow, E. (2016, June 20). Malaysia in talks to move startup of B10 biodiesel program to July. *Reuters*. Kuala Lumpur. Retrieved from http://www.reuters.com/article/us-malaysia-palmoil-biodiesel-idUSKCN0Z60IB

Climate Prediction Center. (2016). Cold and Warm Episodes by Season. Retrieved from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Cooke, F. M. (2013). Constructing Rights: Indigenous Peoples at the Public Hearings of the National Inquiry into Customary Rights to Land in Sabah, Malaysia. *Sojourn: Journal of Social Issues in Southeast Asia*, *28*(3), 512–537.

Corley, R. H. V. (2009). How much palm oil do we need? *Environmental Science & Policy*, *12*(2), 134–139. https://doi.org/10.1016/j.envsci.2008.10.011

Corley, R. H. V., & Tinker, P. . (2015). *The Oil Palm*. John Wiley & Sons, Ltd. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9781118953297.refs/summary

Cramb, R., & Curry, G. N. (2012). Oil palm and rural livelihoods in the Asia–Pacific region: An overview. *Asia Pacific Viewpoint*, *53*(3), 223–239. https://doi.org/10.1111/j.1467-8373.2012.01495.x

Department of Statistics, Malaysia (Ed.). (2016). Statistics Yearbook Sabah 2015. Department of Statistics, Malaysia.

Ericksen, P. J. (2008). Conceptualizing food systems for global environmental change research. *Global Environmental Change*, *18*(1), 234–245.

Ericksen, P., Stewart, B., Dixon, J., Barling, D., Loring, P., Anderson, M., & Ingram, J. (2012). The Value of a Food System Approach. In *Food security and global environmental change*. Routledge. Retrieved from https://books.google.ch/books?hl=de&lr=&id=8lmsBwAAQBAJ&oi=fnd&pg=PR3&dq=Food+Security+and+Global+Environmental+Change&ots=AFKJuk5VTX&sig=PzwWtqp4vMyoTLAaJybbOoyxBb4

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brühl, C. A., Donald, P. F., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution*, *23*(10), 538–545. https://doi.org/10.1016/j.tree.2008.06.012

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, *16*(3), 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockstrom, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. Retrieved from http://www.treesearch.fs.fed.us/pubs/42598

Foster, W. A., Snaddon, J. L., Turner, E. C., Fayle, T. M., Cockerill, T. D., Ellwood, M. D. F., … Yusah, K. M. (2011). Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. *Phil. Trans. R. Soc. B*, *366*(1582), 3277–3291. https://doi.org/10.1098/rstb.2011.0041

Freedom House. (2015). Freedom on the Net 2015; Malaysia. Retrieved from https://freedomhouse.org/report/freedom-net/2015/malaysia

Gallopín, G. C. (1991). Human dimensions of global change: linking the global and the local processes. *International Social Science Journal*, (130), 707–718.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science*, *327*(5967), 812–818.

Government of Malaysia. (2010). Deepending Malaysia's Palm Oil Advantage. In *Economic Transformation Programme Handbook - A Roadmap for Malaysia* (pp. 280–314). Retrieved from http://etp.pemandu.gov.my/Download_Centre-@-Download_Centre.aspx

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., … Bergsma, E. (2010). The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science & Policy*, *13*(6), 459–471. https://doi.org/10.1016/j.envsci.2010.05.006

Hagenmeier, J. (2015). Invest In Malaysia: A Paragon Of Economic And Political Stability. Retrieved from http://daytradingacademy.com/day-trading/malaysia-economic-and-political-stability

Hanim, A. (2016). Planters call for review of windfall profit tax [Online Paper]. Retrieved 13 February 2017, from http://www.thestar.com.my/business/business-news/2016/10/15/planters-call-for-review-of-windfall-profit-tax/

Haque, M. S. (2003). The role of the state in managing ethnic tensions in Malaysia: A critical discourse. *American Behavioral Scientist*, *47*(3), 240–266.

Hoddinott, J. (2014). Looking at development through a resilience lens. *Resilience for Food and Nutrition Security*, 19.

IISD. (2013). Climate Resilience and Food Security. A Framework for Planning and Monitoring. IISD Report. The International Institute for Sustainable Development. Retrieved from www.iisd.org

Ingram, J., Andersson, J., Bammer, G., Brown, M., Giller, K., Henrichs, T., … Young, J. (2012). Engaging Stakeholders at the Regional Level. In *Food security and global environmental change*. Routledge.

Jahn, T., Bergmann, M., & Keil, F. (2012). Transdisciplinarity: Between mainstreaming and marginalization. *Ecological Economics*, *79*, 1–10.

Kopainsky, B., Le Quang, B., & Spörri, A. (2013). *Resilience in Food Value Chains* (Feasability Study). Zurich, Switzerland: World Food System Center ETH Zurich.

Lai, O.-M., Tan, C.-P., & Akoh, C. C. (2015). *Palm Oil: Production, Processing, Characterization, and Uses*. Elsevier.

Liverman, D., & Kapadia, K. (2012). Food Systems and the Global Environment: An Overview. In *Food security and global environmental change*. Routledge.

Ludin, N. A., Bakri, M. A. M., Kamaruddin, N., Sopian, K., Deraman, M. S., Hamid, N. H., … Othman, M. Y. (2014). Malaysian oil palm plantation sector: exploiting renewable energy toward sustainability production. *Journal of Cleaner Production*, *65*, 9–15. https://doi.org/10.1016/j.jclepro.2013.11.063

Lunkapis, G. J. (2013). Confusion over land rights and development opportunities through communal titles in Sabah, Malaysia: Communal titles in Sabah. *Asia Pacific Viewpoint*, *54*(2), 198–205. https://doi.org/10.1111/apv.12019

Majid Cooke, F. (2012). In the name of poverty alleviation: Experiments with oil palm smallholders and customary land in Sabah, Malaysia. *Asia Pacific Viewpoint*, *53*(3), 240–

253. https://doi.org/10.1111/j.1467-8373.2012.01490.x
Majid, F. A. (2009). Migration and Moral Panic: The case of oil palm in Sabah, Malaysia. Oliver Pye & Jayati Bhattacharya (Ed). Singapore*: The Palm Oil Controversy in Southeast Asia - A Transnational Perspective.*
Malaysian Meteorological Department. (2009). Climate Change Scenarios for Malaysia 2001-2099.
Maleksaeidi, H., & Karami, E. (2013). Social-Ecological Resilience and Sustainable Agriculture Under Water Scarcity. *Agroecology and Sustainable Food Systems*, *37*(3), 262–290. https://doi.org/10.1080/10440046.2012.746767
Martin, S., Rieple, A., Chang, J., Boniface, B., & Ahmed, A. (2015). Small farmers and sustainability: Institutional barriers to investment and innovation in the Malaysian palm oil industry in Sabah. *ResearchGate*, *40*. https://doi.org/10.1016/j.jrurstud.2015.06.002
McKenzie, F. C., & Williams, J. (2015). Sustainable food production: constraints, challenges and choices by 2050. *Food Security*, *7*(2), 221–233.
Millennium Ecosystem Assessment (MA). (2005). Ecosystems and Human Well-Being: Synthesis. Island Press, Washington DC. Retrieved from http://www.millenniumassessment.org/en/Synthesis.html
Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., … Nelson, D. (2010). Resilience and Vulnerability: Complementary or Conflicting Concepts? *Ecology and Society*, *15*(3), 11.
Milman, A., & Short, A. (2008). Incorporating resilience into sustainability indicators: an example for the urban water sector. *Global Environmental Change*, *18*, 758–767.
MPOB. (2016). *Malaysian Oil Palm Statistics 2015* (35th ed.). Malaysia: Ministry of Plantation Industries and Commodities, Malaysia.
MPOB. (2017). Statistics - Economics & Industry Development Division. Retrieved from http://bepi.mpob.gov.my/index.php/en/statistics/production.html
Mutalib, H. M. (2017). The other side of Malaysia's enviable economic and multiethnic stability: the obstinate resilience of 'money politics'. *Asian Ethnicity*, *18*(1), 54–73. https://doi.org/10.1080/14631369.2015.1038777
Nesadurai, H. E. S. (2013). Food security, the palm oil–land conflict nexus, and sustainability: a governance role for a private multi-stakeholder regime like the RSPO? *The Pacific Review*, *26*(5), 505–529. https://doi.org/10.1080/09512748.2013.842311
Newton, P., Agrawal, A., & Wollenberg, L. (2013). Enhancing the sustainability of commodity supply chains in tropical forest and agricultural landscapes. *Global Environmental Change*, *23*(6), 1761–1772. https://doi.org/10.1016/j.gloenvcha.2013.08.004
O'Neill, R. V. (1998). Recovery in complex ecosystems. *Journal of Aquatic Ecosystem Stress and Recovery*, *6*(3), 181–187. https://doi.org/10.1023/A:1009996332614
Oosterveer, P. (2015). Promoting sustainable palm oil: viewed from a global networks and flows perspective. *Journal of Cleaner Production*, *107*, 146–153.
Osman, R., Phua, M.-H., Ling, Z. Y., & Kamlun, K. U. (2012). Monitoring of Deforestation Rate and Trend in Sabah between 1990 and 2008 Using Multitemporal Landsat Data. *Journal of Forest and Environmental Science*, *28*(3), 144–151. https://doi.org/10.7747/JFS.2012.28.3.144
Oxford Business Group (Ed.). (2011). *The Report: Sabah*. Oxford Business Group.
Potter, L. (2015). Managing oil palm landscapes: A seven-country survey of the modern palm oil industry in Southeast Asia, Latin America and West Africa. *Occasional Paper*, 122, 1-143. CIFOR.
Rasiah, R., & Shahrin, A. (2005). Development of Palm Oil and Related Products in Malaysia

and Indonesia. *ResearchGate*. Retrieved from https://www.researchgate.net/publication/237474157_Development_of_Palm_Oil_and_Related_Products_in_Malaysia_and_Indonesia

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., … Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, *90*(5), 1933–1949.

Resilience Alliance. (2009). Assessing and managing resilience in social-ecological systems: a practitioner's workbook [a practitioner'sworkbook,Version1.0.]. Retrieved from http://wiki.resalliance.org/index.php/Main_Page.

RSPO. (2017). Roundtable on Sustainable Palm Oil. Retrieved 24 February 2017, from http://www.rspo.org/

Sayed Mahadi, S. A. R. B. (2014). *Indonesian labour migration to Sabah: changes, trends and impacts.* Retrieved from https://digital.library.adelaide.edu.au/dspace/handle/2440/84693

Sheil, D., Casson, A., Meijaard, E., Van Noordwjik, M., Gaskell, J., Sunderland-Groves, J., … Kanninen, M. (2009). *The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know?*. Occasional Paper, 51, 1-67. CIFOR, Bogor, Indonesia. Retrieved from http://www.cifor.org/publications/pdf_files/occpapers/op-51.pdf

Steffen, W., Crutzen, J., & McNeill, J. R. (2007). The Anthropocene: are humans now overwhelming the great forces of Nature? *Ambio*, *36*(8), 614–621.

Sutarta, E. S., Santoso, H., & Yusuf, M. A. (2016). Climate change on oil palm: it's impacts and adaptation strategies. Retrieved from https://www.researchgate.net/publication/265201096_climate_change_on_oil_palm_it's_impacts_and_adaptation_strategies

Suzuki, K., Tsuji, N., & Osaki, M. (2015). Sustainable Self-Sufficient Food based on Energy Potential: Analysis in Sabah, Malaysia. *Global Adavnaced Research Journal of Agricultural Science*, *4*(12), 871–877.

Tenaw, S., Islam, K. Z., & Parviainen, T. (2009). Effects of land tenure and property rights on agricultural productivity in Ethiopia, Namibia and Bangladesh. Retrieved from http://www.helsinki.fi/taloustiede/Abs/DP33.pdf

Tendall, D. ., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. ., … Six, J. (2015). Food system resilience: Defining the concept. *Global Food Security*, *6*, 17–23.

Teoh, C. H. (2010). Key sustainability issues in the palm oil sector. *A discussion paper for multi-stakeholders consultations (Commissioned by the World Bank Group)*. Retrieved from http://siteresources.worldbank.org/INTINDONESIA/Resources/226271-1170911056314/Discussion.Paper_palmoil.pdf

Teoh, C. H., Ng, A., Prudente, C., Pang, C., & Yee, J. T. C. Y. (2001). Balancing the Need for Sustainable Oil Palm Development and Conservation : The Lower Kinabatangan Floodplains Experience. In *Strategic Directions for the Sustainability of the Oil Palm Industry*. Kota Kinablau, Sabah, Malaysia. Retrieved from https://www.researchgate.net/publication/242555372_Balancing_the_Need_for_Sustainable_Oil_Palm_Development_and_Conservation_The_Lower_Kinabatangan_Floodplains_Experience

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, *418*(6898), 671–677.

Wahid, M. B., Abdullah, S. N. A., & Henson, I. E. (2005). Oil Palm — Achievements and Potential. *Plant Production Science*, *8*(3), 288–297. https://doi.org/10.1626/pps.8.288

Walker, B., Anderies, J., Kinzig, A., & Ryan, P. (2006). Exploring Resilience in Social-Ecological Systems Through Comparative Studies and Theory Development: Introduction to the Special Issue. *Ecology and Society*, *11*(1). https://doi.org/10.5751/ES-01573-110112

Woittiez, L. S., van Wijk, M. T., Slingerland, M., van Noordwijk, M., & Giller, K. E. (2017). Yield gaps in oil palm: A quantitative review of contributing factors. *European Journal of Agronomy*, *83*, 57–77. https://doi.org/10.1016/j.eja.2016.11.002

7 Appendix

Appendix I: Data analysis of resilience attributes for value chain step

Sign/Number	Meaning
General score	
+ +	Very high resilience
+	High resilience
/	Medium resilience
-	Low resilience
- -	Very low resilience
XX	No data collected or available or indicator is irrelevant for this value chain step
Importance in regard to shock	
0	Indicator is irrelevant to overcome this shock
1	Low importance to overcome shock
2	Medium importance to overcome shock
3	High importance to overcome shock

VALUE CHAIN STEP: Input trading companies

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	--	3	-6
Recovery from shocks	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	+	3	3
Recovery from shocks	++	3	6
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	++	1	2
Dependency on other stakeholders (number of suppliers, …)	++	3	6
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	-	3	-3
Spatial distribution of the value chain steps and competition	--	3	-6
Expression of diverse opinion	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	++	1	2
Dependency on other stakeholders (number of suppliers, …)	++	3	6
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	-	1	-1
Spatial distribution of the value chain steps and competition	--	1	-2
Expression of diverse opinion	-	1	-1
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	/	0	/
Spare financial capacity	-	3	-3
Storage capacities and stocks within the system	/	2	/
Access to disaster risk management (in case of drought)	XX		
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	/	0	/
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	/	2	/
Access to disaster risk management (in case of flooding)	XX		
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	/	0	0
Condition of electricity supply	-	0	0
Condition of communication infrastructure	/	1	/
Condition of machinery, housing	+	0	0
Natural inputs: accessible, affordable, available	--	3	-6
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	--	1	-2
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	-	3	-3
Condition of electricity supply	-	1	-1
Condition of communication infrastructure	/	3	/
Condition of machinery, housing	+	1	1
Natural inputs: accessible, affordable, available	--	1	-2
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	--	1	-2
Shock-related resilience score			

Governance capacity

DROUGHT

Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	0	
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	-	2	-2
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	/	3	/
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	XX		
Governmental support during shock	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	2	2
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	-	1	-1
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	/	3	/
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	XX		
Governmental support during shock	-	1	-1
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	1	1
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	/	1	/
Exposure to financial risk	-	3	-3
Viability of the process (subsidies, …)	/	3	/
Profitability (business as usual)	-	3	-3
Profitability (times of shock)	--	3	-6
Current labour market and its adaptation to fluctuation	/	1	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	3	3
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	/	1	/
Exposure to financial risk	-	1	-1
Viability of the process (subsidies, …)	/	3	/
Profitability (business as usual)	-	3	-3
Profitability (times of shock)	-	3	-3
Current labour market and its adaptation to fluctuation	/	1	/
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	XX		
Knowledge base	+	3	3
Education level	+	2	2
Experience of actors	+	3	3
Access advisory and extension services	XX		
Access and investment into knowledge and education	+	1	1
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	XX		
Trust and respect between actors	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	XX		
Knowledge base	+	3	3
Education level	+	2	2
Experience of actors	+	3	3
Access advisory and extension services	XX		
Access and investment into knowledge and education	+	1	1
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	XX		
Trust and respect between actors	/	3	/
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	--	3	-6
Opportunity for experimentation and innovation	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	+	3	3
Opportunity for experimentation and innovation	-	1	-1

Shock-related resilience score			

VALUE CHAIN STEP: Nurseries

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	-	3	-3
Recovery from shocks	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	++	3	6
Recovery from shocks	+	3	3
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	1	/
Dependency on other stakeholders (number of suppliers, …)	+	2	2
Diversity of farms, landscapes, crops and varieties	--	3	-6
Diverse activities for income generation	/	3	/
Spatial distribution of the value chain steps	++	2	2
Expression of diverse opinion	+	1	1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	1	/
Dependency on other stakeholders (number of suppliers, …)	+	2	2
Diversity of farms, landscapes, crops and varieties	--	1	-2
Diverse activities for income generation	/	1	/
Spatial distribution of the value chain steps	++	1	2
Expression of diverse opinion	+	1	1
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	+	3	+
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	/	1	/
Access to disaster risk management (in case of drought)	XX		
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	+	0	
Spare financial capacity	/	1	/
Storage capacities and stocks within the system	/	1	/
Access to disaster risk management (in case of flooding)	XX		
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	/	0	
Condition of electricity supply	/	0	
Condition of communication infrastructure	/	0	
Condition of machinery, housing	/	0	
Natural inputs: accessible, affordable, available	-	3	-3
Internal nutrient sources	-	3	-3
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	/	3	/
Condition of electricity supply	/	0	
Condition of communication infrastructure	/	2	/
Condition of machinery, housing	/	2	/
Natural inputs: accessible, affordable, available	-	1	-1
Internal nutrient sources	-	1	-1
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	-	1	-1
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	XX		
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	+	3	3
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	XX		
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	+	3	3
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	/	1	/
Permanent financial flows	-	3	-3
Funds for investment, maintenance and expansion	/	3	/
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	+	3	3
Profitability (business as usual)	/	3	/
Profitability (times of shock)	-	3	-3
Current labour market and its adaptation to fluctuation	/	2	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	/	1	/
Permanent financial flows	-	1	-1
Funds for investment, maintenance and expansion	/	3	/
Exposure to financial risk	+	1	1
Viability of the process (subsidies, …)	+	2	2
Profitability (business as usual)	/	3	/
Profitability (times of shock)	/	3	/
Current labour market and its adaptation to fluctuation	/	2	/
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	XX		
Knowledge base	+	3	3
Education level	+	2	2
Experience of actors	+	3	3
Access advisory and extension services	+	1	1
Access and investment into knowledge and education	/	2	/
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	+	1	1
Trust and respect between actors	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	XX		
Knowledge base	+	3	3
Education level	+	2	2
Experience of actors	+	3	3
Access advisory and extension services	+	1	1
Access and investment into knowledge and education	/	2	/
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	+	1	1
Trust and respect between actors	/	3	/
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	3	3
Learnt lessons from previous shocks	+	3	3
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	3	3
Learnt lessons from previous shocks	+	3	3
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

VALUE CHAIN STEP: SMALLHOLDER FARMERS

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	--	3	-6
Recovery from shocks	--	3	-6
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	+	3	3
Recovery from shocks	+	3	3
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	1	/
Dependency on other stakeholders (number of suppliers, …)	/	1	/
Diversity of farms, landscapes, crops and varieties	-	3	-3
Diverse activities for income generation	/	3	/
Expression of diverse opinion	/	2	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	1	/
Dependency on other stakeholders (number of suppliers, …)	/	2	/
Diversity of farms, landscapes, crops and varieties	-	1	-1
Diverse activities for income generation	/	1	/
Spatial distribution of the value chain steps	/	2	/
Expression of diverse opinion	/	2	/
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	- -	3	-6
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	--	0	0
Access to disaster risk management	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	-	3	-3
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	/	0	/
Access to disaster(flood) risk management	+	3	3
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	-	3	-3
Condition of transport infrastructure	-	1	-1
Condition of electricity supply	/	0	0
Condition of communication infrastructure	/	0	0
Condition of machinery, housing	/	0	0
Natural inputs: accessible, affordable, available	-	3	-3
Internal nutrient sources	--	2	-4
Nutrient depletion	--	1	-2
Emission	XX	XX	XX
Waste cycles	-	1	-1
Adaptation of crop variety to the socio-ecological system	+	3	3
Cost-efficiency thinking	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	-	3	-3
Condition of transport infrastructure	-	3	-3
Condition of electricity supply	/	0	0
Condition of communication infrastructure	/	3	/
Condition of machinery, housing	/	3	/
Natural inputs: accessible, affordable, available	-	3	-3
Internal nutrient sources	--	2	-4
Nutrient depletion	--	3	-6
Emission	XX		
Waste cycles	-	1	1
Adaptation of crop variety to the socio-ecological system	++	3	6
Cost-efficiency thinking	-	3	-3
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	/	3	/
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	- -	3	-6
Autonomy and management skills of actors	-	3	-3
Investment in rural infrastructure	- -	3	-6
Land access and tenure	- -	3	-6
Self-organisation and networking of actors enabled	-	1	-1
Governmental support during shock	- -	3	-6
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	/	3	/
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	- -	3	-6
Autonomy and management skills of actors	-	3	-3
Investment in rural infrastructure	- -	3	-6
Land access and tenure	- -	1	-2
Self-organisation and networking of actors enabled	-	1	-1
Governmental support during shock	+	3	3
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shocks	Shock-related indicator score
Insurance coverage	/	1	/
Funds for investment, maintenance and expansion	/	3	/
Exposure to financial risk	/	1	/

Viability of the process (subsidies, …)	/	2	/
Profitability (business as usual)	++	3	6
Profitability (times of shock)	- -	3	-6
Current labour market and its adaptation to fluctuation	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	/	3	/
Funds for investment, maintenance and expansion	/	3	/
Exposure to financial risk	/	3	/
Viability of the process (subsidies, …)	/	1	/
Profitability (business as usual)	++	3	6
Profitability (times of shock)	-	3	-3
Current labour market and its adaptation to fluctuation	-	1	-1
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	/	2	/
Access to early warning systems	-	2	-2
Knowledge base	- -	3	-6
Education level	- -	1	-2
Experience of actors	+	3	3
Access advisory and extension services	- -	3	-6
Access and investment into knowledge and education	- -	3	-6
Monitoring and record keeping of quality and environmental factors	- -	1	-2
Trust and respect between actors	+	2	2
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	/	2	/
Access to early warning systems	-	3	-3
Knowledge base	- -	3	-6
Education level	- -	1	-2
Experience of actors	+	3	3
Access advisory and extension services	- -	3	-6
Access and investment into knowledge and education	- -	3	-6
Monitoring and record keeping of quality and environmental factors	- -	1	-2
Trust and respect between actors	+	2	2
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	- -	3	-6
Opportunity for experimentation and innovation	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	/	3	/
Opportunity for experimentation and innovation	-	3	-3
Shock-related resilience score			

VALUE CHAIN STEP: Plantation

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	--	3	-6
Recovery from shocks	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	+	3	3
Recovery from shocks	+	3	3
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	0	
Dependency on other stakeholders (number of suppliers, …)	+	1	1
Diversity of farms, landscapes, crops and varieties	--	3	-6
Diverse activities for income generation	-	1	-1
Spatial distribution of the value chain steps and competition	/	1	/
Expression of diverse opinion	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	0	
Dependency on other stakeholders (number of suppliers, …)	+	3	3
Diversity of farms, landscapes, crops and varieties	--	1	-2
Diverse activities for income generation	-	1	-1
Spatial distribution of the value chain steps and competition	/	1	/
Expression of diverse opinion	/	1	/
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score

Spare capacity of natural resources	--	3	-6
Spare financial capacity	++	3	6
Storage capacities and stocks within the system	/	0	/
Access to disaster risk management (in case of drought)	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	-	3	-3
Spare financial capacity	++	3	6
Storage capacities and stocks within the system	/	0	/
Access to disaster risk management (in case of flooding)	+	3	3
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	/	1	/
Condition of transport infrastructure	+	0	
Condition of electricity supply	+	0	
Condition of communication infrastructure	+	0	
Condition of machinery, housing	+	0	
Natural inputs: accessible, affordable, available	/	2	/
Internal nutrient sources	+	3	3
Nutrient depletion	/		
Emissions, Waste cycles	+	3	3
Adaptation of crop variety to the socio-ecological system	+	3	3
Cost-efficiency thinking	-	3	-3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	/	3	/
Condition of transport infrastructure	+	3	3
Condition of electricity supply	+	1	1
Condition of communication infrastructure	+	2	2
Condition of machinery, housing	+	2	2
Natural inputs: accessible, affordable, available	/	1	/
Internal nutrient sources	+	1	1
Nutrient depletion	/	1	/
Emissions, Waste cycles	+	2	2
Adaptation of crop variety to the socio-ecological system	+	3	3
Cost-efficiency thinking	-	2	-2
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	+	3	3
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	/	1	/
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	+	3	3
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	+	3	3
Investment in rural infrastructure	/	3	/
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	0	
Permanent financial flows	+	2	2
Funds for investment, maintenance and expansion	+	3	3
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	++	3	6
Profitability (business as usual)	++	3	6
Profitability (times of shock)	/	3	/
Current labour market and its adaptation to fluctuation	--	3	-6
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	3	3
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	+	3	3
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	++	3	6
Profitability (business as usual)	++	3	6
Profitability (times of shock)	/	3	/

Current labour market and its adaptation to fluctuation	--	2	-4
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	+	1	1
Knowledge base	++	3	6
Education level	+	1	1
Experience of actors	++	3	6
Access advisory and extension services	+	2	2
Access and investment into knowledge and education	+	2	2
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	2	4
Trust and respect between actors	+	1	1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	3	3
Access to early warning systems	+	1	1
Knowledge base	++	3	6
Education level	+	1	1
Experience of actors	++	3	6
Access advisory and extension services	+	2	2
Access and investment into knowledge and education	+	2	2
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	2	4
Trust and respect between actors	+	1	1
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	/	3	/
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	++	3	6
Learnt lessons from previous shocks	/	3	/
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

VALUE CHAIN STEP: MILLS

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	-	3	-3
Recovery from shocks	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	/	3	/
Recovery from shocks	+	3	3
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	XX		
Dependency on other stakeholders (number of suppliers, …)	+	2	2
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	-	3	-3
Spatial distribution of the value chain steps and competition	-	2	-2
Expression of diverse opinion	/	1	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	XX		
Dependency on other stakeholders (number of suppliers, …)	+	3	3
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	-	2	-2
Spatial distribution of the value chain steps and competition	-	1	-1
Expression of diverse opinion	/	1	1
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	--	3	-6
Spare financial capacity	+	3	6
Storage capacities and stocks within the system	++	1	2
Access to disaster risk management (in case of drought)	/	0	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	XX		
Spare financial capacity	++	3	6

Storage capacities and stocks within the system	++	3	6
Access to disaster risk management (in case of flooding)	+	3	3
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	/	3	/
Condition of transport infrastructure	+	1	1
Condition of electricity supply	+	0	
Condition of communication infrastructure	/	0	
Condition of machinery, housing	+	1	1
Natural inputs: accessible, affordable, available	XX		
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	+	3	3
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	/	1	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	/	1	/
Condition of transport infrastructure	+	3	3
Condition of electricity supply	+	2	2
Condition of communication infrastructure	/	3	/
Condition of machinery, housing	+	1	1
Natural inputs: accessible, affordable, available	XX		
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	+	1	1
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	/	1	/
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	++	3	6
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	++	3	6
Investment in rural infrastructure	/	1	1
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	3	3
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	++	3	6
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	++	3	6
Investment in rural infrastructure	/	3	3
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	++	1	2
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	+	3	3
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	++	3	6
Profitability (business as usual)	+	3	3
Profitability (times of shock)	/	3	/
Current labour market and its adaptation to fluctuation	+	1	1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	++	3	6
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	+	3	3
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	++	3	6
Profitability (business as usual)	+	3	3
Profitability (times of shock)	/	3	/
Current labour market and its adaptation to fluctuation	+	1	1
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	+	1	1
Knowledge base	++	3	6
Education level	++	3	6
Experience of actors	++	3	6

Access advisory and extension services	+	1	1
Access and investment into knowledge and education	+	1	1
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	1	2
Trust and respect between actors	/	2	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	3	3
Access to early warning systems	+	3	3
Knowledge base	++	3	6
Education level	++	3	6
Experience of actors	++	3	6
Access advisory and extension services	+	1	1
Access and investment into knowledge and education	+	1	1
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	3	6
Trust and respect between actors	/	2	/
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	2	3
Learnt lessons from previous shocks	++	3	6
Opportunity for experimentation and innovation	+	1	1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	2	2
Learnt lessons from previous shocks	++	3	6
Opportunity for experimentation and innovation	+	1	1
Shock-related resilience score			

VALUE CHAIN STEP: Refinery

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	/	3	/
Recovery from shocks	+	3	3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	/	3	
Recovery from shocks	+	3	

Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	XX		
Dependency on other stakeholders (number of suppliers, …)	++	2	4
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	+	1	1
Competition	--	2	-4
Expression of diverse opinion	XX		
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	XX		
Dependency on other stakeholders (number of suppliers, …)	++	3	6
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	+	1	1
Competition	--	1	-2
Expression of diverse opinion	XX		
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	/	3	/
Spare financial capacity	++	3	6
Storage capacities and stocks within the system	++	1	2
Access to disaster risk management (in case of drought)		0	
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Spare capacity of natural resources	-	1	-1
Spare financial capacity	++	3	6
Storage capacities and stocks within the system	++	3	6
Access to disaster risk management (in case of flooding)		0	
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	+	0	
Condition of electricity supply	+	0	
Condition of communication infrastructure	+	0	
Condition of machinery, housing	+	1	1
Natural inputs: accessible, affordable, available	XX		

Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	+	3	3
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	+	1	1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	+	3	3
Condition of electricity supply	+	2	2
Condition of communication infrastructure	/	3	/
Condition of machinery, housing	+	2	2
Natural inputs: accessible, affordable, available	XX		
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	+	1	1
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	+	1	1
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	++	1	2
Living standard of actors	++	3	6
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	++	3	6
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	++	3	6
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	++	1	2
Living standard of actors	++	3	6
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	++	3	6
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	++	3	6
Investment in rural infrastructure	XX		
Land access and tenure	XX		
Self-organisation and networking of actors enabled	+	1	1
Governmental support during shock	-	1	-1
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	++	1	2
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	++	3	6
Exposure to financial risk	+	2	2
Viability of the process (subsidies, …)	+	3	3
Profitability (business as usual)	+	3	3
Profitability (times of shock)	+	3	3
Current labour market and its adaptation to fluctuation	++	1	2
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	++	3	6
Permanent financial flows	+	1	1
Funds for investment, maintenance and expansion	++	3	6
Exposure to financial risk	+	1	1
Viability of the process (subsidies, …)	+	1	1
Profitability (business as usual)	+	3	3
Profitability (times of shock)	+	3	3
Current labour market and its adaptation to fluctuation	++	1	2
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	1	1
Access to early warning systems	+	2	2
Knowledge base	++	3	6
Education level	++	3	6
Experience of actors	/	2	/
Access advisory and extension services	++	2	2
Access and investment into knowledge and education	++	3	6
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	3	6
Trust and respect between actors	++	3	6
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	+	3	3
Access to early warning systems	+	2	2
Knowledge base	++	3	6
Education level	++	3	6

Experience of actors	/	2	/
Access advisory and extension services	++	2	2
Access and investment into knowledge and education	++	3	6
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	++	3	6
Trust and respect between actors	++	3	6
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	3	3
Learnt lessons from previous shocks	+	3	3
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	+	3	3
Learnt lessons from previous shocks	+	3	3
Opportunity for experimentation and innovation	/	3	/
Shock-related resilience score			

VALUE CHAIN STEP: Transport

Exposure to pressure

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	--	3	-6
Recovery from shocks	--	3	-6
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Past experience of shocks	+	3	3
Recovery from shocks	+	3	3
Shock-related resilience score			

Modularity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	XX		
Dependency on other stakeholders (number of suppliers, …)	+	2	2
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	+	3	3
Competition	-	3	-3
Expression of diverse opinion	/	1	/
Shock-related resilience score			

FLOODING

Factor	General score	Importance in regard to shock	Shock-related indicator score
Diversity of inputs	/	2	/
Dependency on other stakeholders (number of suppliers, …)	+	3	3
Diversity of farms, landscapes, crops and varieties	XX		
Diverse activities for income generation	+	1	1
Competition	-	0	
Expression of diverse opinion	/	1	/
Shock-related resilience score			

Buffering capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Logistical spare capacity	+	1	1
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	/	1	/
Access to disaster risk management (in case of drought)	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Logistical spare capacity	+	1	1
Spare financial capacity	/	3	/
Storage capacities and stocks within the system	/	1	/
Access to disaster risk management (in case of drought)	-	1	-1
Shock-related resilience score			

Environmental capital

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	-	2	-2
Condition of electricity supply	XX		
Condition of communication infrastructure	-	0	
Condition of machinery, housing	-	2	-2
Natural inputs: accessible, affordable, available	XX		
Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	-	1	-1
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Condition and protection of natural resources	XX		
Condition of transport infrastructure	-	3	-3
Condition of electricity supply	XX		
Condition of communication infrastructure	-	0	
Condition of machinery, housing	-	2	-2
Natural inputs: accessible, affordable, available	XX		

Internal nutrient sources	XX		
Nutrient depletion	XX		
Emissions, Waste cycles	XX		
Adaptation of crop variety to the socio-ecological system	XX		
Cost-efficiency thinking	-	1	-1
Shock-related resilience score			

Governance capacity

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	2	2
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	/	3	/
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	/	3	/
Investment in rural infrastructure	--	1	-2
Land access and tenure	XX		
Self-organisation and networking of actors enabled	/	1	/
Governmental support during shock	-	2	-2
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Health status of actors and access to healthcare	+	2	2
Living standard of actors	+	3	3
Transparency, legitimacy, accountability and acceptance of governance	XX		
Stability of the government	XX		
Collaboration between government units	XX		
Long-term planning (policies, strategies, …)	XX		
Capability to manage crisis (leadership, setting of priorities, anticipation of problems, …)	/	3	/
Equality of stakeholders	XX		
Fair rights, laws and policies	XX		
Autonomy and management skills of actors	/	3	/
Investment in rural infrastructure	--	2	-4
Land access and tenure	XX		
Self-organisation and networking of actors enabled	/	1	/
Governmental support during shock	-	2	-2
Shock-related resilience score			

Financial capital and Profitability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	1	1
Permanent financial flows	/	1	/
Funds for investment, maintenance and expansion	+	1	1
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	-	3	-3
Profitability (business as usual)	-	3	-3
Profitability (times of shock)	-	3	-3
Current labour market and its adaptation to fluctuation	/	1	/
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Insurance coverage	+	3	3
Permanent financial flows	/	1	/
Funds for investment, maintenance and expansion	+	1	1
Exposure to financial risk	+	3	3
Viability of the process (subsidies, …)	-	3	-3
Profitability (business as usual)	-	3	-3
Profitability (times of shock)	-	3	-3
Current labour market and its adaptation to fluctuation	/	1	/
Shock-related resilience score			

Information and Learning

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	XX		
Access to early warning systems	XX		
Knowledge base	/	3	/
Education level	/	2	/
Experience of actors	/	3	/
Access advisory and extension services	XX		
Access and investment into knowledge and education	-	2	-2
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	XX		
Trust and respect between actors	+	3	3
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Reliability of communication channels	XX		
Access to early warning systems	XX		
Knowledge base	/	3	/
Education level	/	2	/
Experience of actors	/	3	/
Access advisory and extension services	XX		
Access and investment into knowledge and education	-	2	-2
Collaboration with universities, private sector and governmental departments	XX		
Monitoring and record keeping of quality and environmental factors	XX		
Trust and respect between actors	+	3	3
Shock-related resilience score			

Transformability

DROUGHT			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	/	3	/

Opportunity for experimentation and innovation	XX		
Shock-related resilience score			

FLOODING			
Factor	General score	Importance in regard to shock	Shock-related indicator score
Openness to change (values and behaviours of actors)	/	3	/
Learnt lessons from previous shocks	/	3	/
Opportunity for experimentation and innovation	XX		
Shock-related resilience score			

Appendix II: semi-structured questionnaires for each value chain step

INPUT SUPPLY QUESTIONNAIRE

Date, Location	
Name	
Company	
Phone Nr.	

GENERAL NOTES

1. Nr. of products	

2. To whom do you sell your products? How many?

	Smallholders
	Medium
	Big estates
	Traders

3. (12/45) How is your relationship with your buyers? (trust, challenges, ...)

4. (16/36) Which products/inputs does your company sell? From which companies?

Product	Channel/ Company

5. From how many suppliers do you obtain inputs?

	1	1-5	5-10	10-15	15+	Comments
Fertilizer						
Pesticides						
Tools						

6. How is the availability of the products/inputs?

	Low				High	Comment
Fertilizer						
Pesticides						
Tools						

7. How is the affordability of products/inputs?

	Low				High	Comment
Fertilizer						
Pesticides						
Tools						

8. (45) How is your relationship with your input suppliers? (trust, challenges, ...)

9. (29) What are your challenges in managing supply and demand?

10. (29) Have you ever experienced supply shortage?

- [ ] Several times
- [ ] Rarely
- [ ] Never

Reason:

11. Do you keep stocks of your products?

	1 Month	3 Month	½ year	1 year
Stocks				
Time to order				

12. In your opinion, are the following resources on your company in good condition?

INPUT	Bad	---			Good condition
Trucks					
Machines					
Water system					
Buildings					
Energy source					
Transport infrastructure					
Communication infrastructure					

EL NIÑO/ LA NIÑA

13. (28) How did the last El Niño event affect you (input supply, financially, product distribution, …including benefits)?

Input supply

Sales

Finances

Benefits

14. (28) How did the last La Niña event affect you input supply, financially, product distribution, … including benefits)?

Input supply

Sales

Finances

Accidents/Access to plantations

Buildings

Benefits

15. (2.2) Would the break down of a certain machine/building have a critical impact on the environment (e.g. nearby river)?

16. (30.1) Are there emergency plans/measures to address risks (e.g. supply shortage, process distribution, protection for accidents) in the case of such an event?

El Niño	Flood

17. (28.1) How fast would you say, did you recover from the last El Niño/flood event?

El Niño	**Flood**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

18. (33) Did you in the past after El Niño/flood event modify anything in your process to be better prepared for future disturbances? What?

☐ Yes
☐ No

What? /Why not?

19. (41/41.2) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, input relief, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	

After	

FINANCES

20. (12) Does the process avoid exposure to substantial financial risks (e.g. outstanding debt, risky investments)?

21. (38.2) Does the process generate a net positive profit, business as usual, after El Niño/flood?

	Debt	Zero	Low profit	High profit	Savings
Business as usual					
El Niño					
Flood					

22. (9) Do you have insurance for the case of loss of: infrastructure, personnel, supply disturbance, others?

	Formal	Informal	None
Infrastructure			
Staff			
Supply			
Trucks			
Others			

23. (10) Does the process have access to funds for investment, maintenance, and expansion (e.g. through savings, financial services such as credit, etc.)

Fund source	Used	Easy access	Difficult access
Government supported			
Banks			
Others			

24. (T33.2) In your opinion what should be changed by you or any other actor (government, mills, community, …), so that you are better prepared for the next El Niño/flood event?

El Niño	**Flood**

25. Anything you would like to add.

Do you have a question for us?

Would you make part of a palm oil value chain workshop?

NURSERY QUESTIONNAIRE

Date, Location	
Name	
Company	
Phone Nr.	

GENERAL NOTES

1. Number of seedlings	
2. (11) Nr. of workers (permanent/temporary)	
3. Other sources of income	
4. Other crop seedlings	

5. (47) What is the biggest constraint/problem for your nursery?

EL NIÑO/ LA NIÑA

6. (EP28) How did the last El Niño event affect you?

- [ ] Yes
- [ ] Small effect
- [ ] No

(EC) FFB yield

(EC) Plants (disease, …)

(1.3/3) Water supply

(FC&P) Finances

(B/M) Infrastructure

(G) Workers

Buyers

7. (EP28) Have you experienced any floods in the past years?

- [ ] Yes
- [ ] Small effect
- [ ] No

When? How often?

How did the last flood event affect you?

(EC) FFB yield

(EC) Plants (disease, …)

(FC&P) Finances

(B/M21.2)Road access/ Seedling delivery

(G11.1) Workers

(G) Health/Accidents

Buyers

8. (28.1) How fast would you say, did you recover from the last El Niño/La Niña event?

El Niño	**La Niña**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

9. (30.1) Are there emergency plans/measures to address risks in case of such an event?

El Niño	La Niña

10. (33) Did you change anything on your farm after the last El Niño/flood event?

☐ Yes
☐ No

What?/Why not?

11. (41/31.1) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	
After	

12. (33.2) In your opinion what should be changed by the government, so that you are better prepared for the next El Niño/flood event?

INPUT	Use/ Dependency (3.1/3.2/ 3.3/ 5)	Availability during extreme weather events (16.1)	Affordability (16.1)	Number of suppliers (16)					Number of potential suppliers (16.1)					Stocks (1.2/1.3)					Comment
	Low -------High	Low -------High	Low -------High	1	2	5	10	10+	1	2	5	10	10+	No	1M	3M	6M	12M+	
Industrial fertilizers																			
Organic fertilizer																			
Mulch material																			
Seeds																			
Pesticides																			
IPM assets (traps,…)																			
Implements																			
Polybags																			
Other																			

21. (1) In case of increased demand for palm oil seedlings, would you have the capacity to increase seedling production?

INPUT	Low capacity --- High capacity				
Land					
Labour forces					
Inputs					
Funding for inputs & labour forces					
Others:					

Oil palm seedlings

22. From where do you obtain your seeds?

23. (19.3/7) What varieties of oil palms do you have? What are their benefit? Resistance to drought? Are these varieties suitable for this region?

Hybrid	Benefits	Drought resistance					Suitability for region				

24. (8) What kind of disease & pest are common in your nursery? Is their occurrence higher or lower during El Niño/flood events? Are your varieties resistance towards them?

Pest& Disease	Occurrence higher during El Niño/flood events					Pest & disease resistance				

AGRICUTLRUAL PRACTICES/ RESOURCES

25. (3.3) What kind of land management practices/ (1.3) water conservation/irrigation practices do you use?

Extension services

26. (13.1/13.2) Do you have access to training/extension services?

MARKET/COMMUNITY

Plantations

27. To how many plantations and smallholders do you sell your seedlings?

Smallholder farmers

Plantation

28. (45) How is your relationship with the smallholders? (trust, challenges, …)

29. (45) How is your relationship with the large plantations? (trust, challenges, …)

30. (12/45) What kind of contract/agreements do you have with the plantations?

FINANCES

31. (12) What kind of investments is relatively risky in your activity?

32. (38.2) Does the process generate a net positive profit?

	Debt	Zero	Low profit	High profit
Business as usual				
El Niño				
El Niña				

33. (9) Do you have any kind of insurance for the case of loss of: infrastructure; staff; seedlings?

	Formal	Informal	None
Infrastructure			

Staff			
Seedlings			

34. (10) What possibilities do you have to access to credits? Which ones do you use? How easy are they to access?

Credit source	Used	Easy access	Difficult access
Family/Friends			
Loan Company			
NGO Program			
Government program			
Others			

35. Anything you would like to add.

_____

_____

Appendix II: semi-structured questionnaires for each value chain step

INPUT SUPPLY QUESTIONNAIRE

Date, Location	
Name	
Company	
Phone Nr.	

GENERAL NOTES

1. Nr. of products	

2. To whom do you sell your products? How many?

	Smallholders
	Medium
	Big estates
	Traders

3. (12/45) How is your relationship with your buyers? (trust, challenges, ...)

4. (16/36) Which products/inputs does your company sell? From which companies?

Product	Channel/ Company

5. From how many suppliers do you obtain inputs?

	1	1-5	5-10	10-15	15+	Comments
Fertilizer						
Pesticides						
Tools						

6. How is the availability of the products/inputs?

	Low				High	Comment
Fertilizer						
Pesticides						
Tools						

7. How is the affordability of products/inputs?

	Low				High	Comment
Fertilizer						
Pesticides						
Tools						

8. (45) How is your relationship with your input suppliers? (trust, challenges, ...)

9. (29) What are your challenges in managing supply and demand?

10. (29) Have you ever experienced supply shortage?

- [ ] Several times
- [ ] Rarely
- [ ] Never

Reason:

11. Do you keep stocks of your products?

	1 Month	3 Month	½ year	1 year
Stocks				
Time to order				

12. In your opinion, are the following resources on your company in good condition?

INPUT	Bad	---			Good condition
Trucks					
Machines					
Water system					
Buildings					
Energy source					
Transport infrastructure					
Communication infrastructure					

EL NIÑO/ LA NIÑA

13. (28) How did the last El Niño event affect you (input supply, financially, product distribution, …including benefits)?

Input supply

Sales

Finances

Benefits

14. (28) How did the last La Niña event affect you input supply, financially, product distribution, … including benefits)?

Input supply

Sales

Finances

Accidents/Access to plantations

Buildings

Benefits

15. (2.2) Would the break down of a certain machine/building have a critical impact on the environment (e.g. nearby river)?

16. (30.1) Are there emergency plans/measures to address risks (e.g. supply shortage, process distribution, protection for accidents) in the case of such an event?

El Niño	Flood

17. (28.1) How fast would you say, did you recover from the last El Niño/flood event?

El Niño	**Flood**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

18. (33) Did you in the past after El Niño/flood event modify anything in your process to be better prepared for future disturbances? What?

☐ Yes
☐ No

What? /Why not?

19. (41/41.2) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, input relief, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	

After	

FINANCES

20. (12) Does the process avoid exposure to substantial financial risks (e.g. outstanding debt, risky investments)?

21. (38.2) Does the process generate a net positive profit, business as usual, after El Niño/flood?

	Debt	Zero	Low profit	High profit	Savings
Business as usual					
El Niño					
Flood					

22. (9) Do you have insurance for the case of loss of: infrastructure, personnel, supply disturbance, others?

	Formal	Informal	None
Infrastructure			
Staff			
Supply			
Trucks			
Others			

23. (10) Does the process have access to funds for investment, maintenance, and expansion (e.g. through savings, financial services such as credit, etc.)

Fund source	Used	Easy access	Difficult access
Government supported			
Banks			
Others			

24. (T33.2) In your opinion what should be changed by you or any other actor (government, mills, community, …), so that you are better prepared for the next El Niño/flood event?

El Niño	**Flood**

25. Anything you would like to add.

Do you have a question for us?

Would you make part of a palm oil value chain workshop?

NURSERY QUESTIONNAIRE

Date, Location	
Name	
Company	
Phone Nr.	

GENERAL NOTES

1. Number of seedlings	
2. (11) Nr. of workers (permanent/temporary)	
3. Other sources of income	
4. Other crop seedlings	

5. (47) What is the biggest constraint/problem for your nursery?

EL NIÑO/ LA NIÑA

6. (EP28) How did the last El Niño event affect you?

- [ ] Yes
- [ ] Small effect
- [ ] No

(EC) FFB yield

(EC) Plants (disease, …)

(1.3/3) Water supply

(FC&P) Finances

(B/M) Infrastructure

(G) Workers

Buyers

7. (EP28) Have you experienced any floods in the past years?

- [ ] Yes
- [ ] Small effect
- [ ] No

When? How often?

How did the last flood event affect you?

(EC) FFB yield

(EC) Plants (disease, …)

(FC&P) Finances

(B/M21.2)Road access/ Seedling delivery

(G11.1) Workers

(G) Health/Accidents

Buyers

8. (28.1) How fast would you say, did you recover from the last El Niño/La Niña event?

El Niño	**La Niña**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

9. (30.1) Are there emergency plans/measures to address risks in case of such an event?

El Niño	La Niña

10. (33) Did you change anything on your farm after the last El Niño/flood event?

☐ Yes
☐ No

What?/Why not?

11. (41/31.1) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	
After	

12. (33.2) In your opinion what should be changed by the government, so that you are better prepared for the next El Niño/flood event?

INPUT	Use/ Dependency (3.1/3.2/ 3.3/ 5)	Availability during extreme weather events (16.1)	Affordability (16.1)	Number of suppliers (16)					Number of potential suppliers (16.1)					Stocks (1.2/1.3)					Comment
	Low -------High	Low -------High	Low -------High	1	2	5	10	10+	1	2	5	10	10+	No	1M	3M	6M	12M+	
Industrial fertilizers																			
Organic fertilizer																			
Mulch material																			
Seeds																			
Pesticides																			
IPM assets (traps,…)																			
Implements																			
Polybags																			
Other																			

21. (1) In case of increased demand for palm oil seedlings, would you have the capacity to increase seedling production?

INPUT	Low capacity --- High capacity				
Land					
Labour forces					
Inputs					
Funding for inputs & labour forces					
Others:					

Oil palm seedlings

22. From where do you obtain your seeds?

23. (19.3/7) What varieties of oil palms do you have? What are their benefit? Resistance to drought? Are these varieties suitable for this region?

Hybrid	Benefits	Drought resistance					Suitability for region				

24. (8) What kind of disease & pest are common in your nursery? Is their occurrence higher or lower during El Niño/flood events? Are your varieties resistance towards them?

Pest& Disease	Occurrence higher during El Niño/flood events					Pest & disease resistance				

AGRICUTLRUAL PRACTICES/ RESOURCES

25. (3.3) What kind of land management practices/ (1.3) water conservation/irrigation practices do you use?

Extension services

26. (13.1/13.2) Do you have access to training/extension services?

MARKET/COMMUNITY

Plantations

27. To how many plantations and smallholders do you sell your seedlings?

Smallholder farmers

Plantation

28. (45) How is your relationship with the smallholders? (trust, challenges, …)

29. (45) How is your relationship with the large plantations? (trust, challenges, …)

30. (12/45) What kind of contract/agreements do you have with the plantations?

FINANCES

31. (12) What kind of investments is relatively risky in your activity?

32. (38.2) Does the process generate a net positive profit?

	Debt	Zero	Low profit	High profit
Business as usual				
El Niño				
El Niña				

33. (9) Do you have any kind of insurance for the case of loss of: infrastructure; staff; seedlings?

	Formal	Informal	None
Infrastructure			

Staff			
Seedlings			

34. (10) What possibilities do you have to access to credits? Which ones do you use? How easy are they to access?

Credit source	Used	Easy access	Difficult access
Family/Friends			
Loan Company			
NGO Program			
Government program			
Others			

35. Anything you would like to add.

_____

_____

SMALLHOLDER FARMERS QUESTIONNAIRE

Location _____
Date _____
Name _____
Phone Nr. _____

1. Ownership	Yes/No
2. Age of palm trees	t
3. Nr. of temporary/ permanent workers(11)	workers

GENERAL QUESTIONS

1. (M6/36/19.2)) What sources of income do you have? (Livestock, business, other crops, forest, …)

Source	**Amount/ha**
1.	
2.	
3.	
4.	

2. (T47) What is the biggest constraint/problem for you in palm oil production?

EL NIÑO/LA NIÑA

3. (EP28) How did the last El Niño event affect you?

- ☐ Yes
- ☐ Small effect
- ☐ No

(EC) FFB yield

(EC/B1.3/3) Water supply

(EC) Plants (disease, pollination,…)

(FC&P) Income

(B/M) Infrastructure

(G) Workers

(G) Health

(G) Household

4. (EP28) How did the last event affect you?

- ☐ Yes
- ☐ Little effect
- ☐ No

When? How often?

(EC) FFB yield

(EC) Plants (disease, pollination,…)

(FC&P) Income

(B/M21.2) Road access/ FFB delivery/Accidents

(G) Workers

(G) Health

(G) Household

5. (G28.2) After the last drought/ flood event, were you able to re-establish your function on your own (e.g. through use of own savings, ... etc.)?

Drought	**Flood**
☐ Fully	☐ Fully
☐ Mostly	☐ Mostly
☐ Partly	☐ Partly
☐ Not at all	☐ Not at all

6. (B28.1) How long did take you to recover after drought/ flood event?

Drought	**Flood**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

7. (I&L34) How do you get informed about weather/ market price information?

☐ Extension services
☐ Other farmers
☐ Mobile phone
☐ Internet
☐ Newspaper
☐ Radio
☐ Others:

8. (I&L2.3) Are the communication channels reliable?

☐ Very reliable
☐ reliable
☐ It depends
☐ unreliable

9. (G1.5/ 41/31.1) Are there programs/measures from the government to support you before (prevent), during and after drought/ flood event? (e.g. warning systems(I&L), disaster intervention measures(B), financial aid, irrigation schemes(B) etc.)

Drought	**Flood**
Before	
During	
After	

10. (G41/43) Are there informal programs/measures from community/own measures to support you before, during and after drought/ flood event? (e.g. community support for recovering from disasters, etc.)

El Niño	**La Niña**
Before	
During	
After	

11. (T33) Did you change anything on your farm after the last drought/ flood event?

Drought	**Flood**
☐ Yes	☐ Yes
☐ No	☐ No

What?/ Why not?

_____

_____

_____

INPUT

INPUT	12. Use/ Dependency (EC/M 3.1/3.2/ 3.3/ 5/16.1)		13. Availability during extreme weather events (B)					14. Affordability (B/M)					15. Number of suppliers (M16)					16. Stocks (B1.2/1.3)					Comment (Name of supplier,…)
	No	Yes	Low				High	Low				High	1	2	5	10	10+	No	1M	3M	6M	12M+	
Industrial fertilizers																							
Compost																							
Mulch material																							
Seeds (soil cover)																							
Pesticides																							
IPM assets																							
Implements																							
Fuel																							
Machines/ Truck																							
Other																							

17. (B/EC 2) In your opinion, are the following resources on your farm in good condition?

INPUT	Bad		---		Good condition
(EC)Palm tree					
(EC)Soil cover					
(EC) Soil (fertility, structure,…)					
(EC) Water system					
(B)Buildings					
(B) Transport infrastructure(including road access)					
(B) Communication(mobile phone, reception,…)					

AGRICUTLRUAL PRACTICES/ RESOURCES

18. (M19.3) What hybrid of oil palms have you planted? (EC7/EP8) Is this variety more/less resistant to drought/high rainfall/ to pest and diseases?

Hybrid	Susceptible		---		Resistant
Drought					
High rainfall/Flooding					
Pests & Disease					

19. (EC2/3.1/3.3/5) What kind of land management practices do you use (mulching, cover crops, palm residues use?

_____

_____

_____

20. (B/EC 1.3) How well can your soil absorb/retain water?

Absorbance
- ☐ Very good
- ☐ Good
- ☐ Medium
- ☐ Low

Retention
- ☐ Very good
- ☐ Good
- ☐ Medium
- ☐ Low

21. (EC3) Have you observed one or several of the following types of soil/land degradation?
- ☐ Erosion from wind(loss of topsoil)
- ☐ Erosion from water, (loss of topsoil)
- ☐ Compaction
- ☐ Land slides

Extension services

22. (I&L13.2) What kind of access to extension and advisory services and education opportunities do you have? How often do you get training/support?

	Used	Every week	Every month	½ year	1 year+
No					
NGO					
Government					
Company					
Others					

Did you receive training on:
- ☐ Land management practices
- ☐ Soil conservation
- ☐ Water conservation
- ☐ Drought
- ☐ Floods
- ☐ _____
- ☐ _____

Mills

23. (M16) To whom do you sell your FFB?

_____

_____

24. (FC&P10/12) What kind of contract/agreements do you have with the mills?

_____

25. (I&L45) How is your relationship with the mills? (communication, trust, challenges, …)

_____

_____

_____

_____

FINANCES

4. (FC&P28.2) Does the process generate a net positive profit, business as usual, after drought/ flood event, higher CPO prices?

	Debt	Zero	Low profit	High profit	Saving generated
Business as usual					

Drought					
Flood					

Insurance

26. (FC&P9) Do you have any kind of insurance for the case of loss of: infrastructure; personal; crops; livestock?

	Formal	Informal	None
Infrastructure			
Personal			
Crops			
Livestock			

Credit

27. (FC&P10) What possibilities do you have to access to credits? Which ones do you use? How easy are they to access?

Credit source	Used	Easy access	Difficult access
Family			
Friends/Neighbours			
Loan Company			
NGO Program			
Saving Group			
Government program			
Others			

28. (G35.1) Do you have access to affordable health care in case of accidents/disease?

- [ ] Affordable
- [ ] Unaffordable
- [ ] Always accessible
- [ ] Very long distance
- [ ] Inaccessible during high rainfall/flooding

29. (T33.2) In your opinion what should be changed by you or any other actor (government, mills, community, …), so that you are better prepared for the next drought/ flood event

Drought	**Flood**

30. Anything you would like to add.

Do you have a question for us?

Would you make part of a palm oil value chain workshop?

PLANTATION QUESTIONNAIRE

Date	
Location	
Name, Job	
Company	

GENERAL NOTES

1. Farm size	ha
2. FFP Production	mt/year
3. (11) Nr. of temporary/ permanent workers	workers
4. (M19.2) Other crops planted	
5. (M36) Other income sources	
6. Companies working with	

7. (T47) What is the biggest constraint/problem for your plantation?

EL NIÑO/ LA NIÑA

8. (EP28) How did the last El Niño event affect you?

- ☐ Yes
- ☐ Small effect
- ☐ No

(EC) FFB yield

(EC) Plants(disease, pollination,…)

(1.3/3) Water supply

(FC&P) Finances

(G) Workers

(G) Health

Input suppliers/Mill

9. (EP28) Have you experienced any floods in the past years?

- ☐ Yes
- ☐ Small effect
- ☐ No

When? How often?

How did the last flood event affect you?

(EC) FFB yield

(EC) Plants(disease,…)

(FC&P) Finances

(B/M21.2) Road access/ FFB delivery

(G) Workers
(G) Health/Accidents
Input suppliers/ Mill

10. (30.1) Are there emergency plans/measures to address risks (e.g. supply shortage, process distribution) in case of such an event?

El Niño	Floods

11. (28.1) How fast would you say, did you recover from the last El Niño/flood event?

El Niño	**Flood**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

12. (33) Did you change anything on your farm after the last El Niño/flood event?

El Niño	**Flood**
☐ Yes	☐ Yes
☐ No	☐ No

What? /Why not?

13. (41/31.1) Are there **programs/measures from the government** to support you before (prevent), during and after such disturbances? (e.g. warning systems, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	
After	

INPUT	14. Use/ Dependency (EC/M 3.1/3.2/ 3.3/ 5/16.1)		15. Availability (during extreme weather events (B))					16. Affordability					17. Number of suppliers (M16)					18. Stocks (B1.2/1.3)					Comment
	No	Yes	Low -------High					Low -------High					1	2	5	10	10+	No	1M	3M	6M	12M+	
Industrial fertilizers																							
Organic fertilizer																							
EFB																							
PKE																							
Mulch material																							
Crop cover																							
Pesticides																							
IPM assets																							
Machines																							
Other																							

19. (2) In your opinion, are the following resources on your farm in good condition?

INPUT	Bad		---		Good
Oil palms					
Soil (fertility, structure,…)					
Irrigation system					
Buildings					
Energy source					
Transport infrastructure					
Communication infrastructure					

AGRICUTLRUAL PRACTICES/ RESOURCES

20. (19.3/7) What hybrid of oil palms have you planted? What are their benefit? Resistance to drought? Are these varieties suitable for this region?

Hybrid	Benefits	Drought resistance					Suitability for region				

21. (8) What kind of disease & pests are common in your plantation? Is their occurrence higher or lower during El Niño/La Niña years?

Pest& Disease	Occurrence higher during el Niño/La Niña years				

22. (2/3.1/3.3) What kind of land management practices (including water and soil conservation practices, (19.2)) do you use?

_____

_____

23. (1.3) How well can your soil absorb/retain water?

Absorbance

- ☐ Very good
- ☐ Good
- ☐ Medium
- ☐ Low

Retention

- ☐ Very good
- ☐ Good
- ☐ Medium
- ☐ Low

24. (3) Have you observed one or several of the following types of soil degradation?

- ☐ Erosion from wind(loss of topsoil)
- ☐ Erosion from water, (loss of topsoil)
- ☐ Compaction
- ☐ Land slides

MILLS

25. To how many mills do you sell your product?

mills

_____

26. External mill: (12/45) What kind of contract/agreements do you have with the mills?

_____

_____

27. (45) How is your relationship with the mills? (trust, challenges, …)

_____

_____

FINANCES

28. (12) Does the process avoid exposure to substantial financial risks (e.g. outstanding debt, risky investments)?

_____

_____

29. (9) Do you have any kind of insurance for the case of loss of: infrastructure; staff; oil palm, FFB yield?

	Formal	None
Infrastructure		
Staff		
Oil palms		
FFB yield		

30. (10) Do you have access to funds for investment, maintenance, and expansion (e.g. through savings, financial services such as credit, etc.)

Fund source	Available	Used	Easy access	Difficult access
Government supported				
Investors				
Banks				
Others				

31. (28.2) Do you generate a net positive profit, business as usual, after El Niño/La Niña?

	Debt	Zero	Low profit	High profit	Savings generate
Business as usual					
El Niño					
Flooding					

32. (T33.2) In your opinion what should be changed by you or any other actor (government, mills, community, …), so that you are better prepared for the next El Niño/La Niña event?

El Niño	La Niña

33. Anything you would like to add.

MILLS QUESTIONNAIRE

Date	
Location	
Name	
Company	
Phone Nr.	
Job	

GENERAL NOTES

1. CPO output per year		t
2. CPO storage capacity / CPO stored currently	t	t
3. Nr. of temporary/ permanent staff (11)		staff

4. (M36) What products does your mill produce and sell? (M16) Through what channel and markets do you sell them? (number of buyers/relevant company names, domestic or exported)

Product	Channel/ Company/Export

5. (G31/T47) What is the biggest constraint/problem for you in your activities?

6. What does your mill do with your EFB, shell and fiber, boiler ash, POME?

EFB

Shell

Fibre

Boiler Ash

POME

EL NIÑO/ LA NIÑA

1. (EP28) How did the last El Niño event affect you?

- ☐ Yes
- ☐ Small effect
- ☐ No

(M) FFB supply

(M) CPO delivery

(FC&P) Finances/market price

(B1.3) Water supply

(G) Workers

(G) Health

(M15) Suppliers

(M15) Buyers

2. (EP28) How did the last flooding event affect you?

- ☐ Yes
- ☐ Small effect
- ☐ No

When? How often?

(M) FFB supply

(M) CPO delivery

(M) Buildings

(B/M) (1/18) Machines

(I&L) Communication

(FC&P) Finances/Market price

(G) Health/(G35) Accidents

(M15) Suppliers

(M15) Buyers

7. (G30/ 30.1) Are there emergency plans/measures to address risks (e.g. supply shortage, water supply, flooding, accidents) in case of such an event?

El Niño	Flood

8. (EP28.1) How fast would you say, did you recover from the last El Niño/flood event?

El Niño
- ☐ Few weeks
- ☐ Few month
- ☐ 1-2 year
- ☐ > 2 year

Flood
- ☐ Few weeks
- ☐ Few month
- ☐ 1-2 year
- ☐ > 2 year

9. (T33) Did you in the past after El Niño/flood modify anything in your process to be better prepared for future disturbances? What?
- ☐ Yes
- ☐ No

What?/ Why not?

10. (G41/31.1) Are there programs/measures from the government to support you before (prevent), during and after El Niño/floods? (e.g. warning systems, disaster intervention measures, financial aid, etc.)

El Niño	**Floods**
Before	
During	
After	

RESOURCES

11. (B1.2/1.3) Do you keep stocks of these inputs?

INPUT	No	1 month	½ year	>1 year
Spare parts				

12. (B/EC2) In your opinion, are the following resources on your mill in good condition?

INPUT	Bad	---			Good condition
(M) Machines					
(EC/B) Water system					
(B) Buildings					
(B) Energy source					
(B) Transport infrastructure					
(B) Communication infrastructure					

WORKERS

13. (FC&P11) Do you have enough man power to deal with challenging situations (floods, …)?

- ☐ Sufficient
- ☐ Marginal
- ☐ Lacking

14. (11.1) Have you ever needed to reduce the number of workers during/after El Niño/flood event?

- ☐ Yes
- ☐ No

Reason:

_____

MARKET

15. (M16) From how many farmers/collection centres do you receive FFB?

	Farmers

16. (I&L 45) How is your relationship with your farmers? (trust, challenges, communication, trainings, support in times of drought/flooding, …)

_____

_____

_____

17. (FC&P12/I&L45) How do you buy FFB? (contract, weight-based on day of acquisition, spoken agreement)

_____

_____

18. (12/45) How is your relationship with your buyers? (trust, challenges, ...)

_____

_____

FINANCES

19. (FC&P12) Does the process avoid exposure to substantial financial risks (e.g. outstanding debt, risky investments)?

_____

_____

20. (FC&P9) Do you have insurance for the case of loss of: infrastructure, staff, FFB supply disruption, others?

	Formal	None	Comment
Infrastructure			
Staff			
CPO delivery			
Others			

21. (FC&P10) Does the process have access to funds for investment, maintenance, and expansion (e.g. through savings, financial services such as credit, etc.)

Fund source	Used	Easy access	Difficult access
Government			
Investors			
Banks			
Others			

22. (FC&P28.2) Does your company generate a net positive profit, business as usual, after El Niño/floods?

	Debt	Zero	Low profit	High profit	Saving generated
Business as usual					
El Niño					
Floods					

Education

23. (13.1) Does your company have the opportunity to receive training? on what?

	Available	Used	Training Topics
Company organized			
NGO			
Government			
Others			

24. (T33.2) In your opinion what should be changed by you or any other actor (government, mills, community, …), so that you are better prepared for the next El Niño/La Niña event?

El Niño	Flood

Do you have a question for us?

Would you make part of a palm oil value chain workshop?

REFINERY QUESTIONNAIRE

Date	
Location	
Name	
Company	
Phone Nr.	
Job, Education level (13.4)	

GENERAL NOTES

1. CPO processed	t
2. CPO storage capacity	
3. Certification (RSPO, ,…)	
4. Years of experience in refining business (13.3)	years
5. Nr. of permanent staff (11)	staff
6. Nr. of temporary workers (11)	worker

7. (36) What products does your refinery produce?

8. (31/47) What is the biggest constraint/problem for you in your activities?

EL NIÑO/ LA NIÑA

9. (28) How did the last El Niño event affect you (CPO supply, financially, product quality ,…including benefits)?

10. (28) How did the last La Niña event affect you (CPO supply, financially, product quality, …including benefits)?

11. (1/18) Do you have alternatives, if a machine breaks down in times of shock (due to flooding)?

12. (35) How high is the risk for accidents in the refinery during increased rainfall/floods? Are there protective measures?

13. (1.3) Do you have sufficient access to water (even during an El Niño event)?

Normally	**El Niño**
☐ Very good	☐ Very good
☐ sufficient	☐ sufficient
☐ Critical	☐ Critical
☐ Insufficient	☐ Insufficient

Do you have any measures against that risk?

14. (30.1) Are there emergency plans/measures to address risks (e.g. supply shortage, process distribution) ?

El Niño	La Niña

15. (28.1) How fast would you say, did you recover from the last El Niño/La Niña event?

El Niño	La Niña
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month

☐ 1-2 year ☐ 1-2 year
☐ > 2 year ☐ > 2 year

16. (28.2) After the last El Niño event, were you able to re-establish your function on your own (e.g. through use of own savings, ... etc.)?

☐ Fully
☐ Mostly
☐ partly
☐ Not at all

17. (11.1) Have you ever needed to reduce the number of workers during/after El Niño/La Niña period?

☐ Yes
☐ No

Reason:

18. (33) Did you in the past after El Niño/La Niña modify anything in your process to be better prepared for future disturbances? What?

☐ Yes
☐ No

What? /Why not?

19. (41/31.1) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, disaster intervention measures, financial aid, etc.)

Before

During

After

20. (33.2) In your opinion what should be changed by you or the government, so that you are better prepared for the next El Niño event?

RESOURCES

21. (1.2/1.3) Do you keep stocks of these inputs? (can we have a look at the storage room?)

INPUT	No	1 month	½ year	>1 year
CPO				
Processed products				
Spare parts				

22. (2) In your opinion, are the following resources of your refinery in good condition?

INPUT	Bad --- Good condition				
Trucks					
Machines					
Water system					
Buildings					
Energy source					
Transport infrastructure(including road access)					
Communication infrastructure					

Workers

23. (11) Do you have enough labour force on your refinery?

☐ Sufficient
☐ Marginal
☐ Lacking

24. (35) Does personnel have access to healthcare?

☐ In the area, affordable
☐ In the area, very high cost
☐ Very far distance
☐ Not at all
☐ No, other reason:

SERVICES

Government

25. (25) Are there any government laws, regulations which affect your activity? (social, economical, environmental, taxation, export, hygiene)

26. (29) Is there any government support for refineries like yours? (e.g. subsidies, tax reductions, knowledge transfer, etc.)

Education/Knowledge

27. (13.1) Does your company have the opportunity to receive training? on what?

	Available	Used	Training Topics
Company organized			
NGO			
Government			
Conference			
Others			
El Niño/la Niña specific			

MARKET

Mills

28. (16/16.3) From which mills do you obtain CPO?

Company	Location

29. (45) How is your relationship with your CPO suppliers? (trust, challenges,...)

30. (12/45) How do you buy CPO? (contract, weight-based on day of acquisition, spoken agreement)

31. (29) How do you manage supply and demand?

Trader

32. (16) Through what channel and markets do you sell your product? (number of buyers)

Product	Channel/ Company

33. (12/45) How is your relationship with your buyers? (trust, challenges, ...)

FINANCES

34. (10) Is the financial flow permanent throughout the year?

- ☐ Permanent
- ☐ High variability
- ☐ Known intervals
- ☐ unreliable

35. (12) Does the process avoid exposure to substantial financial risks (e.g. outstanding debt, risky investments)?

36. (9) Do you have insurance for the case of loss of: infrastructure, personnel, low CPO supply, others?

	Formal	Informal	None
Infrastructure			
Personnel			
CPO supply reduced/hindered			
Others			

37. (10) Does the process have access to funds for investment, maintenance, and expansion (e.g. through savings, financial services such as credit, etc.)

Fund source	Available	Used	Easy access	Difficult access
Government supported				
Investors				
Banks				
Others				

38. (28.2) Does the process generate a net positive profit, business as usual, after El Niño/La Niña, higher CPO prices?

	Debt	Zero	Low profit	High profit	Saving generated
Business as usual					
El Niño					
El Niña					
Higher CPO prices					

39. (47) What do you think should be changed in the palm oil industry?

40. Anything you would like to add.

Do you have a question for us?

Would you make part of a palm oil value chain workshop?

TRANSPORTERS QUESTIONNAIRE

Name _____
Company _____
Phone Nr. _____
Location _____
Date _____

GENERAL NOTES

1. Number of trucks	
2. (11) Number of workers (permanent/temporary)	workers
3. How many transports do you do per day?	

4. (M36) What sources of income do you have? What goods do you transport?
   1)
   2)
   3)
   4)

5. (T47) What is the biggest constraint/problem for you/your workers in your activities?

EL NIÑO/ LA NIÑA

6. (28) How did the last El Niño event affect you (amount of FFB/CPO transported, financially, …including benefits)?

Transport

Finances

Benefits

7. (28) How did the last flood event affect you (flooding, impaired roads, truck break down sales, financially, …including benefits)?

Truck s

(31.1/1/2) Road access/Accidents

FFB delivery

Finances

Benefits

8. (28/15) Have you been unable to deliver FFB/CPO to the mill in the past 5 years? What kind of incidence?

- ☐ Never
- ☐ On yearly basis
- ☐ On monthly basis
- ☐ On weekly basis
- ☐ Daily basis
- ☐ Accidents
- ☐ Impassable roads
- ☐ Floods
- ☐ Truck break down
- ☐ Lack of workers
- ☐ Others:

How do you know, if a road is impassable?

9. (28.1) Did it take long for you and your process to recover from the last drought/flood? (financially, number of transports, …)?

El Niño	**Flood**
☐ Few weeks	☐ Few weeks
☐ Few month	☐ Few month
☐ 1-2 year	☐ 1-2 year
☐ > 2 year	☐ > 2 year

10. (30.1) Are there emergency plans/measures to address risks (accidents, spare transport, trucks,…) in case of such an event?

11. (33) Did you change anything in your business after the last El Niño or flood event?

El Niño	**Flood**
☐ Yes	☐ Yes
☐ No	☐ No

What?

12. (41/31.1) Are there programs/measures from the government to support you before (prevent), during and after such disturbances? (e.g. warning systems, disaster intervention measures, financial aid, roads etc.)

EL Niño	**Flood**
Before	
During	
After	

INPUTS: FUEL/SPARE PARTS

13. (16) From how many sellers can you get fuel/spare parts in this area?

	1	2-5	5-10	10-20	>20
Fuel					
Spare parts					

14. (1.2/1.3) Do you keep stocks of fuel/spare parts (tyres,…)?

INPUT	No	1 month	½ year	>1 year
Fuel				
Spare parts				

15. (2) In your opinion, are the following resources in good condition?

INPUT	Bad		---		Good	Comment
Buildings						
Trucks						
Energy source						
Transport infrastructure						
Communication infrastructure						

16. Does the government invest sufficiently in roads?

Mills

17. (16) How many customers do you have?
Customers

18. (45) How is your relationship with your customers? (trust, challenges, incidences)

FINANCES

19. (10) What possibilities do you have to access to credits? Which ones do you use? How easy are they to access?

Credit source	Used	Easy access	Difficult access
Family, Friends			
Loan Company			
NGO Program			
Own savings			
Government program			
Others			

20. (12) Does your mill face substantial financial risks (e.g. outstanding debt, risky investments)?

21. (28.2) Does the process generate a net positive profit, when business as usual, after El Niño/flood?

	Debt	Zero	Low profit	High profit	Saving generated
Business as usual					
El Niño					
Floods					

22. (9) Do you have any kind of insurance for the case of loss of: infrastructure; personnel; crops; livestock?

	Formal	Informal	None
Infrastructure			
Personal			
Trucks			

23. (33.2) In your opinion what should be changed by you or the government, so that you are better prepared for the next El Niño/flood event?

_____

_____

_____

Anything you would like to add.

_____

_____

Do you have a question for us?

Would you make part of a palm oil value chain workshop**?**
Date: 01.12.16
Location:
Time: 10.30 AM- 3.30 PM
Reimbursement: - Transport costs
Lunch offered

- ☐ Yes
- ☐ Maybe
- ☐ No