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Permaculture Farming for The Future:
A Resilience Perspective

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Declaration

I, Line Leistad, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

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ABSTRACT

Permaculture has been argued to be a sustainable alternative to industrial agriculture, with the potential to avoid the negative social and ecological consequences associated with large-scale monocultures. Through the lens of social-ecological theory, this study analyzes two permaculture farms in Costa Rica, based on findings from qualitative interviews and participatory observation. The analysis concludes that the farmers' management strategies closely parallel the pre-defined indicators of farm resilience. Permaculture farming is knowledge-intensive, and requires farmers to be innovative and market responsive. Perennial based systems further represent benefits and challenges. It takes time to establish a productive system that generates income, but the reward is a self-regulating, resilient system.

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1 INTRODUCTION

1.1 Background

Our global food system is at a crossroads. A rapidly growing population and industrial agriculture has put increased pressure on the Earth's natural resources, which has resulted in a degeneration of them (FAO 2016). As our main source of food, agriculture is a fundamental human activity and crucial for humans' survival on Earth (Pimentel 2011). When natural resources, as the basic foundations of agriculture; fertile soil, nutrient recycling, genetic diversity and ecosystem services of natural ecosystems are being deteriorated, the food supply of tomorrow is being put at risk (Gliessman 2014).

Moreover, agricultural lands occupy nearly half of the Earth's land area (Smith et al. 2007). Thus, the global environmental impacts of agriculture are significant. Due to scientific and technological innovations, new plant varieties, fertilizers, pesticides and irrigation systems, modern agriculture has had a dramatic increase in productivity and created a food abundance (Gliessman 2010). However, it does not mean it will do so in the long-term. The techniques, practices and policies this model is based upon, have also deteriorated the conditions that make agriculture possible (Gliessman 2014). To facilitate mechanized cultivation, industrial farming cultivates vast fields of one crop variety, also known as monocultures. These types of crop systems are vulnerable to pests and diseases, because they lack diversity. In addition, monoculture farming is nutrient demanding, and rapidly deplete the soils nutrients. As a result, monocultures are heavily dependent on external inputs, such as fertilizers and pesticides (Hathaway 2015; Tilman 1999).

Modern industrial agriculture contributes to many of the most severe environmental problems, such as climate change, loss of biodiversity, water and energy use and pollution from toxic chemicals. At the same time, we experience challenges of poverty, hunger and malnutrition. As a consequence, we need to fundamentally change our agricultural systems (FAO 2014; Hathaway 2015). FAO (2016)'s *State of Food and Agriculture* report stress the importance of restructuring modern agriculture, and replace it with systems that create synergies with the natural environment instead of depleting natural resources. Further, they recommend agroecology as one such sustainable approach, that build resilience through management practices such as green manuring, nitrogen-fixing crops and integration of agroforestry.

1.2 Agroecology

Agroecology is a science, a practice and a part of a social movement that focuses on transforming food systems to sustainability (Gliessman 2014). The modern agroecology as a practice emerged in Mexico in Latin-America in the 1970's, as a response to the Green Revolution that had created social and environmental problems (Wezel et al. 2009). Similar to what we see on a global scale, monoculture production was causing degradation of soil, loss of biodiversity, pests, poverty, malnutrition and loss of livelihood diversity in the area. The initiative started looking to local farmers, which had a rich agricultural tradition, based on traditional farming systems (Gliessman 2014).

Today's Agroecologial initiatives aim to transition industrial agriculture towards an alternative way of farming, that encourages local initiatives, small-scale production and the use of local renewable resources (Altieri & Toledo 2011). Interacting plant and animal species have coevolved over centuries to use the local natural resources most efficiently. Therefore, natural ecological systems provide a model of survival and relative stability upon which we can design modern agroecosystems (Francis et al. 2003). The greater the structural and functional similarity, the more sustainable the agroecosystem will be (Gliessman et al. 1998). By focusing only on productivity as common in industrial agriculture, the large investments in energy and materials that are required for production, processing and transportation throughout the food chain, are ignored. Consequently, a sustainable food system should aim to use renewable energy, close nutrient cycles, promote environmental health and bring back the focus on ecology and uniqueness of place. (Francis et al. 2003).

Within agroecology, there are several other and movements. One of these is the permaculture movement, which has been argued to be a counterweight in moving towards a sustainable society (Veteto & Lockyer 2008).

1.3 Permaculture

Permaculture is a "global grassroots development, philosophy and sustainability movement that encompasses a set of ethical principles and design guidelines and techniques for creating sustainable, permanent culture and agriculture" (Veteto & Lockyer 2008).Bill Mollison, the "father of permaculture" has defined permaculture as "*the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their* *food, energy, shelter, and other material and non-material needs in a sustainable way*" (Mollison 1990). The ethics of permaculture include care for the earth (soil, forests and water), care for people (look after self, kin and community) and fair share (limit consumption and redistribute surplus) (Holmgren 2007) .

The main philosophy behind permaculture is to mimic natural ecosystems, and work with, rather than against nature. Permaculture looks at the system as unit, where all parts are interconnected, and aims to design ways to fix problems in a long-term, sustainable way. Permaculture farming is a continuous process of improving the system through recognizing patterns in natural systems, and learn from past mistakes (Mollison 1990). Further, permaculture focuses on learning from indigenous, and cultures of places, because these people have lived in relative balance with their environment, using methods that have survived for generations(Holmgren 2007).

The permaculture literature presents a set of guidelines for designing agroecosystems. These 12 principles are described in table 1 below.

Table 1- Permaculture Design Principles
Principle 1: Observe and interact The first principle is getting to know your land, to design a site-specific system (McManus 2010). Farmers need to consciously observe their land to learn patterns of the sun, wind, water flow or animals (TimberPress 2013) The aim is to see how resources and human competence can be used as efficient and sustainable as possible (Holmgren 2007).
Principle 2: Catch and store energy Collecting and storing resources when they are abundant, ensures self-sufficiency in times of need. Sources of energy are sun, wind, runoff water flows, waste from agriculture (Holmgren 2007). Catching and storing energy can take many forms, for instance canning food, and harvesting rainwater or recycling greywater for irrigation during dry periods (TimberPress 2013).
Principle 3: Obtain a yield Systems should be designed to ensure the self-reliance of the farm and the people that live there, and the energy used effectively to maintain the system and generate more energy. Energy include harvest yield, income, and functions as a reward, which in turn encourages spreading of successful systems (Holmgren 2007).
Principle 4: Apply self-regulation and accept feedback Self-maintaining and regulating systems is one of the key objectives of permaculture. By receiving and understanding feedback from the system, the design can be adjusted to reduce

the work necessary for corrective management. Also by being more attuned to feedback signals, we can prevent overexploitation of our resources (Holmgren 2007). Responding to feedback can involve replanting unproductive areas or regenerate soils (TimberPress 2013).A typical permaculture approach to this is choosing hardy, self-pollinating and semi-wild species (Holmgren 2007).

Principle 5: Use and value renewable resources and services

Renewable resources can be renewed by natural processes, within reasonable time, without the need for non-renewable inputs. A simple example of using renewable resources is drying clothes in the sun, rather than in a tumble dryer. A renewable service, can be using a tree for shade and shelter. A permaculture approach is using animals for preparing the ground, to avoid tractors and artificial fertilizers, while saving both money and the environment (Holmgren 2007).

Principle 6: Produce no waste

In permaculture farms, there is no waste because everything can be repurposed. (TimberPress 2013). The expression "refuse, reduce, reuse, repair, recycle" is a motto to live by (PermacultureAssociation 2017). Reuse of waste is essential for reducing our ecological footprint (Holmgren 2007). In permaculture, a pollutant is defined as "an output of any system component that is not being used productively by any other component of the system", and would result in the unnecessary work of dealing with these (Mollison 2002). A classic example is composting, where food scraps are recycled into nutrient rich soil, that can be put back into the vegetable garden as soil amendment (TimberPress 2013).

Principle 7: Design from patterns to details

Permaculture aims to mimic successful natural patterns, and by recognizing these patterns, a permaculture designer can start to make sense of the site and create a suitable design. By starting with the large patterns, to take a step back and look at the larger picture, rather than getting lost in the details. The use of zones is common in permaculture. Zone 1 is the house and the spaces most frequently used, whereas zone 5 is natural forest which is rarely visited. (Holmgren 2007; Mollison 2002; TimberPress 2013).

Principle 8: Integrate rather than segregate

This principle emphasizes the connection between plants, animal, people and infrastructure. A good design should place elements so that they benefit each other, in a self-regulating system that requires minimal corrective management. The two main guidelines of this principle are "each element performs many functions" and "each important function is supported by many elements" (Holmgren 2007).

Principle 9: Use small and slow solutions

Permaculture does not look for immediate pay-off, but instead promotes a long-term design. The farm should be composed of many small parts which combined result in a well-functioning system (TimberPress 2013). Small scale systems require less energy input, which in turn make them energy efficient (Mollison 1981). The use of perennial plants is an example of a slow solution. They form stable, biodiverse systems, require less work, water and fertilizers to grow, which combined makes them more productive, sustainable and energy efficient than annuals (Eliades 2009).

Principle 10: Use and value diversity Permaculture encourage biodiversity and the use of polycultures (opposite of monoculture). Diversity should also include built or living structures and people, with their different cultures (Holmgren 2007). Diversity also includes the functional connections between elements (Mollison 1981).
Principle 11: Use edges and value the marginal Edges are transition zones between two systems, where for example genetic material or experience can be exchanged. Edges can be between ecosystems, habitats, succession stages, natural or domesticated fields, as well as cultures or communities in social systems. Ecological transition zones are often high in productivity and biodiversity (Turner et al. 2003), and permaculture therefore recommends increasing the number of edges and creatively using these (Mollison 2002). In social systems, edges are zones where cultures meet and interact with each other (Turner et al. 2003).
Principle 12: Creatively use and respond to change Agroecosystems should be designed to make use of change, in a deliberate and cooperative way, and creatively respond or adapt to large-scale system change, which is beyond our control or influence. These changes include temperature, temperature, pests or rainfall, and the natural and predictable development in ecosystems, such as plant succession (Eliades 2009; Holmgren 2007; TimberPress 2013).

In contrast to agroecology, permaculture is criticized for being isolated from scientific science. Although it emerged for an academic collaboration between a professor and his student, permaculture suffers from a lack of reference to modern science (Ferguson & Lovell 2014). Permaculture has also been accused for overreaching and simplifying claims. This includes both claims of land and labor productivity of complex perennial systems. In addition, the literature also tends to ignore the challenges of designing and maintaining highly complex agroecosystems (Ferguson & Lovell 2014). As such, more research is needed to fully understand the perceived benefits of permaculture farming.

1.4 Agroecosystems as social-ecological systems

Humans depend on the capacity of ecosystems, to provide ecological goods and services. Although humans dominate agroecosystems, they rely on the functioning of ecological processes. This interconnectedness is why an agroecosystem can be considered a social-ecological system (Milestad 2003; van Apeldoorn et al. 2011). Because people are an integrated part of the ecosystem, and largely affected by the system's success or failure, building resilience in agroecosystems is a long term investment for the global population

(Francis et al. 2003). A resilient agroecosystem can maintain the capacity to provide people with the natural resources they depend upon for their livelihood (Cabell & Oelofse 2012).

Based on the understanding that agroecosystems are social-ecological systems, Social-Ecological Resilience-theory is an appropriate framework.

1.5 Conceptual Framework

1.5.1 Social-Ecological Resilience Theory

The concept of ecological resilience was first introduced by Holling (1973), criticizing the conventional view of nature as a predictable 'equilibrium, linear, steady-state' science. Instead of considering resilience as the 'return-time to stable state after disturbance', he defined ecological resilience as "*the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures*" (Gunderson 2000). This approach further viewed systems as non-linear, with constant changes and thresholds. The future is unpredictable with periods of gradual change, interacting with periods of rapid change. This concept has later been developed to include the social dimension. Social-ecological resilience is now an interdisciplinary concept, used for understanding linkages and dynamics between natural and social systems (Folke 2006).

The resilience of social-ecological systems depend upon three main properties (Carpenter et al. 2001; Milestad 2003);

- *The amount of change and extrinsic force the system can undergo and still maintain the same controls on structure and function (**buffer capacity**)*

  *The degree to which the system can build the capacity to learn and adapt. **Adaptive capacity** is a component of resilience that reflects the learning and appropriate action in response to disturbance (Gunderson 2000)*

- *The degree to which the system is capable of **self-organization**, versus lack of organization or organization forced by external factors. (Another expression for this would be the capacity for reorganization).*

1.5.2 Buffer Capacity

The first characteristic is the system's buffer capacity. Buffer capacity is the capacity to absorb disturbance (surprise, change, crisis), and possibly use the opportunities that arise from them (Berkes et al. 2003; Speranza 2013). The impact of a disturbance can be buffered by rearranging resources temporarily, such as spending economic reserves or investing in extra labor, to maintain the farm's structure and function during difficult times (Darnhofer 2014).

Disturbances can also result in positive outcomes. To prevent the buildup of a crisis, a successful farm management will allow disturbances to enter on a small scale (Cabell & Oelofse 2012). To understand this concept, we can use the analogy of a football team. 'Never change a winning team' is not a good long-term plan, because to keep winning, the team needs a certain amount of renewal (Berkes et al. 2003). The same principle applies to agroecosystems. After a disturbance, the system can reorganize and form new and better structures, by triggering social incentives and recombine sources of knowledge and experience. This can spark innovation, which ultimately leads to renewal and development of the system (Connell 1978; Folke 2006; Folke et al. 2010).

1.5.3 Adaptive Capacity

The adaptive capacity is the system's ability to learn and adjust management as experience and knowledge increases (Berkes et al. 2003). The function of adaptive capacity is to increase the range of coping strategies, to both current and future conditions, to reduce harmful outcomes of disturbance (Brooks & Adger 2005). Indicators of adaptability in agroecosystems include natural resources (biodiversity, genetic diversity and variety in and of landscapes), social capital (social networks which promote collective action and knowledge), human resources (farming skills, knowledge and experience) and financial capital (Brooks & Adger 2005; Carpenter et al. 2001). Because human actions influence social-ecological systems the most, adaptability is mainly a social component and is defined as "the capacity of actors in the system to influence resilience" (Walker et al. 2004). To influence resilience, farmers need to combine knowledge and experience with the ability to identify problems, prioritize and mobilize resources (Darnhofer 2014). In other words, a farmer that is ready to receive and respond to feedback from the system (Milestad & Darnhofer 2003).

1.5.4 Self-organization

The capacity for self-organization is the system's social capital and collective action (Berkes & Seixas 2005). In the context of agroecosystems, this can be a group of farmers that form a social or economic network or institution. The skills, learning, human relationships and mutual trust these types of institutions facilitate contribute to building resilience (Milestad & Darnhofer 2003). Self-organized agricultural networks can contribute to economic, environmental and socially sustainable food systems, that rely on local resources, and serve local markets and consumers. Thus, is can also be considered the community's problem solving capacity (Lyson 2005).

1.6 Aim of Thesis

Bearing in mind the interconnected social and ecological nature of agroecosystems, this study has adapted a social-ecological resilience framework. Using a set of pre-defined farm resilience indicators, this thesis aims to identify current social and ecological farm features that can be conducive to building farm resilience, and which factors represent challenges. Permaculture is an approach to farming which has been claimed by its proponents to be truly sustainable. Considering the emergent need for a transformation of the current agriculture system, this study uses findings from two farms in Costa Rica that have adopted a permaculture-based management approach, while basing the analysis on the farmers own perspectives.

1.7 Objective and Research Questions

The overall objective of this thesis is to analyze permaculture-based farming in a social-ecological resilience framework.

- ***Is the current management approach enhancing or detracting from social and ecological resilience?***

- ***What are the main challenges of a permaculture-based farming approach?***

2 ANALYTICAL FRAMEWORK

2.1 Indicators of Farm Resilience

To assess the farms' resilience, I have used a set of indicators adopted from Cabell and Oelofse (2012) which, when identified in agroecosystems, imply resilience. Although the authors stress the complexity of, and difficulty in measuring resilience in agroecosystems, the absence of these indicators can help identify vulnerabilities in the system. Based on the three main properties resilient social ecological systems depend upon, I have categorized the indicators as visualized in table 2.

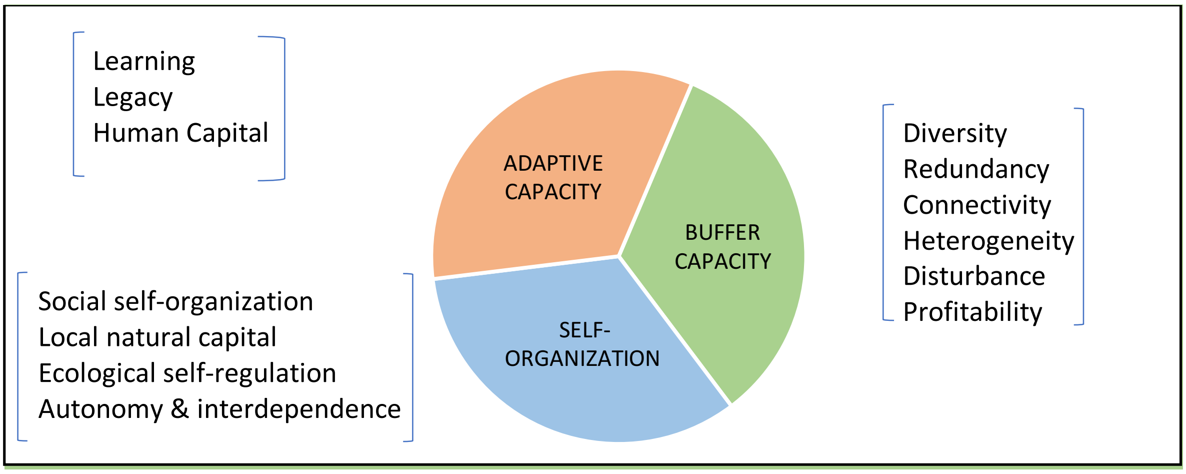

Table 2- Three Main Categories of Farm Resilience

Due to the abstract and multidimensionality of resilience theory, it is difficult to operationalize (Cumming et al. 2005). Thus, there might be other ways of categorizing and defining these indicators. Also, some overlap between two categories. I have aimed to base my categories on the work of Milestad and Darnhofer (2003). I will begin with the system's buffer capacity, then its adaptive capacity and finally the capacity for self-organization.

Table 3- Indicators of Farm Resilience
Buffer Capacity
Functional and Response Diversity Indicators of diversity in agroecosystems include diversity of genes, species, landscape patches, pest controls, cultural groups, income sources and governance institutions (Biggs et al. 2012; Cabell & Oelofse 2012). Diversity is important because it spreads risk by having several options for responding to change (Berkes et al. 2003; Chapin et al.

2009a). In an ecosystem, there can be groups of species that have the same function such as photo-synthesizers, pollinators and nitrogen fixers. These groups are called functional groups (Berkes et al. 2003; Levin 1998). *Functional diversity* is having more species in each functional group (Elmqvist et al. 2003). An example could be beans, clover and peanuts, all of which fix nitrogen to the soil (Homestead&Gardens 2014). Functional diversity can increase the total performance of an agroecosystem, because the species complement each other. Ways species do this, is by growing at different speeds, taking water from different depths or store different amounts of carbon (Elmqvist et al. 2003). In addition to having several species within a functional group, it is also important that the species respond differently to environmental changes. Variations in reactions is what we call *response diversity.* Response diversity is important for agroecosystems in the face of disturbance, because it has several response options (Elmqvist et al. 2003). For instance, a farm whose economy depends on a single crop, does not have response diversity. Thus, it is vulnerable to disturbance, because if their one crop fails, it lacks options for recovery (Berkes et al. 2003; Chapin et al. 2009a).
Optimally Redundant Redundancy means that if a species decline or go extinct, its function can be compensated for by another (Walker 1995). As insurance in case of failure, one or preferably all system components, should perform more than one function. If the components also react different to disturbances (response diversity), the system is generally more resilient. An example of this, is seed dispersal by mammals in a forest. Small animals (e.g. mice) that have a limited range of movement, will be more affected by local disturbances than larger animals (e.g. monkeys), who can move to another area and still maintain their function as seed dispersers (Simonsen et al. 2012). In a farming context, redundancy can be achieved by planting several crop varieties and having multiple sources of water or nutrients (Cabell & Oelofse 2012)
Appropriately Connected The way elements in a social-ecological system interact or fit together, is referred to as *connectedness*. In resilient systems, there is not just a diversity of elements (e.g. people, institutions, ecosystem types, resources or water), but also in the relationships between them (e.g. food webs or nutrient cycles). The elements alone do not (Cabell & Oelofse 2012; Cumming et al. 2005; Levin 1998). On a farm, you can find examples of both social and ecological connectedness. *Social connectedness* is when farmers cooperate with other farmers and consumers, have multiple suppliers and sell their produce to different vendors. This ensures the system to be flexible and diverse, instead of being completely dependent on a few relationships (Cabell & Oelofse 2012). *Ecological connectedness* can be achieved by cultivating polyculture crops (Cabell & Oelofse 2012). Polycultures increase biomass productivity compared to monocultures

due to better utilization of resources (such as different root lengths), and positive interactions between species (legumes that increase nitrogen availability for other plants) (Elmqvist et al. 2003; Fargione et al. 2007; Picasso et al. 2011).

Spatial and Temporal Heterogeneity

Heterogeneity of agroecosystems is defined as "the lack of uniformity across the landscape and through time" (Cabell & Oelofse 2012). Landscape heterogeneity is important for species richness, biodiversity and the capacity for both functional and response diversity, which in turn increases the overall system resilience (Di Falco & Chavas 2008; Fahrig et al. 2011; Weibull et al. 2002). Most social-ecological systems contain elements both on different temporal and spatial scales. For example do most families have members of different ages, with different skills and perspectives, and natural forests have trees at different ages, in various stages of regeneration from disturbance (Chapin et al. 2009b). Agroecosystems usually have less heterogeneity than natural ecosystems, but those that do typically contain patches of undisturbed or less managed land (Fahrig et al. 2011). Indicators of *spatial heterogeneity* on farms are variations in microclimates, soil types, mixture of managed and unmanaged land, whereas *temporal heterogeneity* can be practicing crop rotation to maintain soil health (Cabell & Oelofse 2012; Mäder et al. 2002).

Exposed to Disturbance

Disturbances are sudden or slow increases in pressure, that can result in transformation of the system. Sudden spikes in pressure (shocks), can be earthquakes or a financial crisis, and slowly increasing pressures (stressors) can be human induced soil degradation (Gallopín 2006). A transformation of the system is a change that is difficult or impossible to reverse, and happens when a threshold is crossed, that changes the overall structure or function. Examples are fisheries and grazing systems that have collapsed due to overexploitation (Scheffer et al. 2000).

However, when a system is exposed to carefully managed disturbances, it is beneficial for the system. This is because small scale disturbances breaks up established connections, that otherwise would have been difficult to change, and the result is new and spontaneous formations (Connell 1978). A practical example in the context of agroecosystems, is a pest management regime that tolerates a small invasion, followed by selection of resistant plants (Cabell & Oelofse 2012).

Reasonably Profitable

A farm should be reasonably profitable, which means that farmers and farm-workers must be able to make a livable income. They should not have to depend on secondary employment or large subsidies (Cabell & Oelofse 2012). One of the main threats of economic farm resilience, is dependence on a narrow range of natural resources. This can result in unstable income in the face of economic (cyclical swings in prices) or natural (droughts, floods, pests or diseases) disturbances (Adger 2000). Accumulating wealth allows farmers to make investments, and increases the range of available options and resources in the face of disturbance (Holling 2001).

Farmers can stabilize their economy by diversifying their sources of income. This also makes responding to new market opportunities and adapting their farms to changing agricultural environments easier (Barbieri & Mahoney 2009). Some ways to diversify income include cultivating multiple crops, integrate tourism or recreation, pack and process products on site, rent buildings or areas and change marketing and distribution methods to reach new markets (Barbieri et al. 2008). Although the farms economic situation is classified as buffer capacity here, it is arguable also an important aspect of adaptive capacity, because as stated above, it determines the range of possible options for responding and adapting to change (Barbieri & Mahoney 2009; Holling 2001).
Adaptive Capacity
Builds Human Capital Human capital can be understood with the analogy of a bank account that is filled with knowledge rather than money. It consists of the knowledge, experience and skills of people (Luthans et al. 2004). Because agroecosystems are greatly affected by people, their role in the system is essential. The more knowledge they possess, the more positive influence they can have on both social and ecological parts of the system(Cabell & Oelofse 2012). Thus, on a personal level, training and education can be considered investments in the human capital (Becker 1994). On a larger scale, some approaches can be investing in infrastructure and provide meeting places, where interaction between cultures and generations can encourage learning (Cabell & Oelofse 2012; McManus et al. 2012).
Reflected and Shared Learning This indicator relates to the system's adaptive capacity, and is the ability of individuals and institutions to learn from past experiences. By sharing of knowledge and experimenting, farmers can shape their future and foresee change. Resilience indicators of reflective and shared learning are cooperation and knowledge sharing between farmers, farmers' knowledge about the state of the system, record keeping and advisory services (Cabell & Oelofse 2012). Adaptive capacity is an ongoing learning process of trial and error. By actively experimenting farmers can get a better understanding of system dynamics. Experimenting is for example examining the influence of buffer strips on insect population. The feedback they receive allows farmers to adjust their practices and increase their repertoire of response-options for the future (Darnhofer et al. 2010; Milestad et al. 2012). Adaptive management also involve social relations, which are important for increasing knowledge. Institutions or networks can facilitate reflective and shared learning through social interaction. One example is farmer's markets, which provide farmers with face-to-face interactions with other farmers and consumers. These interactions allow farmers to

exchange experiences and knowledge, and consumers can provide useful product feedback, which is a form of collection information about their system (Milestad et al. 2010) .
Honors Legacy while Investing in the Future The system's legacy is "the accumulated experience and history of the system" (Folke 2006). The system's legacy consists of sources of traditional knowledge and experience from the past; elderly people or other individuals, institutions, organizations, seed banks, archives and libraries (Berkes et al. 2003; Cumming et al. 2005). One way farmers can incorporate legacy, is consulting elders, locals or indigenous people to gain access to valuable traditional knowledge (Cabell & Oelofse 2012). Traditional knowledge is locally developed methods or resource uses that have been practiced and passed down through generations (Berkes et al. 2000; Ohmagari & Berkes 1997). A second option is to reintroduce traditional plant varieties (heirloom seeds) and cultivating practices. A typical traditional practice is a multiple species management, which is not common in conventional agriculture. Reintroducing traditional cultivating practices can increase the system resilience, because they often maintain ecosystem processes and functions (Berkes et al. 2000; Cabell & Oelofse 2012).
Self-Organization
Socially Self-Organized The capacity for self-organization, is the capacity of stakeholders to organize themselves and form local networks or institutions. Examples are advisory networks, cooperatives or farmer's markets (Cabell & Oelofse 2012; Milestad & Darnhofer 2003). Small, groups are more adaptive and responsive to changes than larger, top-down entities. Also, because these types of initiatives are formed by the farmers themselves, they are adapted to the local context. When people with the same interests come together, they can meet likeminded people and share ideas and experience, which makes it an arena for building social relationships and knowledge (Cabell & Oelofse 2012; Holling 2001; Milestad & Darnhofer 2003).
Ecologically Self-Regulated Ecological self-organization are the stabilizing feedback mechanisms between ecological elements (Cabell & Oelofse 2012; Peterson 2009). Ecological feedbacks are processes like water flow control, changes in biodiversity or soil fertility (Holling 2001; Sundkvist et al. 2005). Most of these processes depend on interactions between organisms, and their role in building, adjusting and maintaining ecosystems. One such process is performed by soil bacteria. The soil bacteria glue soil components together to regulate water infiltration, retention and evaporation, which in turn reduces soil erosion. Other examples are tall plants, which alter their microenvironment, and earthworms that affect soil nutrient recycling, mineral composition and drainage. When organisms regulate resources as described above, we can also say that they are acting as ecosystem engineers (Jones et al. 1994).

Undisturbed ecosystems will naturally establish diverse and stable systems. Agroecosystems however, depend on manipulation by humans to suit our needs. If left to self-organize after disturbances, such as tilling or harvesting, the agroecosystem would no longer meet those needs. The key is therefore to find a balance between ecological self-regulation and disturbance. On a farm, this might look like maintaining plant cover and diversity, include perennials in the cropping system, provide habitat for wildlife and take advantage of ecosystem engineers (Cabell & Oelofse 2012).

Responsibly Coupled with Local Natural Capital

This indicator refers to a system's use of local natural capital (Cabell & Oelofse 2012). Natural capital is the stock of natural materials and consists of both nonrenewable resources such as oil reserves, and renewable ecosystem resources, such as plants, animals and water (Chapin et al. 2009b; Costanza et al. 1997). The aim is to create an agroecosystem that uses local natural resources as much as possible, but in a responsible way. This includes conserving water, building soil organic matter and recycle waste (Cabell & Oelofse 2012).

Modern agroecosystems are increasingly dependent on external input such as fertilizers, and the output which is often waste or pollution, is exported out of the system. When a system is dependent on external inputs, it is no longer coupled with the natural capital and ecosystem services. In addition, the more dependent the system is on external input, the more changes in regulations and price will affect the system, which means the system is less resilient. The ecological consequence of external input dependency is the loss of internal recycling structures, which results in depletion of long term accumulated ecological capital (van Apeldoorn et al. 2011). The ecological principle that every waste is a resource, should be the basis of the agroecosystem management strategy (Cabell & Oelofse 2012).

Globally Autonomous and Locally Interdependent

Autonomy is "the freedom to determine one's own actions and behavior" (Stock et al. 2014). A system which is completely dependent on external control and influences (e.g. regulations, subsidies and global markets) is vulnerable, because it lacks autonomy(Milestad & Darnhofer 2003). Its counterforce is local interdependence, which is the mutually dependent relationship between local actors. Interdependency has the potential to build trust and encourage collaboration and cooperation. Global autonomy and local interdependency, can be increased by relying less on external markets and resources, and more on local alternatives. More specifically, this includes collaboration between farmers (e.g. farmer co-ops), less external input (e.g. internal nutrient cycling) and close relationship with consumers (e.g. through farmer's markets) (Cabell & Oelofse 2012; Milestad & Darnhofer 2003).

3 STUDY AREA

3.1 Geographical location and population

The small Centro-American country of Costa Rica, measuring 51.100 km^2 (Thuesen 2017), with a population of 4.9 million (INEC 2016). After they abolished their army in 1948, the military budget was redirected to the education, health and environment-sectors, and the country is currently one of the most developed in Central-America (WFC 2017).

Figure 2- Map of Costa Rica's location (media.radiosai.org 2017)

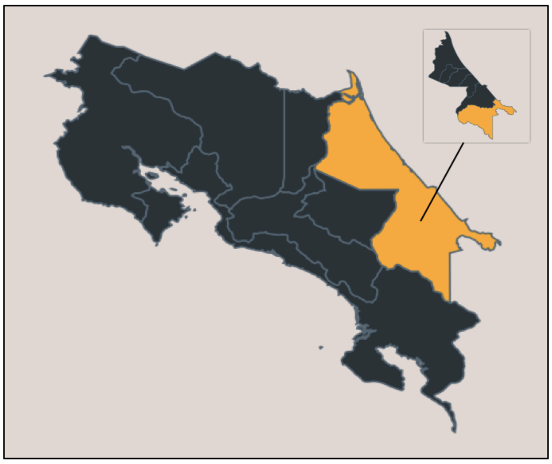

Figure 1- Map of Costa Rican provinces. Large yellow area is the Province of Limón. Small frame shows the cantons in Limón, in which the yellow area is Talamanca (INEC 2016)

Costa Rica consists of 8 provinces, which are divided into cantons. Both farms in the study are located in Cantón de Talamanca in Provincia de Limón (figure 3), on the Caribbean coast of Costa Rica. Talamanca, bordering Panama in the south, measures 2.800 km ^{2} (CorredorBiológico 2017), and has a population of around 38.000 (INEC 2011). Talamanca also hosts the greatest cultural diversity in Costa Rica (CorredorBiológico 2017). The population consists of Afro-Caribbean, Latino, Chinese groups, in addition to a growing community of North-American and European expats, and several indigenous tribes (Brandon & O'Herron 2004). At 11.000, Talamanca is home to the largest indigenous population in the country (INEC 2008), with the Bríbri and Cabécar tribes being the largest (Jordan et al. 1999).

3.2 Climate and Ecology

Talamanca and the Caribbean coast of Costa Rica is characterized by a tropical rainy climate, with an average yearly rainfall of 4,000 mm and average temperature of 25.6°C (Damiani

2001). Although there are no distinct differences, December through April is considered dry season, and May to November the rainy season (Herrera 1985).

The area's diverse topography ranges from cloud forests, mid-altitude and lowland rainforests, to steep mountainsides, wetlands and Costa Rica's only coral reef (Lynch 2004). The tropical forest ecosystem in Talamanca is one of the most biodiverse areas in Central-America (Jordan et al. 1999), and home to around 3% of the world's known plant and animal species. The 500.000ha Talamanca Range-La Amistad Reserve is on the UNESCO World Heritage Biosphere list. There, 14.000 species of plants, 215 species of mammals, 600 species of fish and 250 species of reptiles and amphibians have been recorded, many of which are endangered (UNESCO 2017).

3.3 Forest Protection and Agriculture

The current state of Talamanca's forests has not always been a given. From the 1950's Costa Rica was subject to one of the fastest deforestation rates in Latin America. Forests were converted in to agricultural land, which resulted in a decline in forest cover from 70% in 1950 to only 20% in 1989 (Porras et al. 2013). In the 1970-80 major areas of agricultural land was abandoned due to diseases (e.g. cacao fungus), global collapse in food markets (e.g. coffee, banana and beef) in addition to economic and political instabilities created by the wars in neighboring countries (Fendt 2014; Porras et al. 2013). In Talamanca, the cacao fungus monilia (*Moniliophthora roreri)* that appeared in the late 1970's after a period of low cacao prices was devastating to farmers. From being the most important crop between 1940 and 1979, the production dropped to nearly zero. This resulted in abandonment of most cacao plantations in the area (Slingerland & Gonzalez 2006).

During the 1980's, a conservation movement that was calling for change started to emerge in Costa Rica. The Forestry Law 7575, which banned conversion of established forests, came in 1996. Later, various governmental forest protection projects and programs (such as the Payment for Ecosystem Services program) were established. As of 2013, the forest cover had returned to around 52% (Porras et al. 2013). In Talamanca, 88% of the land is under a form of protection, which is the highest percentage in the country (CorredorBiológico 2017).

3.4 Alternative Farming in Talamanca

After the fungus blight that destroyed most of the cacao in the 1970's, many farmers in Costa Rica realized the vulnerability of mono-cropping. In response, they started organic crop cultivation, which also would reduce costs of chemical pesticides and health problems caused by them (Slingerland & Gonzalez 2006). In Talamanca, the local NGO Asociación ANAI together with Association of Small Producers of Talamanca (APPTA) and the Corredor Biológico Talamanca started the Talamanca Initiative. The aim was to encourage farmers to diversify their farming practices, based on perennial crops and ecological principles(Lynch 2004). The initiative also encouraged farmer organization and a marketing cooperative and helped developing ecotourism. As of 2004, over 1500 farmers in Talamanca have established organic agro-ecosystems, that aim to mimic the function and structure of the rainforest (Lynch 2004). One of the practical approaches, to combat the fungus, was initiated by the agricultural research center CATIE (Centro Agronómico Tropical de Investigación y Enseñanza), that developed six varieties of disease-resistant cacao, that is now being planted with good results (Fendt 2014).

4 METHODOLOGY

In this chapter I will describe the study design, the methods I used and why I used them. The chapter begins with the overall research approach and goes on to explain interview and observation methods, and introduce participants, before ending with critical reflections.

4.1 Study design

In this study, I wanted to identify the perspectives, practices and motivations of the farmers. Considering this purpose, the study is framed by a phenomenological approach. Phenomenology is the study of a phenomena experienced from the first-person perspective. A phenomena is whatever we are conscious of, such as ourselves, other people or events around us (Woodruff 2013). Phenomenology is describing things as one experiences them, and the primary focus is to explore the world we experience in everyday life (O'Donoghue & Punch 2003).

When planning the study, and deciding what method to use, considered both qualitative and quantitative methods. I decided on qualitative method for two main reasons. The first, was availability of informants. Before I went to Costa Rica, I had not been able to identify any permaculture- based farms that were not educational-type of farms. Because quantitative studies have selections with multiple participants (Thagaard 2013), practically, this was not an option. Second, because of my interest for the research topic, I wanted to visit the farms and have an in-depth conversation with farmers, which corresponds with a qualitative method (Kvale & Brinkmann 2009).

The type of information this study aims to identify is also difficult to quantify. Thus, the most appropriate method is a qualitative study, which is recommended for gaining an in-depth understanding rather than statistical generalizations (Holme & Solvang 1996; Opdenakker 2006). In contrast to quantitative method, a qualitative study does not aim to use a selection in order to generalize. Instead the intention is to get an understanding of a phenomena, and potentially use that understanding to explain a similar case in another context. In addition, the goal is not to confirm or discard a predetermined hypothesis. Instead, a qualitative ‘hypothesis’ can develop and change throughout the research process (Thagaard 2013).

4.2 Methods

4.2.1 Interview

The most commonly used method of qualitative research is interview. Interviews are suitable for providing information about people's experiences and points of view. It allows informants to explain how they perceive their own experiences and life situation (Thagaard 2013). As the objective of this study was to get an understanding of the agroecosystem from the perspective of the informants, I found interview to be the most suitable collection method.

Before the interviews, I developed a list of questions based on *A Workbook for Practitioners for Assessing Social-Ecological Systems* (Resilience-Alliance 2010) and *Principles for Building Resilience in Social-Ecological Systems* (Simonsen et al. 2015) by the Stockholm Resilience Center. Both papers instruct researchers on how to approach, and what to look for in a resilience assessment. I took notes from both papers, which I compiled into a list of questions, that covered the main topics of a resilience assessment. When topics are pre-decided, but the order they are covered in is decided during the interview, the interview is *semi-structured* (Silverman 2011). This structure allows for follow-up questions on the answers that are given and the stories that are told, similar to that of a natural conversation (Kvale & Brinkmann 2009).

Further, there are different kinds of semi-structured interviews. The interview style I chose, to best match the study's purpose is considered as a *semi-structured life-history interview*. This interview, with roots in phenomenology, aims to learn from the informant, understand their world, know what they know and see things how they see them. The interview covers several topics, to collect a variety of stories and experiences from the informants' daily life (life-world) (Kvale & Brinkmann 2009).

When I contacted the informants, I presented myself and described the topic and purpose of the study. Based on the written information they received, they agreed to participate. Before I started asking questions, I repeated the information, as a reminder and introduction to the questions. By Kvale and Brinkmann (2009) this is considered "setting the scene". The function of this, is to allow informants to get a clear perception of the interviewer and their motives, before they start talking about their lives and experiences. Both farmers were interviewed once, and the interviews lasted for 1,5 hours. During the interview, the informants were allowed to talk as freely as possible. The purpose of this, is to allow informants to elaborate on the topics they find important (Holme & Solvang 1996).

With consent from the farmers, the interviews were recorded with a cellphone, as recommended by Silverman (2011). I explained that the sole purpose of recording was to make sure I did not forget any details, and that I could focus on the conversation, rather than taking notes. In addition to allowing the researcher to fully focus on what is being said, using a recorder ensures that the interview report is more accurate than writing out notes (Opdenakker 2006). Also, I assured them that I would be the only one with access to the recording, and that it would be deleted after I had transcribed it.

4.2.2 Observation

A second common qualitative method is observation. Observation enables the researcher to describe situations based on the five senses, to make a "written photograph" (Erlandson et al. 1993). *Participatory observation* is a method of collecting data, where researchers participate in the general social interactions of the group or society they are studying (Fangen 2010). The fieldwork was conducted from January to April 2017. During the three months I stayed in Talamanca, I felt as if I got to know the local environment well. The first two weeks, I volunteered at Punta Mona, a local educational permaculture farm. There I got an introduction to permaculture farming in tropical climate, met people that were connected to the local food production, and the people that eventually connected me with my informants. The rest of the time I stayed in or nearby the town of Puerto Viejo. Puerto Viejo is relatively small, with a population of about 2,000 (Brownlee 2017). Hence, it was easy to get to know people, and get a picture of how things work, and who knows who, etc. The advantage of longer-term field studies, is a rich data material, and multiple observations that can indicate a pattern. It also takes time to understand the culture and get to know people (Fangen 2010).

Participatory observation can be considered a scale, that stretches from only observing to only participating (Fangen 2010). I would consider my approach somewhere in between, depending on the situation I was in. Most Saturdays I went to the Farmer's Market in Puerto Viejo, where I acted more observer than participant. Although I talked to farmers, artisans and customers, I was always aware of how I presented myself, and tried asking questions rather than expressing opinions, to have a neutral appearance. In the beginning, the language was also a barrier to engage in conversations with local Spanish-speaking farmers. In my daily life, I acted more as a participant. When I went to visit local farms, talked to farmers, volunteers or locals, I did not consider my role as a researcher, but acted as a private person. The reason why, was because I considered my stay there as an opportunity to get to know the culture from different perspectives, and get an understanding of the local food production network beyond the information I could get from the interviews. This, in contrast to exclusively having an observer-role and writing out daily field-notes.

4.3 Participants

Both participants are immigrants, coming from France and the United States. They have both lived on their farms in Costa Rica for more than 12 years, and their farm activities are their main incomes. The farmers were chosen based on information I gathered through talking with different people in the community. The first farmer, Tristan, I first heard about while volunteering. I met a previous volunteer, that described his ideals and how he manages the farm. In addition, several people I met on the farm and in town, seemed to know (about) him and his farm, and recommended me to talk to him if I was interested in permaculture. I contacted him via internet, and we scheduled the interview a few days later.
The second farmer, Peter, I learned about through talking to locals and various other people I met. They all said they thought his farm might be interesting for my project. Also, during the interview with Tristan, he mentioned Peter (who is a friend of his) and his farm several times. I thought it would be interesting to interview two farmers, with different approaches to permaculture.

4.4 Critical reflections

Who the researcher is as a person greatly affects the outcome of the research, because personal preferences can influence choice of topic, method, theory and analysis. Personal background, faith, political opinions and experiences can affect data more than when analyzing a quantitative set of data (Enerstvedt et al. 1989; Tjora 2012). My choice of topic was indeed a result of my personal background and interests, and I am aware of my bias in favor of natural farming methods. Nevertheless, a qualitative study can never be completely objective (Yin 2014), yet I intend to present the material as objective and unbiased as possible.

During the interview, the researcher influences what informants will answer. They are active participants by opening or closing various topics, choosing what to expand on and the interaction as a whole (Silverman 2011; Thagaard 2013). This was something I was conscious of during the interviews. My strategy was to ask open questions and keep responses as neutral as possible. I let them talk as freely as possible, although sometimes I asked them to clarify or expand on topics that I found interesting or important. Regardless of this, there is no doubt that I have influenced the information given, as the interviewer is the research-instrument itself (Kvale & Brinkmann 2009).

Next, when conducting an interview in another culture, misunderstandings can occur because of differences in body language, parlance, or other cultural differences (Kvale & Brinkmann 2009). However, I argue that because both the French and American are part of the Western culture, they have relatively similar social rules and codes as those in Norway. In addition, because I have visited both countries several times, and I have friends from both cultures, I believe I have a general understanding of their parlance and culture. That being said, I cannot be completely sure I have not misunderstood or misinterpreted information that was given.

The final aspect worth mentioning is the language. The interviews were conducted in English, and one of the informants are French, with a distinct French accent. However, I did not experience the language as an issue. The informant has a good vocabulary and expressed himself clearly. Yet, during the transcription, there were a few words I had trouble understanding. Although the sentences made sense to me without the missing words, I can potentially have missed the meaning.

5 FINDINGS

In this section I will begin with presenting the farms, and then present the findings from the interviews. Unless stated otherwise, the information presented, both in presentation of farms and the indicators, is based on statements of the farmers.

5.1 Finca Inti

Finca Inti is a 6 ha, family run farm, situated near Hone Creek, in Talamanca. The farm is situated on a south-faced hill and can only be reached by climbing a steep trail. The road is 20 meters above sea level and the top part is 120. The owners, Tristan (originally from France) and his Costa Rican wife live there with their daughter and three dogs.

With a background in tropical geography and a fascination for plants, Tristan travelled the world and volunteered at various organic farms. He always felt as if there was something wrong with how the society is organized and was not sure what to do, until he realized that growing food is a big freedom, which allows you to get out of the system. As such, his motivation for farming is to be as self-sufficient as possible, and considers growing food a lifestyle.

During his time of volunteering, he learned about permaculture and did an online permaculture course. After visiting Costa Rica several times and volunteering several months at Punta Mona permaculture farm in Talamanca, he bought the first piece of the farm together with his wife in 2006. The first piece of land he bought was prepared for a monoculture plantain crop and all the trees were cut down, which is why they decided to buy it. The land had previously been used for pasture, bananas, beans and corn.

The farm is run by Tristan and his wife. Two days of the week, they also have a worker that helps with the crops. In addition, he has occasional interns and volunteers that help with farm work and processing of produce for the market. The commitment to preserving biodiversity and co-creating with nature are important aspects of Tristan's idea of farming. All elements of the farm are designed to be as sustainable and based on natural processes as possible. The design of the farm has been based on permaculture principles, and features a diversity of fruit trees, medicinal plants,root crops and herbs. Tristan wants to live in sync with nature, and considers his work on the farm a lifestyle, rather than a job. This is also why the main purpose of the farm is self-sufficiency for a good quality of life, rather than aiming to be a large, commercial farm. He could never imagine living in the city, because on the farm he has everything he needs for "*really living it*".

Figure 3-Finca Inti: View from the main house, overlooking zone 1

Figure 4- Finca Inti: One of the buildings for housing visitors, constructed with materials from the farm

5.2 Finca La Isla

Finca la Isla or mostly known as the Botanica Garden, is a family farm located in Playa Negra, Talamanca.

Peter was a hobby grower ever since he was young. He had always been attracted to the tropics and decided he wanted to grow plants there. With working experience from various nurseries, Peter bought the first piece of the farm in 1987. The goal was to create a sustainable, commercial, organic farm to work in harmony with the rainforest (Finca-La-Isla 2015). The first piece of land they bought was 5,5 ha of abandoned cacao plantation. Later, he bought two more parts and the farm is now 17 ha.

Their mission from the beginning was to create a sustainable, commercial, organic farm working in harmony with the rainforest (Finca-La-Isla 2015). Inspired by the early permaculture literature and the Japanese agroforestry teacher Masanobu Fukuoka, they started their farm, based on the principles of natural farming, permaculture and agroforestry principles. Peter also wants to be an example to both local and other foreign farmers, to show it is possible to produce income in a sustainable way, without money from outside.

The farm is run by Peter, his wife and their son. In addition, they have 4 workers, that supports four families. Two of them are exclusively farm workers, one is half farm worker and half maintenance, whilst the part time worker works in the kitchen with chocolate making and drying fruit. In addition to the permanent workers, Peter has a paid intern which comes 2-3 days a week to work and learn about the nursery with propagations and learning to graft trees. All workers are locals, and have been working on the farm for years.

In the beginning, they started with root crops and black pepper. Today, the farm has over 200 different species of fruit trees.

Figure 5- The farm has plants that grow in different layers.

A Figure 6-Lower layer plants and leaf litter provide ground cover

Logs are left on the ground to mimic

5.3 Buffer Capacity

5.3.1 Functional and Response Diversity

Finca Inti

Tristan has around 150 different species of trees on his farm For food production the trees originate from all over the world, whereas he normally plants native plants or plants from the Amazon in the forest zones. He is concerned with conserving endangered species, both local (e.g. Panama) or species that are threatened because of the rainforest being cut down. He says the variety of plant and tree species also attracts a variety of wildlife species. Although the animals sometimes eat fruits, because of the large variety of species, there is always something that nobody attacks.

Finca La Isla

In addition to the chocolate production, Peter says he has he has around 200 species of fruit trees, thereof around 25 commercial. They also grow black pepper, a variety of root crops and nuts to name a few (see appendix 2).

Functional diversity is having more species in each functional group (Elmqvist et al. 2003). An example of functional diversity at Peter's farm, is with the Myrtaceae family. A function of this family of trees is providing forage for bees, that in turn are essential for pollination (Hilário & Imperatriz-Fonseca 2009). At Finca La Isla, there are 19 planted tree types from the Myrtaceae family (see appendix 1). This means that if one or more of these tree types fail, the farm still has trees to attract pollinators.

Another example from Peter's farm, relates to response diversity. Peter has access to a diversity of cacao with different genes. Although he mostly grows old cacao on the farm, he has different varieties (see appendix 2). In addition, he needs more cacao that they grow themselves, so he buys from other farmers. These farmers also have different varieties, and he says many cacao farmers in the area are planting the disease-resistant varieties developed by CATIE.

5.3.2 Optimally Redundant

Finca Inti

The purpose of redundancy is to have a backup for important system components in case of failure (Walker 1995). Examples of redundancy in agroecosystems, are having multiple sources of water and crop variety (Cabell & Oelofse 2012). The first 5 years they lived on the farm, they used to collect water from a nearby river, but now the rainwater is collected in large tanks. Altogether they have 6 tanks that contain a total of 11,000 liters. In addition to the water tanks and the river, they also have access to well water.

Finca La Isla

At Finca La Isla, Peter, his family and the workers all have their main area of responsibility. Peter is the farm administrator. He also runs the nursery, and most of the fruit production. His wife manages the egg production and the chocolate production, while their son administers the botanical garden and works on the farm. The workers have various assignments, and help out where it is needed. Peter says the workers have been working for them for years, so they all know what to do. Although they all have their main responsibilities, everyone can work in the different projects. People that work on a farm can be considered a resource. Because multiple people can do the same work, the farm has redundancy in case the person with the main responsibility is indisposed.

5.3.3 Appropriately Connected

My impression after 3 months of living in and observing the local food production community, is that there is a close connection both between farmers and farmers and farmers and consumers, particularly in the expat-community. Farmers I talked to often mentioned things that were done in their friends' farm and projects they had done together. Also, owners of local cafés and shops (particularly the organic ones) were frequently observed at the Farmer's Market, and they all seemed to know each other.

Finca Inti

When I visited the cafés and organic shops, they all knew Tristan. During the interview, Tristan said he sells directly to a local organic shop (e.g. leaves for making teas or essential oils), and sometimes he also sells fruit and vegetables to local cafés and restaurants. Selling to different vendors is an indicator of connectedness, because it implies that the farmer has a diversity of relationships of which he depends upon, rather than just one.

Another indicator of connectedness in agroecosystems is cultivating polyculture crops (Cabell & Oelofse 2012). With around 150 different species of trees, in addition to other plants such as root crops, Finca Inti can surely be characterized a polyculture. When he plans his planting regime, he says he considers the characteristics of the plants, for example nitrogen-fixing, shading, size and when it comes into production.

Finca La Isla

The produce at Finca La Isla is mainly sold at the Farmer's market on Saturdays. Peter also sells fruit to local shops when he harvests more than once a week, and they also sometimes sell fruit to visitors of the Botanical Garden. The plants he sells from the nursery, he sells to individuals that contact him, which means he has multiple buyers rather than selling to a company. This ensures the system to be flexible and diverse, instead of being completely dependent on a few relationships (Cabell & Oelofse 2012).

5.3.4 Spatial and Temporal Heterogeneity

Finca Inti

Tristan has implemented the permaculture principle of zoning, which means that zone 1, the area closest to the main house, is the most intensively managed and zone 5, furthest away from the house is the least visited (Mollison 2002). Zone 4 and 5 of Tristan's farm are mostly natural forest, and some parts he has not even visited for 4-5 years, because "*the forest is not for him, but for the animals*". Tristan also plants directly after he harvests, to save time, energy and knowing he has a continuous growth of new crops. Both these management practices are examples of spatial heterogeneity.

Finca La Isla

Agroecosystems should have elements of both spatial and temporal heterogeneity. Spatial heterogeneity includes variations in microclimates and mixture of managed and unmanaged land (Cabell & Oelofse 2012). According to Peter, 2/3 of the farm consists of natural forest. In permaculture, this is explained as zoning (principle 7: design from patterns to details) (Mollison 2002). When they clear new areas on site, Peter says they always make sure to leave good corridors of forest (which includes secondary cacao) between the open spaces, because they support the soil and serve as a refuge for wildlife. In addition to providing habitats, natural forest adds variation in microclimates.

In addition to ecological heterogeneity the farm has social heterogeneity. Between Peter and his wife, their son and their farm workers, there are variations in age, educational and cultural background.

5.3.5 Exposed to Disturbance

Finca Inti

The last few years, the farm has experienced several disturbances in the forms of droughts, an earthquake, landslides, rainstorms and pests. These events are considered shocks, or sudden disturbances to the system, and because they come from outside the system, they are outside of the control of the farmer (Gallopín 2006). Although there are seasonal variations, Tristan believes climate change is causing many of the extreme weather events we are experiencing. Although the extreme events are rare, he says they are happening more often than before. This year, a hurricane came very close for the first time, and they have had more strong winds that he is used to, where some large trees fell. The drought they had lasted for about 2-3 years, but this did not have any immediate dramatic consequences for the farm. Tristan explains that a durian, which is a tropical tree needs about 2 meters of rain per year, so when they received about 3 meters, in comparison with 5meters on a normal year, the plants did not suffer. In fact, they experienced an increase in production.

After the drought, there was a period of heavy rain. Although they are in a tropical area with a lot of rain, extreme rain is something Tristan says they are experiencing more often than before. For instance did they recently have a rainstorm where it rained about 15cm in 90 minutes.15cm of rain during the night it is normal for them, but 15 cm during the day in about 90 minutes was intense. Extremely heavy rain like that is damaging for the farm, because they lose valuable top soil.

They have also had two landslides the last 4 years. In the last one, Tristan lost land with an area of 15 meters wide and 300 meters long. In the same period, there was an earthquake of about 4.5 on the Richter's Scale. This is not particularly strong, but the epicenter was just below the farm, and not very deep. Tristan believes the drought, in combination with the earthquake created cracks in the soil, and when followed by heavy rain, this is what caused the landslide. Although the landslide changed part of the scenery dramatically, ultimately Tristan does not think of it at losing the land, because it creates another space.

Finca La Isla

The cacao-disease that resulted on a large-scale abandonment of cacao in the late 70's (Slingerland & Gonzalez 2006), has continued to create problems for cacao-farmers in the area, including for Peter. One of Peter's approaches to this, is to be selective with the trees;

"There's millions of trees, so genetically everyone's a bit different. And if you look at these trees, some trees are resistant and some trees produce much more than others. So, what I'll do, if a tree is not good, I'll cut it out low, it sprouts out again, and I can graft onto that, from a tree that's good."

In addition to being selective with his own trees, he trades resistant and productive grafting material from other farmers. This type of management regime, where the farmer selects resistant plants after a disturbance, is beneficial for the system and an indicator of a resilient management approach (Cabell & Oelofse 2012) .

5.3.6 Reasonably Profitable

Finca Inti

When Tristan and his wife first bought the farm, they both had part time jobs. The process of getting the farm up and running, was both work demanding and time consuming. The trails that run throughout the farm and all farm structures are manually built, which was hard work. In addition, he had to start planting to have something to eat then and there, as well as to set up a plan and start planting for the future, as not to stay in the short term all his life.

According to Tristan, the process of becoming self-sufficient is long and challenging. Especially, if you start farming where there is nothing, and you need to start planting from scratch. Because the system is based on perennials, it can take years before the trees come into production. However, the real challenge, is to be able to live from the farm, and make enough money for all your expenses. To succeed, he says you need to differentiate, and not only rely on the cash crops.

For the market, he tries to come up with specialties that nobody else has. For instance, was he the first to sell biriba *(Rollinia deliciosa)* and dried *organic* pineapple *(Ananas comosus)* at the market. When other people started selling these crops, he started selling dried pineapple instead. When I visited his stand at the Farmer's Market, he was selling organic curry (spice blend), that I did not see anyone else at the market selling. During my visit at the farm, he and his volunteers were preparing Sacha Inchi *(Plukentia volubilis)* nuts, which are currently a trending 'superfood' (Thomson 2016). The nuts are processed and packed on site, before they are sold at the market or to the local organic shop. In addition to selling produce, they also have income derived from people that visits the farms. According to their website (Finca-Inti

2017), they offer farm tours, workshops, lodging in their Guest House, and they also accept paying volunteers and interns.

Although the farm initially was a lot of work, the workload has lessened throughout the years and he no longer needs a part time job outside the farm. According to Tristan, if he only lived off the materials he has on the farm, he could support himself and his family, with only 8-10 hours of planting and harvesting per week. However, since he wants to earn more money and has expenses such as electricity, he spends time processing and preparing products for sale.

Finca La Isla

In the beginning, Peter started growing root crops, that were harvestable within a season. He walked around in the town of Puerto Viejo to sell crops. Tristan mentions in the interview that it took Peter around 10 years to be able to life off the farm's income. Now, Peter's farm has income from a broad variety of activities. The main farm activities include crop production and processing, egg production, a plant nursery and a botanical garden which is open for visitors.

Peter says the most important and consistent income is from chocolate. All ingredients (e.g. cacao, vanilla, sugar cane, black pepper) are grown on site, and the chocolate is produced and packed on site. They sell it at the Farmer's Market, in some local stores, and some is shipped to the Pacific Coast of Costa Rica. The fruit production (as explained in *optimally redundant*) is also a significant income. The fruit, either fresh or dehydrated, is primarily sold at the market. In periods of high production, Peter also occasionally takes it for whole sale in local stores. They also keep some fruit in boxes on the farm, that they sell to 'drop-in' customers. Next, they have commercial production of quale eggs, which results in around 100 eggs with a worth of $18-20, that they sell on the market every week. On their website, they also inform that they sell homemade soaps, natural care products, medical tinctures, black pepper and processed nuts.

From the plant nursery, they sell grafted trees, fruit tree seedlings and ornamental plants. Because his nursery is specialized on rare plants, he has customers from all over Costa Rica, and even Panama. Peter says the nursery plant sales can make more than the chocolate, but it is less consistent because they don't sell things from the nursery every week. For a while the botanical garden was an important income for the farm, but now their son has taken over the responsibility and its income.

Peter and his wife also have income from off-farm activities. Peter says he regularly offers garden or farm-consulting, for instance for people who are starting a farm. In addition, on their website they inform that they also give farm-tours, classes, courses and workshops. Workshops include biochar, orchard management, grafting and propagation, fermentation, medicinal plants and plant lore. They also recently announced a chocolate internship on their website, where people can learn the process of making handmade artisan chocolate, from bean to bar.

The family and three of the workers work full time on the farm. In addition, they have one person that works 2-3 days a week. Peter does not specify his income, but says they are doing well and that they can easily pay the workers, *"and you know, we have a good car"*.

5.4 Adaptive Capacity

5.4.1 Builds Human Capital

Finca Inti

Tristan mentions several times during the interview that he is "*still learning a lot*" about plants and farming. He is always eager to acquire new knowledge, in which he thinks the internet is a good source. He also says he learns a lot from books and talking to other people. Before starting his own farm, Tristan took a permaculture course and had years of working experience from volunteering at organic farms in different climatic conditions. He also volunteered at Punta Mona, a Talamancan permaculture farm, where he spent months working alongside a local farmer who taught him a lot about local fauna and conditions. In addition to his training and working experience from other farms, Tristan has lived on the farm site for 12 years. During these years, he says he has gained a lot of knowledge and experience with the nature and his plants through a process of trial, error and continuous observation.

As explained in the section about self-organization, the weekly Farmer's Market is an important place for social networking. Having lived in the area for more than 12 years, Tristan also knows many people and has several farming-colleagues and friends that he collaborates with. According to Tristan, by working together, they can exchange general knowledge about plants, discoveries and can help each other in finding solutions to ecological challenges.

Finca La Isla

Before starting his own farm, Peter only had experience from working in plant nurseries. Based on his fascination for tropical plants, he says he came to Costa Rica with "*books and ideas*", with the intention to start a sustainable farm. Inspirations for the farm came through reading permaculture and agroforestry literature, and the natural farming teacher Fukuoka was a great inspiration.

His passion for plants and increasing his knowledge about them, appears to be one of Peter's main motivations for farming. He likes working with tropical plants, because many of the plants he is working with do not have much information that is known about them, so it is a lot of discovery to be made. He says he les to be *"on the cutting edge"* of new discoveries, is always working to improve and constantly seeks new knowledge. He frequently uses the internet, where he especially gets a lot of information from fruit and biochar forums. He exchanges information and plant material with farmers from different parts of Costa Rica, and he says the Farmer's Market in Puerto Viejo is a good place for networking, because there he meets many people. In addition, the counseling, workshops and courses he gives are other noteworthy arenas for meeting people and exchanging knowledge.

5.4.2 Reflected and Shared Learning

Finca Inti

Reflected and shared learning involves learning from past experiences, experimenting, and sharing of knowledge via social networks or between farmers (Cabell & Oelofse 2012). As discussed in the indicators *appropriately connected* and *properly self-organized*, Tristan has a network of farmer friends and colleagues, which whom he can confer. His friends share his fascination for rare plants and 'specialties'. Together they can discuss and adjust management practices and exchange tricks and ideas.

The farmer's understanding and knowledge about the system, is an essential aspect of *reflected and shared learning* (Cabell & Oelofse 2012). Having lived on site for 12 years, Tristan says he knows the land well. As a result of his commitment to preserving endangered and/or local species, he has also experimented with many different trees and crops throughout the years. Through trial and error, and careful observation of feedback signals, he says he has gotten to know the plants and learned what works and what does not. He also thinks that because they bought the farm piece by piece, they were able to continuously learn and improve, because they were learning from their previous mistakes.

The first aspect of reflected and shared learning is actively experimenting, to get a better understanding of the system (Milestad et al. 2012). The element of experimenting is incorporated into Peter's management to the degree that when asked about his vision for the farm, he refers to experimenting;

> *"I'm planting all the time. And I mean, everything you do is a bit of an experiment, and I just wanna carry on improving. So things that don't work, we'll take them out, and we're always looking for new things. Every year I've been planting something that hasn't been planted before here, and also something comes into production that I've never had before. Some of these things, you know like I'll hear about something, or somebody will bring me a seed, and I'll plant it."*

Through trial and error, he has chosen which plants to grow and also what to sell at the Farmer's Market. By bringing things that he thought people would want to buy, and talking to other farmers to see what sells in other places, he has experimented with what sells and what does not.

Finca La Isla

The Farmer's Market seems to have a keystone function of Finca La Isla's. Most of his produce is sold at the market, and it is an important arena for social networking, as emphasized by Peter himself. In addition to the Farmer's Market, Peter cooperates and exchanges material with Corredor Biológico, and other farmers in the area.

5.4.3 Honors Legacy While Investing in The Future

Finca Inti

To "honor legacy while investing in the future", farmers can consult local or indigenous people to gain access to the local accumulated experience and history of the system (Cabell & Oelofse 2012; Folke 2006). Traditional local knowledge has been important for Tristan since the beginning. While volunteering before buying his own land, he spent months working alongside an indigenous local farmer, who taught him a lot about local fauna and conditions.

Throughout the years, he says he has learned a lot from locals, for example about planting bananas. He also has a local, indigenous worker from the Bríbri tribe, that comes in to help him 2-3 days a week. He has worked for him for 8 years, and Tristan appreciates him because he is careful with, and has a lot of knowledge about plants. He also knows a lot about the local wildlife, for example how to deal with snakes.

However, Tristan is also selective with advice from locals, because many of them have learned about planting while working in the plantations. The methods used in monoculture plantations are not always the right for how Tristan works. He gives the example of cutting the banana plant flowers to increase productivity. This is an investment in time and energy he says would only make sense in large-scale intensive farming, where a 10-20% productivity increase makes a big difference.
The traditional knowledge and practices he has picked up from working with local indigenous people, he combines with modern knowledge. He is actively seeking new knowledge, and learns through experience, from books, other people, and the internet.

Tristan has a passion for cultivating and conserving endangered species, both native to the local area and the rainforest. Preserving genetic legacy, and using traditional plant varieties is another way of 'honoring legacy' (Berkes et al. 2000; Cabell & Oelofse 2012). Some of the trees he has, are disappearing from Costa Rica because they are not as productive, and others because the rainforest is being cut down;
"We have native fruits nobody knows anymore, like the Anona family from Panama which are endangered now. And I've got four trees here, they're called bearley (?) tree. It's funny, because I got it from a company who grow them in Hawaii. I didn't even get them from here, cause you can't even get the seeds here now, or rarely you know. (….) Some trees do not have big value, they don't produce much, and nobody plant them anymore, and they are disappearing. Or, they are cutting a lot of forest in New Guinea or like in Indonesia, then it is good to save some of these trees"

Finca La Isla
When Peter bought the land, most of it was abandoned cacao plantation. They started opening areas to plant fruit trees, and root crops common to the area. They have left corridors of abandoned cacao, or secondary cacao as they call it, between open areas of the farm. According to Peter, these corridors serve as a refuge for wildlife, and supports the soil. In

addition, these patches of old cacao trees is also an inherited biophysical resource, which is a form of legacy (Shava et al. 2010).

Peter says most of the cacao they grow are old, heirloom varieties, that have been grown in the area for hundreds of years. After the cacao-disease in the 70's, there has been a lot of trouble for cacao farmers in the area, himself included. The disease-resistant varieties that was introduced to the area is now what more farmers are planting. And now, both types are now grown in the area. This is a practical example of a case where farmers are combining traditional and modern varieties as an attempt to increase the plants resilience (Cabell & Oelofse 2012).

To increase resilience by incorporating legacy into the system, farmers can consult indigenous, local people to gain access to traditional local knowledge (Cabell & Oelofse 2012). The main way Peter has incorporated local knowledge in his system, is by hiring local farm workers, whom have been working for him for years. They now have four families, whose livelihood depends upon them. He says he does not want to have volunteers, because in addition to not being very good workers, they displace Central American workers.

5.5 Capacity for Self-Organization

5.5.1 Socially self-organized

Finca Inti

A socially self-organized agroecosystem contains social establishments organized by the farmers themselves (Milestad & Darnhofer 2003). The most important farmer establishment for Tristan, is the Farmer's Market in Puerto Viejo. Tristan says the Farmer's Market is where he sells most of his produce, thus being essential to his economic situation. He has his own stand at the market, where he takes his produces most Saturdays. When people come together at farmer's markets, they can meet others with the same interests and share ideas and experience, which makes it an arena for building social relationships and knowledge (Cabell & Oelofse 2012; Holling 2001; Milestad & Darnhofer 2003). Seeing Tristan at the market, he was always busy talking to friends and explaining customers about his products, which confirms the social relevance of the market.

Finca La Isla

The most important farmer establishment in Talamanca for Peter, is the Farmer's Market. A farmer's market is an example of a social network that increases resilience, because it can easily adapt to small changes and local needs. In addition, it also acts as an arena for building social relationships and knowledge (Cabell & Oelofse 2012; Milestad & Darnhofer 2003). Peter is the president of the Farmer's Market in Puerto Viejo, which he and his wife are also founding members of. Since it started in 2004, Peter says he marked has had ups and downs, but is now well established and provides a steady income for the farm. He says he is a big advocate for the market, and will not sell his produce anywhere else, that he can sell at the Farmer's market. Even so, if anyone asks to buy all his fruit, he would tell them to wait and see what he has left after the market day. Peter also emphasizes the importance of the Farmer's Market for social networking. There, he says, he meets a lot of people, both customers and other farmers.

5.5.2 Ecological Self-Regulation

Finca Inti

When I was walking along the trails through the farm, it was not easy to see that Tristan's farm is in fact a farm. There are no long, straight rows of crops or large open fields. Instead the farm consists of a seemingly unorganized system of trees, shrubs and herbs, similar to that of a natural forest (see figure 3). Tristan says his philosophy is to create an ecosystem that mimics a natural forest;

> *"Sometimes local people are like, why do you plant this plant over there with the red flowers? It's a luxury plant I doesn't produce anything. No, it produces something actually, it produces organic matter. This is a fertilizer. It attracts hummingbirds. Hummingbirds they eat not only the nectar of the plant, they eat a lot of insects. And it's bug control. And at the end you recreate an ecosystem, it's the idea actually. The idea of permaculture, especially here, in this climate, is to really recreate a forest. And you will create an ecosystem who will work for itself"*

Maintaining plant cover, which also is an indicator of a self-regulating agroecosystem (Cabell & Oelofse 2012), is also a management practice Tristan is conscious of. He says that when it rains heavily, a plant cover, including taller plants, will prevent the loss of valuable top soil, because it slows down the raindrops. An example is the Vetiver grass (*Chrysopogon zizanioides)* he has planted on the slopes, which slows down the water and reduces soil erosion (Truong & Loch 2004).

Main indicators of an ecological self-regulating agroecosystem, are when farms have plant diversity, plant cover, perennials and wildlife habitats included in their system (Cabell & Oelofse 2012). He is also conscious of maintaining plant cover.

Finca La Isla

Ecological self-regulation is dependent on feedback mechanisms between ecological elements, such as interactions between soil organisms (Jones et al. 1994; Peterson 2009). Peter does not apply fertilizer to his crops, but instead he aims to mimic the nutrient cycle in the forest. Instead of artificial fertilizers, he applies mulch and biochar that he makes on the farm (which will be explained further in *responsibly coupled with local natural capital)*. The function of this method is to optimize conditions for soil microorganisms, to mimic the nutrient cycle of a natural ecosystem. Organisms that regulate resources are also called ecosystem engineers (Jones et al. 1994). The conscious use of ecosystem engineers in the ecosystem is considered a management method for facilitating ecological self-regulation(Cabell & Oelofse 2012).

Other ways farmers can enhance self-regulating mechanisms is by incorporating perennials and wildlife habitats (Cabell & Oelofse 2012). Peter says 2/3 of his farm is forest that has been left untouched since they bought the farm, with the purpose to serve as wildlife habitat and support the soil. Also, since his farm is built as a food forest, the basis of his crop production consists of perennial trees.

5.5.3 Responsibly Coupled with Local Natural Capital

Finca Inti

From the beginning, Finca Inti was an ‘off the grid’ farm, with the aim to be as self-sufficient with food and resources as possible. For farms to be ‘responsibly coupled with natural local capital’, the agroecosystem must use local resources as much as possible (Cabell & Oelofse 2012). Tristan explains how all constructions on site are built with materials from the farm, except the roofs and a few cement elements in the main house. Up until they had their daughter they only used firewood and collected water from the river. Now, they have installed a cable which provides them with electricity, which Tristan says he does not mind because most of the electricity in Costa Rica comes from renewable resources (hydropower).

Another way of sustainably use natural resources, is by conserving water (Cabell & Oelofse 2012). The farm is self-sufficient with water, from collecting rainwater. They have water tanks which hold close to 11.000 liters of water, which according to Tristan, means they still have water even after a month of no rain. The local water supply is occasionally cut off to save water, but because they have their own source of water, they are not affected by this. The water they collect is for household purposes, because the main crops do not need additional watering. Another way of conserving water, is by recycling greywater. Tristan occasionally waters the seedlings in his greenhouse, and for this purpose he plans to make a system of water recycling with the house grey water. The grey water can be used for watering, because the family only uses natural household products. This management approach is in accordance with the recommendations of Cabell and Oelofse (2012), that every waste should be considered a resource.

In addition to the water recycling, the family have food compost, and a compost toilet system. Nutrient-rich humanure collected from the food scrap- compost or the compost toilets can be used for sensitive plants such as the seedlings in the greenhouse and when planting. However, except for the seedlings, Tristan does not 'waste' his time on fertilizers;

> *"…In the forest, you see the size of the trees! Do you need to fertilize the forest? No. Then your system basically is this. You recreate a forest, and the forest don't need fertilizer. (…) The tree I'm growing here to fix nitrogen drops so many leaves, look! All organic matter. You don't need fertilizer. (…) I don't do any natural bug control, I don't fertilize, I don't do all these things. It's too much work. I could do it, I had pineapple. Pineapple they… you mix one gallon of pee with water, and you can fertilize half a hectare with it. It works good, the pineapple will grow a bit faster, but it takes time. Just because you want the things to produce a bit faster. For me it is no point you know, I just leave it. You just need to be patient. And it is okay, because you have so much diversity, and you always have something else"*

Another way of increasing the natural capital, is by protecting and restoring degraded ecosystems (Chapin et al. 2009b). On Peter's farm, about 2/3 of the land is forest that is left mostly undisturbed. Sometimes they open new areas or do a little bit of harvesting, but Peter says this is always done in a responsible way, always leaving good corridors of forest between the open areas.

Finca La Isla

Finca La Isla's main philosophy is to duplicate the natural recycling processes as those in the forest;

> *"When you go and look in the forest that's going great, nobody is out there throwing fertilizer around. If you look at the ground, the ground is not grass, and it's not swept clean, it's a lot of decomposing leaf litter, leaves and sticks and a bunch of rotting fruit and stuff like that. (...) So on our farm we spread biomass, which is leaf litter, underneath the trees. We have a kind of a trinity of essential things to make the trees grow. And that's biomass, biochar and microorganisms."*

Peter explains how the biomass in the forest has a rich community of yeast, fungus and bacteria that breaks down the material, turning it into food for plants. Because the farm does not have the same balance of microorganisms as a large forest, they apply microorganisms to mimic the decomposing process. When they prune trees, they leave the larger sticks and leaves under the trees. The medium sized pieces are cut into pieces and stacked to dry. When it is dry, they make charcoal with it. The charcoal is soaked in microorganisms (that they buy) and placed under the trees, together with the rotting biomass. Peter says the charcoal has many benefits, but one of the most important is serving as a microorganism-refuge during drought;

> *"A cubic cm of this charcoal has a surface area of a football field. There are so many little holes in there. So when we put the biomass out under the trees we also put this charcoal. (...) It's getting dry there now. So, microorganisms that are just in those leaves, it's gonna be too dry for them, but they can hide out in the charcoal and survive through the dry period. And when it starts raining again, they can start eating the leaves again."*

In addition, Peter says that in contrast to most other soil amendments, the charcoal is permanent, and does not have to be added repeatedly.

5.5.4 Globally Autonomous and Locally Interdependent

Finca Inti

The global autonomy refers to the freedom a farm has from external control, such as regulations, economic subsidies or global markets (Folke et al. 2005; Milestad & Darnhofer 2003). In comparison with Europe, Tristan thinks Costa Rica is a good place to be a farmer, because of the lack of governmental interference. He does not receive any subsidies, and in return he does not have to pay expensive taxes. To sell at the market, the only regulations he has to follow are passing a course on how to manipulate food, and he has to pay for his stand, both of which he says is only natural. After this, he can sell up to $1,000 worth of produce every month without having to pay tax. And according to him, this is the way it should be;

> *"You are farming, it's a service to people. You should never pay tax for this. (...) In the farmer's market, they don't care how much I sell, they don't check this. (...) As long as you don't earn more than $1,000 per month they will not check. If I had a big 4x4 parked at the entrance, they will maybe check what I'm doing, and maybe I will have to pay tax. When you have a hotel or this or that, or a business, of course yeah, they tax you. Its normal because you use the service of the state"*

Tristan exclusively sells his produce locally and directly to consumers, shops or restaurants. This allows him to maintain autonomy, rather than depending on global food prices and regulations (Cabell & Oelofse 2012). In addition, the opportunity to talk with customers face to face, can be linked to flexibility and adaptive capacity (Milestad & Darnhofer 2003). Global autonomy and local interdependency, can be increased by relying less on external markets and resources, and more on local alternatives. This includes close collaboration between farmers, less external input (e.g. internal nutrient cycling), and close relationship with consumers (e.g. through farmer's markets) (Cabell & Oelofse 2012; Milestad & Darnhofer 2003).

Finca La Isla

As discussed in *responsibly coupled with natural capital* the farm does not apply fertilizers on their crops, but instead aims to mimic the natural nutrient cycles in the forest. On their website, they also write about their Black Soldier Fly bins, which are used for composting and helps feed the chickens. "*The frass (*insect excretion*) becomes a rich soil amendment for our nursery and vegetable beds. By replicating nature, we can close the loop, making the forest more efficient, more sustainable*" (Finca-La-Isla 2015).

Peter says he meets many people at the market, which is a good arena for building relationships with customers. Being one of the establishers, Peter has had a stand at the market since 2004. My impression from living in Puerto Viejo, is that both the locals and foreigners that live there knows who he is. The people I talked to either knew him from the Farmer's Market, or from having visited the Botanical Garden.

Visitors are also welcome to visit the Botanical Garden, either walking around by themselves or in guided tours. This is also an arena for customers to get to know him and his production, and for him to make new acquaintances.

6 DISCUSSION

The overall objective of this study is to analyze permaculture based farming, in a social ecological framework. Based on the three main properties of social-ecological systems; buffer capacity, adaptive capacity and self-organization (Carpenter et al. 2001; Milestad & Darnhofer 2003), in the following chapter I will discuss each of these. As previously stated, the categories are not mutually exclusive, and several indicators are relevant for more than one "category". In accordance with my research questions, the focus of the discussion, will be on how the findings from the farms relate to resilience theory, and which aspects may represent challenges.

6.1 Buffer Capacity

The buffer capacity determines the system's ability to absorb disturbance (Speranza 2013). The farm resilience indicators that relate to the agroecosystem's buffer capacity include *diversity, redundancy, connectivity, heterogeneity, reasonably profitable and exposed to disturbance*.

Both farmers in this study emphasize their focus on diversity. Tristan has around 150 species of fruit trees, and Peter close to 200. Peter also sells plants from his nursery, which is focused on rare species. Both farms are designed as perennial-based polycultures, which is an indicator of connectedness (Cabell & Oelofse 2012). Tristan says he considers the intrinsic characteristics of the plants when he designs his system. When crops are planted based on their intrinsic characteristics, they can complement each other and increase the productivity (Picasso et al. 2011).

Further, the cacao crops in the area have a history of being affected by fungus (Slingerland & Gonzalez 2006), which can be considered a threat to the farm because their main income is from chocolate production. Although Peter himself mostly grow old cacao varieties, he says most cacao farmers in the area are planting the disease-resistant varieties developed by CATIE (Fendt 2014). Because he buys cacao from other farmers with different varieties he has access to cacao with different genetics, which can serve as an insurance for a stable supply of cacao in case of an outbreak of disease (Chapin et al. 2009b), and can be considered an indicator of response diversity (Elmqvist et al. 2003).

An example of functional diversity at Peter's farm is the 19 different species he has from the Myrtaceae family. A function of this family of trees is providing forage for bees, that in turn are essential for pollination (Hilário & Imperatriz-Fonseca 2009). At Finca La Isla, there are 19 planted tree types from the Myrtaceae family (see appendix 1). This means that if one or more of these tree types fail, the farm still has trees to attract pollinators.

Their biodiverse farms, and interest in preserving rare and endangered species contribute to preserving biodiversity. In addition to being an indicator of resilience (Cabell & Oelofse 2012), this can be considered a counteract to the decline of biodiversity observed on a global scale in industrial agriculture (FAO 2014; Hathaway 2015). However, when considering this in a global context, it may also be worth considering how achievable this level of species diversity is for farmers in other parts of the world. Regional factors, such as climate and soils vary greatly among ecosystems and parts of the world (Edwards et al. 1993). Talamanca, that is home to 3% of the worlds known species (UNESCO 2017), may therefore not be a realistic measure for farms in other contexts.

Both farmers have the farm work as their main occupation. They are able to support themselves and their families without depending on secondary employment or subsidies, which is the main indicator of economic resilience on a farm (Cabell & Oelofse 2012). However, to get in this position has taken several years for both Peter and Tristan. Perennial systems take several years before they start producing. The first years, they had to work outside the farm to generate enough income to survive. Tristan says the process of becoming self-sufficient is long and challenging, but the real challenge is to be able to generate enough income to live off the farm. According to him, the key is to differentiate income, and not only rely on cash crops. This trend is also observed among farmers across North-America (Barbieri & Mahoney 2009) order to be more adaptive and responsive to new market opportunities. Diversity of income is also seen as a key aspect of economic resilience (Adger 2000; Barbieri & Mahoney 2009). Tristan has diversified his income through processing nuts and fruits, selling his income to different vendors, and offering volunteering, internships, farm tours and housing on site, in addition to his cash crops. Peter has also a diversity of income, ranging from cash crops, egg and chocolate production to selling plants and teaching. Both farmers come off as innovative people. For instance was Tristan the first to sell both biriba (*Rollinia deliciosa)* and organic pineapple (*Ananas comosus)* at the local market. They both experiment with which crops to grow and continuously look for new products to sell, that nobody else has or people would want to buy. This is a management approach that requires farmers to be entrepreneurial, and also market- aware and responsive (Barbieri et al. 2008).

FAO (2016) recommends agroecologial management practices, in which permaculture is a part, as a future strategy for agriculture. Thus, this type of farming needs to provide a livable income for farmers around the globe. The question that arises, is whether the management strategies from the farms explored in this thesis is replicable in other contexts. When exploring diversification of farm activities, (McNally 2001) found that to successfully diversify farm income, firstly, there must be available market opportunities, which in some places might be limited. In addition, they claim that not all farmers are in the position to take advantage of any opportunity that arises. Diversification requires additional labor, that can be difficult to manage, especially if the farmer has other off-farm work or runs the farm alone.

6.2 Adaptive Capacity

The key word for adaptive management is knowledge. It comprises different ways of acquiring, sharing, facilitating and implementing knowledge, on individual, farm and local level. Three of the farm resilience indicators deal with different aspects of adaptive capacity; '*builds human capital', 'reflected and shared learning', and 'honors legacy while investing in the future'*.

Neither of the farmers have any plant- or agriculture related educational background or grew up working on farms. Their motivations for starting a permaculture farm, were based on the desire to have a meaningful lifestyle, being self-sufficient and an interest in (tropical) plants and sustainable farming. They were introduced to permaculture through literature about sustainable farming and volunteer work at other permaculture farms.

They both share a general attitude of not being fully taught, but rather sees farming as a continuous process of learning. They also share an interest in experimenting with endangered and rare plant species. Tristan has an emerging interest in medicinal plants, and continuously learns new usages for them. For Peter, one of the main drivers and inspirations for working with tropical plants, is the lack of knowledge about them, in comparison with well-studied crops of modern agriculture. This eagerness for discovering new knowledge, implies farmers who are committed to continuously improve their understanding and knowledge about their systems, which indicates a resilient management approach (Berkes et al. 2003; Milestad & Darnhofer 2003).

Both farmers identify the same main sources for new knowledge and information. Firstly, they both emphasize the experimentation they have done on their farm throughout the years. Through trial and error, and living on site for several years, they know which crops grow well on site and which species go well together. Actively experimenting is fundamental for the farmer's understanding and knowledge about the system (Milestad et al. 2012). The feedback farmers receive from experimenting, allows farmers to adjust their practices and increase their repertoire of response-options for the future (Darnhofer et al. 2010), which is the key feature of adaptive capacity (Milestad et al. 2010). Further, the process of understanding the land, and responding to feedback, includes learning the patterns of the sun, wind and water flow, which relates to the permaculture design principle, observe and interact (TimberPress 2013).

Secondly, they mention the importance of talking to other people, such as farmer-colleagues. Through social relations, farmers can both receive feedback and increase knowledge through the experimentation of other farmers. Being connected to social networks that facilitate this, is essential for the adaptive capacity (Conley & Udry 2001; Milestad et al. 2010; Milestad et al. 2012). Both farmers mention several arenas for social interactions that encourage learning. They both work with colleagues in the area, and Peter also confers with farmers in other places, to learn from their experiences. In Talamanca, an important place for social networking for farmers, is the weekly Farmer's market. Both farmers have a regular stand at the market. Peter is also a founding member, and says he is actively advocating the market. When people with the same interests come together, they can meet likeminded people, share ideas and experience, which makes it an arena for building social relationships and knowledge (Cabell & Oelofse 2012; Milestad 2003). Farmer's markets also enable face-to-face interactions between farmers, and farmers and consumers. Through these interactions, they can learn from each other, for instance about each other's food or farming conditions. When actors learn, it can increase their adaptive capacity (Milestad et al. 2010). In addition, because of the diversity of people, the market also facilitates sharing of knowledge between generations and cultures.

Thirdly, they both consider the Internet as an important source of knowledge. A key benefit of Internet is the increased supply of information. This information can be related to production, machinery or potential customers. The Internet can also help farmers to diversify and market niche products directly to customers (Rolfe et al. 2003). Permaculture has been criticized for the lack of scientific research (Ferguson & Lovell 2014). Consequentially, farmers that have adapted a permaculture management approach, are left to develop knowledge, skills and test agro-ecological innovations through trial and error (Kroma 2006). Permaculture practices require access to knowledge, skills, and information platforms, which are different from conventional (industrial) agricultural knowledge. In addition, the science of regenerative agriculture, such as permaculture, has long had a reputation for not being a valid agricultural knowledge (Flora et al. 2001). Thus, this may represent a challenge to permaculture farmers, and a barrier for those new to farming, or those looking to shift their current practices.

Another aspect of knowledge, and an indicator of resilience, is including local traditional knowledge into the farm management (Cabell & Oelofse 2012). Talamanca is the area in Costa Rica with the highest concentration of indigenous population (INEC 2008). Indigenous and local people have been practicing farming methods for generations, and know the local growing conditions well. Both Peter and Tristan have exclusively hired local workers on their farms. Traditional local knowledge has also been important for Tristan. Before he bought his farm, he worked alongside an indigenous farmer while volunteering at a permaculture farm. In addition, he says he has learned a lot from his indigenous farm worker, for example how to deal with snakes. Because permaculture is about coexisting with nature, the knowledge on how to live with snakes without killing them, is an example of the design principle integrate rather than segregate (Holmgren 2007). Having knowledge about the local wildlife, can teach people how to use the intrinsic behaviors of the animals to their benefit, such as snakes regulating the rodent population (Hishaw & Gloyd 1926).

Even though both Peter and Tristan have worked with local people, they both insinuate that they are not necessarily the best sources of knowledge for improvement strategies for permaculture farms. Tristan explains that many locals and indigenous people in the area have been working on monoculture plantations, and therefore have abandoned traditional practices. This corresponds with the findings of (Harvey et al. 2006), who state that indigenous agroforestry systems in Talamanca, are being increasingly replaced by plantain monocultures *(musa* BB spp.).

A second way of honoring traditional knowledge, is conserving natural forest. Natural forests are considered the system's inherited "biophysical knowledge", and thus a part of the system's ecological legacy (Shava et al. 2010). Both farmers have included large areas of natural forest on their farms, to provide habitat for wild life and contribute to biodiversity. This practice aligns with the permaculture principle of zoning (Holmgren 2007). Including natural areas and continually planting provides variations in microclimate, and trees at different ages and in various stages of succession, which is also an aspect of temporal and spatial heterogeneity (Chapin et al. 2009b). Peter does not however, use the concept the way it is stated in permaculture, where the most frequently used areas are close to the house and vice versa. Instead, he grows the crops where he thinks they might grow best. The untouched forest areas on Peter's farm include patches and corridors of secondary cacao, that have been left untouched since he bought the farm 30 years ago. Cacao-ecosystems in Talamanca have been found to support a higher number of bird-species, than forests with no seasonal effect Talamanca (Reitsma et al. 2001).

6.3 Self-organization

A farm's capacity for social self-organization is the system's social capital and collective action (Berkes & Seixas 2005), whereas the ecological aspect include responsible and conscious use of natural resources and processes (Cabell & Oelofse 2012). The associated farm resilience indicators are *social self-organization, ecological self-regulation, local natural capital and globally autonomous and locally interdependent*.

The first indicator of socially self-organized agroecosystems is the presence local networks or institutions (Cabell & Oelofse 2012). The farmers in the area seem to be closely connected, where everyone knows each other. The most important arena for social networking for the farmers in this study, is the Farmer's Market, which is also their most important source of income. Peter also mentions that he has collaborated and exchanged material with Corredór Biologico. Apart from this, neither report being members of any other types of networks. As previously discussed, Permaculture is highly knowledge intensive. Therefore it is important that farmers are included in local grass root initiatives that promotes experimentation and collaboration within the community (Altieri & Toledo 2011). A relevant farmer co-op in the area, is The Talamanca Small Farmers Association (APPTA-Asociación de Pequeños

Productores de Talamanca), that works with organic certification, promoting organic production and conservation of the rain forest in Talamanca (Damiani 2001). Bearing in mind that permaculture is criticized for being detached from scientific science and institutions (Ferguson & Lovell 2014), collaborating with local associations, can represent a strategy for reconnection.

Although the farmers are not members of farmer organizations, the way they have structured their business and management, provides independency. When farms are completely dependent on external controls, they lack autonomy, which is a threat to resilience (Cabell & Oelofse 2012). Essentially, the farmers in this study can choose what to sell, where to sell it. Also, because they have nobody to “answer to”, they can decide when they want to work and not. However, the two farms have a difference in management and structure which represents a difference in autonomy. Peter’s approach, is to run a commercial farm, and he has four families that depend on the income from the farm. In contrast, Tristan’s aim is to be self-sufficient with what he grows, because he does not want to depend on an external system. Although he has a farmer that works 2-3 days, and needs to pay a monthly electricity bill, he says that with 8-10 hours of work per week, he could easily feed himself and his family. Also, they installed electricity out of convenience, rather than necessity. In theory, Tristan could therefore manage both without the worker, and the electricity. I argue that a farm that is self-sufficient with food, with no large economic expenses, that can manage without external help, has a high level of autonomy.

The ecological aspect of self-organization refers to responsible and conscious use of natural resources and processes (Cabell & Oelofse 2012). An indicator of resilient management strategy, is when the agroecosystem that depends on internal recycling structures instead of external inputs (Cabell & Oelofse 2012; van Apeldoorn et al. 2011). In permaculture, this aspect is covered by the principle of using renewable resources and services (Holmgren 2007). Tristan does not fertilize his crops, because as he says; a natural forest does not need additional fertilizer. In addition, he does not consider the little extra yield worth the work. For seedlings or planting, he has available compost and humanure from the farm. Internal recycling of resources is important for reducing dependence on external inputs (van Apeldoorn et al. 2011), and in addition, it saves him money, time and energy for labor.

On Peter's farm, they use biochar as soil amendment. In addition to increasing soil organisms, application of biochar has shown consistent and promising benefits on the soils water holding capacity, nutrient availability, increased yields, and sequestering carbon to the soil. As such it has been argued as a means to mitigate climate change, both due to capacity for storing carbon, and the avoided N_2O emissions from producing fertilizers. In addition, increased water holding capacity can reduce the need for irrigation in certain systems (Atkinson et al. 2010; Lehmann et al. 2011; Sohi et al. 2010; Woolf et al. 2010).

7 CONCLUSION

The aim of this study has been to analyze permaculture farming from a resilience perspective. The results suggest that both farms' current management strategies, consistently parallel the indicators of farm resilience. In my analysis, I could not identify any emergent deviations from the resilience indicators, that imply vulnerability and a need for intervention.

Permaculture farms do however, face challenges with establishing a livelihood. For both farmers, it took several years for the farm to provide a livable income. In contrast to conventional annual crop systems, which can be harvested and generate income the first year, perennials systems take years to come into production. Further, cash crops alone, does not provide a sufficient source of income for either of the farms in this study. Permaculture farmers must therefore actively seek alternative sources of income, which require them to be innovative and market responsive.

Next, the benefits of perennial systems, is that with time, they require less work than annual systems because they do not need to be reestablished every year. Also, when permaculture farms design systems that mimic natural ecosystems, they create systems that need less intervention, because they regulate themselves. This include natural recycling of nutrients, which in turn except farmers from dependence on expensive, work demanding fertilizing methods that are damaging to the environment.

Finally, permaculture practices require access to knowledge, skills, and information platforms, which are different from those of conventional agriculture. In addition, permaculture does not have the well-established institutions of conventional agriculture. However, this also represents a freedom, by depending less on external institutions and processes.

For further research, it would be interesting to look at a local food system as a whole, to understand the role of permaculture farms in a larger perspective. Also, it could be useful to perform biophysical measurements of farm components, to be able to quantify ecosystem and environmental effects of permaculture methods.

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Appendix 2- List of Species (Finca Inti)

Sorted by family name

Acanthaceae
Justicia amarilla (*Justicia aurea*)
Pavaron Amarillo, golden shrimp plant (*Pachystachys lutea)*
Pavon rojo, Brazilian red cloak *(Megaskeplasma erythrochlamys)*
Pavoncilo rojo (*razisea spicata*)
Sky vine (*thunbergia grandiflora)*
Tilo, carpenter's bush *(justicia pectoralis)*

Agavaceae
Cabuya (*furcraea cabuya)*
Itabo, spineless yucca (*yucca guatemalensis)*
Lenguea de suegra, sansevieria (*sansevieria trifasciata)*

Amaryllidaceae
Lirio de playa, spider lily (*hymenocallis littoralis)*

Anacardiaceae
Mango *(mangifera idica)*
Marañon, cashew nut *(anacardium occidentale)*
Jocote, purple mombin *(spondias purperea)*
Yuplon, ambarella *(spondias dulcis)*

Annonacea
Biriba *(rollinia deliciosa)*
Corazon, custard apple *(annona reticula)*
Guanabana, soursop *(annona muricata)*
Guanabana de montanaña, mountain soursop (*annona montana*)
Kepel *(stelechorcarpus burahol)*
Panama cherimoya *(annona spraguei)*
Anon, sugar apple *(annona squamosal)*
Soncoya (*annona purpurea*)
Ylang ylang *(cananga odorata)*

Apiaceae
Culantro coyote, wild coriander

Apocynaceae
Allamanda, yellow allamanda *(allamanda cathartica)*
Carissa *(carissa grandiflora)*
Chirca, yellow oleander *(cascabela thevetia)*
Frangipani (*plumeria rubra)*
Thevetia ahouai

Araceae
Ceriman, swiss cheese plant (*monstera delicoca*)
Dieffenbachia cultivar

Dieffenbachia oerstedii
Cobija de pobre, dubia philodendron (*philodendron radiatum*)
Filodendron, tree philodendron (*philodendron cultivar*)
Malanga, taro (*colocasia esculenta*)
Oreja de elefante, elephant ear (*xanthosoma undipes*)
Tiquisque, tannia (*xanthosoma sagittifolium*)

Arecaceae
Acai (*Euterpe edulis*)
Aiphanes aculeate
Guagara, rootspine palm (*cryosophila warscewiczii*)
Coco, coconut (*cocos nucifera*)
Maquenque, stilt palm (*socratea exorrhiza*)
Onocarpus bataua
Pacaya Costa Rican bamboo palm (*chamaedorea costaricana*)
Peijbaye, peach palm (*bactris gasipaes*)
Sugar palm (*arenga pinata*)
Sugar palm (*caryoya urens*)
Suita (*geonoma congesta*)

Asteliaceae
Caña india, red dracaena (*cordyline fruticosa*)

Asteraceae
Boton de oro, West Indian creeper (*sphagneticola trilobata*)
Gaviliana, jack ass bitters (*neuroloena iobata*)
Tithonia rotundifolia
Balsaminaceae
Chinas, impatiens (*impatiens walleriana*)

Begonicaceae
Begonia sp. (Many species)

Bignonaceae
Jacaranda (*jacaranda mimosifolia*)
Jicaro, calabash (*Crescentia cujete*)
Llama del bosque, African tulip tree (*spathodea campanulata)*
Roble de sabana *(tabebuia rosea)*
Paut d'Arco (*tabebuia impectignosa*)
Vainillo, yellow elder (*tecoma stans*)

Bixaceae
Achiote, annato (*bixa orellana*)

Bromeliaceae
Piña, pineapple (*ananas comosus*)
Piñuela, bromelia penguin (*bromelia pinguin*)

Burseraceae
Jinocuabe, gumbolimbo (*bursera simaruba*)

Cactaceas
Tuna, prickly pear cactus (*opuntia tuna*)

Caricaceae
Papaya (*carica papaya*)
Papaya de montaña (*carica monoica)*

Caesalpiniaceae
Guapinol, stinky toe tree (*hymenaea courbaril*)
Hoja sen, dwarf poincianna (*caesalpinia pulcherrima*)

Cesalpinaceae
Caña fistula, golden rain tree (*cassia fistula)*
Carao (*cassia grandis*)

Chenopodiaceae
Apazote, wormweed (*chenopodium ambrosioides*)

Chrysobalanaceae
Icaco, cocoplum (*chrysobalanus icaco)*

Cluciaceae
Bakupari (*garcinia brasilensis*)
Brunei cherry (*garcinia parvifolia*)
Charichuelo (*garcinia macrophylla*)
Cherapu, button mangosteen (*garcinia prainiana*)
Cherry mangosteen (*garcinia intermedia*)
Imbe (*garcinia livingstonei*)
Kandis (*garcinia forbesii*)
Madrono (gar*cinia madruno*)
Mamey, mamey apple (*mammea americana*)

Commeliniaceae
Hoja de milagro, wandering jew (*tradescantia zebrina*)

Crassulaceae
Hoja del aire, life everlasting (*kalanchoe pinnata*)

Ebenaceae
Mabolo, velvet apple (*diosphyros blancoi)*
Zapote negro, black zapote (*diosphyros digyna*)

Esterculiaceas
Guzimo, tropical elm (g*uzuma ulmifolia*)

Euphorbiaceae
Castor bean, ricino (*ricinus communis*)
Chicasquil, Chaya (*cnidoscolus aconitifoluis)*
Croton *(codiaeum variegatum)*

Poinsettia (*euphorbia pulcherrima*)
Piñon (*jatropha curcas*)
Yucca, cassava (*manihot esculenta)*

Fabacea
Gandul, pigeon pea (*cajanus cajan*)
Gavilan (*pentaclethra macroloba*)
Madero negro, rat killer tree (*gliricidia sepium*)
Sea heart (*entada gigas)*
Sensitive plant, dormilona (*mimosa pudica*)
Tamarindo (*tamarindus indica*)

Gramineacae
Maiz, corn (*zea mays*)

Labiataea
Menta, mint (*menta rotundifolia*)
Ortiga, stinging nettle (*urtica sp.)*

Lamiaceae
Albahaca, basil (*ocimum basilicum L.*)

Lauraceae
Aguacate, avocado (*persea americana*)
Canela, cinnamon (*cinnamomum zeyllaanicum*)
Engkala (*litsea graciae*)

Liliacea
Sabila, aloe vera (*aloe vera*)
Itabo, yucca (*yucca elephantipes*)

Longaniacea
Salvia virgen, wild sage (*buddleia americana*)

Malpighiaceae
Acerola, Barbados cherry (*malpighia punicifolia*)

Malvaceae
Amapola, hibiscus (*hibiscus spp.)*
Escobilla, broom stick (*sida rhombifolia)*

Meliaceae
Cedro, tropical cedar (*cedrela mexicana*)
Neem (azadirachta indica)

Moraceae
Breadnut, castaña (*artocarous camansi)*
Champedak (*artocarpus integer*)
Fruta de pan, breadfruit (*artocarpus altilis*)
Guarumo, cecropia tree (*cecropia spp.)*

Higueron, strangler fig (*ficus glabrata and F.jimenezzii*)
Jaca, jackfruit (*artocarpus heterophyllus*)
Lakoocha (*artocarpus lakoocha*)
Marang (*artocarpus odoratissimus*)
Mulberry (*morus spp.)*
Pedalai (*artocarpus sarawakensis*)

Musaceae
Banano, banana (*musa*)

Myrtaceae
Araza *(Eugenia stipitata*)
Blue grape (*myrciaria vexator*)
Brumichama, brazil cherry (*Eugenia brasiliensis)*
Guayaba, guava (*psidium guajava*)
Guabita cereza, cattley guava (*psidium cattleianum*)
Eucalypto arco iris, rainbow eucalyptus (*eucalyptus sp.)*
Jaboticaba (*myrciaria cauliflora*)
Manzana de agua *(Eugenia maaccensis*)
Pimiento de Jamaica, allspice (*pimiento dioica*)
Pitanga, Surinam cherry
Wax apple (*syzygium samarangense*)

Oxalidaceae
Bilimbi (*averrhoa bilimbi*)
Carambola, starfruit (*averrrhoa carambola*)

Passifloraceae
Granadilla real (*passiflora quadrangularis*)
Maracuya, passionfruit (passiflora edulis)

Piperacea
Anisillo, star leaf (*piper auritum*)
Pimienta negra, black pepper

Poaceae
Zacate de limon, lemon grass (*cymbopogon citratus*)

Polyconaceae
Uva de playa, sea grape (*coccobola uvifera*)

Rosaceae
Nispero jopones, japanes plum (*eriobotrya japonica*)

Rubiaceae
Café, coffee
Borojo (*alibertia patinoi*)
Noni (*morinda citrifolia*)

Rutacea

Kaffir lime (*citrus hystrix*)
Kumquat (*fortunella spp.)*
Limon, lemon (*citrus limettioides*)
Lima, lime (*citrus spp.)*
Mandarin, tangerine (*citrus reticulata*)
Naranja, orange (*citrus sinensis*)
Toronja, grapefruit *(citrus x paradisi*)

Terminaliacea
Almendro de playa, indian almond (*Terminalia catappa*)

Salicaeae
Guatonga (*casearia sylvestris*)

Sapindaceae
Akee (*blighia sapida*)
Alupag (*dimocarpus didyma*)
Longan (*dimocarpus longan)*
Lychee (*litchi sinensis)*
Mamoncillo (*melicocca bijuga*)
Pulasan (*nephelium mutabile)*
Rambutan (*nephelium lappaceum*)

Sapotaceae
Abiu, caimito (*pouteria caimito*)
Caimito, star apple (*chysophyllium cainito*)
Canistel, eggfruit (*pouteria campechiana*)
Chicozapote, sapodilla (*manilkara zapota*)
Fruta milagrosa, miracle fruit (*synsepalum dulcificium*)
Jacana, bully tree (*pouteria multiflora*)
Mamey zapote (*pouteria sapota*)
Satin leaf (*chrysophyllum oliviforme*)
Zapote verde, green zapote (*pouteria viridis*)

Simarubaceae
Hombre grande, bitters (*quassia amara*)

Smiliacaceae
Cuculmeca, china root (*smilax lancolata*)
Zarzaparilla, sasparilla (*smilax medica*)

Solanacae
Chile picante, hot pepper (*capsicum frutescens*)

Tiliaceae
Mozote de caballo, horsesticker (*triunfetta semitriloba*)

Umbelliferae
Culantro, cilantro (*coriandrum sativum*)
Gotu kola (*centella asiatica*)

Perejil, parsley (*carum petroselinum*)

Verbenaceae
Junilama (*lippia alba*)

Zingiberaceae
Caña agria, spiral flag (*costus spicatus and costus ruber*)
Curcuma, turmeric (*curcuma longa*)
Jenjibre, ginger (*zingiber officinale)*

Appendix 2 – List of Species (Finca La Isla)

Fruit, Nut and Spice Trees

Common name (*Family name*) Latin name

A

Abiu (*Sapotaceae*) Pouteria caimito
Acai (*Arecaceae*) Euterpe oleracea
Acerola (*Malpighiaceae*) Malpighia glabra
Achacharu (*Clusiaceae*) Garcinia humilis
Achiote (*Bixaceae*) Bixa orellana
Akee (*Sapindaceae*) Blighia sapida
Aiphanes (*Arecaceae*) Aiphanes aculeata
Allspice (*Myrtaceae*) Pimento officinalis
Amazonian Tree Grape (*Moraceae*) Pourouna cecropifolia
Ambarella (*Anacardiaceae*) Spondias dulcis
Araza (*Myrtaceae*) Eugenia stipitata
Avocado (*Lauraceae*) Persea americana

B

Banana (*Musaceae*) Musa acuminata
Bataua (*Arecaceae*) Oenocarpus bataua
Black sapote (*Sapotaceae*) Diospyros digyna
Black pepper (*Piperaceae*) Piper nigrum
Black berry jam (*Rubiaceae*) Randia formosa
Bilimbi (*Oxalidaceae*) Averrhoa bilimbi
Biriba (*Annonaceae*) Rollinia deliciosa
Brazilian cas (*Myrtaceae*) Psidium guineense Sw.
Borojoa (*Rubiaceae*) Borojoa patinoi
Breadfruit (*Moraceae*) Artocarpus altilis
Bromelia penguin (*Bromeliaceae*) Bromelia pinguin
Brunei Cherry (*Clusiaceae*) Garcinia parvafolia
Button mangosteen (*Clusiaceae*) Garcinia prainiana

C

Cabeluda (*Myrtaceae*) Eugenia tomentosa
Cacao (*Sterculiaceae*) Theobroma cacao
Calabash (*Bignoniaceae*) Crescentia cujete
Calamondin (*Rutaceae*) x Citrofortunella microcarpa
Caimito type (*Sapotaceae*) Pouteria sp.
Caimito (*Sapotaceae*) Chrysophyllum cainito
Canistel (*Sapotaceae*) Pouteria campechiana
Capulin (*Myrsinaceae*) Ardisia compressa
Carambola (*Oxalidaceae*) Averrhoa carambola
Cashew (*Anacardiaceae*) Anacardium occidentale
Champedak (*Moraceae*) Artocarpus integer
Champedak X jackfruit (*Moraceae*) Artocarpus
Cherry mangosteen (*Clusiaceae*) Garcinia intermedia
Cinnamon (*Lauraceae*) Cinnamomum zeylanicum
Cinnamon apple (*Sapotaceae*) Pouteria hypoglauca
Clove (*Myrtaceae*) Eugenia caryophyllata

Coconut (*Arecaceae*) Cocos nucifera
Cola nut (*Sterculiaceae*) Cola acuminata
Coquito (Arecaceae) Astrocaryum alatum
Cupuasu (*Sterculiaceae*) Theobroma grandiflorum
Curry leaf tree (*Rutaceae*) Murraya koenigii
Custard Apple (*Annonaceae*) Annona scleroderma

D
Duku (*Meliaceae*) Lansium domesticum
Durian (*Bombacaceae*) Durio dulcis
Durian (*Bombacaceae*) Durio graveolens
Durian (*Bombacaceae*) Durio kutejensis
Durian (*Bombacaceae*) Durio testudenarium
Durian (Bombacaceae) Durio zybenthis
Dwarf June plum (*Anacardiaceae*) Spondias dulcis (dwarf)
Dwarf Inchi (*Euphorbiaceae*) Caryodendron sp
Dwarf Mulchi (*Myrtaceae*) Eugenia sp

E
Engkala (*Lauraceae*) Litsea garciae

F
Finger lime (*Rutaceae*) Citrus australasica

G
Galangal (*Zingiberaceae*) Alpinia galanga
Garcinia lateriflora (*Clusiaceae*) Garcinia lateriflora
Garcinia magnifolia (*Clusiaceae*) Garcinia magnifolia
Gin berry (*Rutaceae*) Glycosmis pentaphylla
Ginger (*Zingiberaceae*) Zingiber officinale
Gnetum (*Gnetaceae*) Gnetum gnemon
Governors plum (*Flacourtiaceae*) Flactourtia indica
Grenadilla (*Passifloraceae*) Passiflora alata
Guanabana (*Annonaceae*) Annona muricata
Guarana (*Sapindaceae*) Paullinia cupana
Guava (*Mrytaceae*) Psidium guajava
Guayabilla (*Mrytaceae*) Eugenia victoriana

H
Horse mango (*Anacardiaceae*) Mangifera foetida

I
Inchi nut (*Euphorbiaceae*) Caryodendron orinocense

J
Jaboticaba (*Myrtaceae*) Myrciaria cauliflora
Jackfruit (*Moraceae*) Artocarpus heterophyllus
Jambolan (*Myrtaceae*) Syzgium cuminii
Jingapa (*Arecaceae*) Bactria setulosa
Jobo (*Anacardiaceae*) Spondias mombin
Johore cherry (Sapindaceae) Lepisanthes alata
Jungle sop (*Annonaceae*) Anonodium mannii

K
Kafir lime (*Rutaceae*) Citrus hystrix

Keppel (*Annonaceae*) Stelechocarpus burahol
Kukui nut (*Euphorbiaceae*) Alueritis molucanna
Kumquat Rutaceae Fortunella margarita

L
Lakocha (*Moraceae*) Artocarpus lakocha
Langsat Meliaceae Lansium domesticum
Lime (*Rutaceae*) Citrus Aurantifolia
Lime berry (*Rutaceae*) Triphasia trifolia
Litchi (*Sapindaceae*) Litchi chinensis
Longan (*Sapindaceae*) Dimocarpus longan
Lovi lovi (*Flacourtiaceae*) Flacourtia inermis

M
Mabolo (*Ebenaceae*) Mabolo diospyros
Madrono (*Clusiaceae*) Garcinia acuminata
Malabar chestnut (*Malvaceae)* Pachira aquatica
Mamey americana (*Clusiaceae*) Mammea americana
Mamey sapote (*Sapotaceae*) Pouteria sapota
Mamoncillo (*Sapindaceae*) Melicoccus bijugatus
Mangle Bois (*Clusiaceae*) Tovomita plumieri
Mango (*Anacardiaceae*) Mangifera indica
Mango kesteri (*Anacardiaceae*) Mangifera casturi
Forbesii (*Clusiaceae*) Garcinia forbesii
Mangosteen (*Clusiaceae*) Garcinia mangostana
Maracuya (*Passifloraceae*) Passiflora edulis
Marang (*Moraceae*) Artocarpus odoratissima
Maprang (*Anacardiaceae*) Bouea macrophylla
Mata kuching (*Sapindaceae*) Euphoria malaiense
Miracle fruit (*Sapotaceae*) Synsepalum dulcificum
Monkey cacao (*Sterculiaceae*) Herrania cuatra casana
Monkey cacao (*Sterculiaceae*) Herrania nycteroendrun
Monstera (*Araceae*) Monstera deliciosa
Mulberry (*Moraceae*) Morus alba
Mulchi (*Myrtaceae*) Eugenia sp
Mundu (*Clusiaceae*) Garcinia dulcis

N
Natal plum (*Apocynaceae*) Carissa macrocarpa
Nispero (*Sapotaceae*) Manilkara zapota
Noni (*Rubiaceae*) Morinda citrifolia
Nutmeg (*Myristicaceae*) Myristica fragrans

O
Olosapo (*Chrysobalanaceae*) Stelechocarpus burajol
Orange (*Rutaceae*) Citrus sinensis

P
Papaya (*Caricaceae*) Carica papaya
Pataste (*Sterculiaceae*) Theobroma bicolor
Peanut butter fruit (*Malpighiaceae*) Bunchosia argentea
Pedalai (*Moraceae*) Artocarpus odoratissimus
Pejibaye (*Arecaceae*) Bactris gasipaes
Peruvian balsam (*Leguminosae*) Myroxylon pereirae
Phalsa (*Malvaceae*) Grewia asiatica

Pili nut (*Bursereaceae*) Canarium ovatum
Pineapple (Bromeliaceae) Ananas comosus
Pitahaya (*Cactaceae*) Selenicereus megalanthus
Pitanga (*Myrtaceae*) Eugenia uniflora
Pitangatuba (*Myrtaceae*) Eugenia neonitida
Pulusan (*Sapindaceae*) Nephelium mutabile

R
Rainforest plum (Myrtaceae) Eugenia candolleana
Rambai (*Phyllanthaceae*) Baccarea dulcis
Rambutan Sapindaceae Nephelium lappaceum
Rosita de cacao (Bombacaceae) Quararibea funebris

S
Sacha inchi (*Euphorbiaceae*) Plukentia volubilis
Santol (*Meliaceae*) Sandoricum koetjape
Salak (*Arecaceae*) Salacca edulis
Salak (*Arecaceae*) Salacca affinis
Salak (*Arecaceae*) Salacca wallichiana
Sapotaceae (*Pouteria sp*.) Bocas
Sapote Colombiano (*Bombacaceae*) Matisia cordata
Sofou (*Bursereaceae*) Dacryodes edulis
Sonsapote Chrysobalanaceae Licania platypus
Spanish tamarind (*Rubiaceae*) Vangueria madagascariensis
Spiny longan (*Sapindaceae*) Dimocarpus longan
Stinking toe (*Fabaceae*) Hymenaea courbaril
Sugar cane (*Gramineae)* Saccharum officinarum

T
Tahitian chestnut (*Fabaceae*) Inocarpus fagifer
Tangerine (*Rutaceae*) Citrus reticulata
Theobroma glauca (*Sterculiaceae*) Theobroma glauca
Turmeric (*Zingiberaceae*) Curcuma longa

U
Uvalha (*Myrtaceae*) Eugenia uvalha

V
Vanilla (*Orchidaceae*) Vanilla planifolia

W
Wampi (*Rutaceae*) Clausena lansium
Water Apple (*Myrtaceae*) Syzygium malaccense
Watermelon (*Gourd Bignoniaceae*) Crescentia sp.
Wax jambu (*Myrtaceae*) Syzygium samarangense
Wild date (*Arecaceae*) Phoenix sylvestris
Willy nilli (*Mrytaceae*) Banksia baxteri

Y
Yerba mate (*Aquifoliaceae*) Ilex paraguariensis

Medicinal Plant List
Common name: Latin name (*Family name*)

A
Achiote: Bixa Orellana (*Bixaceae*)- Leaf, root, shoot, bark
Ajos Sacha/ Garlic Vine: Mansoa alliacea (*Bignoniaceae)*- Bark, leaf, root
Amapola: Hibiscus sabdariffa (*Malvaceae*) - Flowers, leaves
Arnica: Chaptalia nutans (*Asteraceae*) - Whole plant
Azul de Mata: Justicia tinctorea *(Acanthaceae)* - Leaves

C
Chancra Piedra / Rinoncillo: Phyllanthus niruri / amarus (*Euphorbiaceae*) - Whole plant
Citronella: Cymbopogon nardus (*Cardiopteridaceae*) - Leaves, essential oil
Clove: Syzygium aromaticum (Myrtaceae) - Flower buds, leaves
Coralillo: Hamelia patens (*Rubiaceae*) - Leaves, flowers
Cucaracha: Tradescantia zebrine *(Commelinaceae)* - Leaves, stem, juice
Cuculmeca: Smilax cordifolia *(Smilacaceae)* - Root
Culantro: Eryngium foetidum (*Apiaceae)* - Leaves, roots
Curcuma: Curcuma longa (*Zingiberaceae*) - Root, rhizome

D
Dog's Tongue: Pseudoelephantopus spicatus (*Asteraceae*) - Leaves, roots
Dormilona: Mimosa pudica (*Mimosaceae*) - Leaves, roots

E
Escobilla: Sida rhombifolia *(Malvaceae)*- Leaves, roots

G
Galangal: Alphinia galanga *(Zingiberaceae)* - Rhizome
Gavilana: Neurolaena lobata *(Asteraceae)* - Leaves, root
Gotu Kola: Centella asiatica (*Apiaceae*) - Leaves

H
Hoja Santa: Piper auritum (*Piperaceae*) - Whole plant
Hombre Grande: Quassia amara (*Simaroubaceae)* - Wood, leaves

I
Impatiens: Impatiens walleriana *(Balsaminaceae*) - Leaves, stem, root

J
Jengibre: Zingiber officinale *(Zingiberaceae)* - Rhizome
Jergon sacha / Terciopelo Dracontium pitteri (*Araceae*)- Rhizome
Juanilama: Lippia alba (*Verbenaceae*) - Leaves, essential oil

L
Life Everlasting: Kalanchoe pinnata (*Crassulaceae*) - Leaves, juice

N
Noni: Morinda citrifolia (*Rubiaceae*) - Fruit, leaves, roots

M
Madera Negra: Glircidia sepium (*Fabaceae*) - Leaves, flowers, seeds
Mother-in Law's Tongue: Sansevieria trifasciata (*Asparagaceae*) - Leaves

O
Orozuz: Lippia dulcis (*Verbenaceae*) - Leaves
Ortiga: Urera baccifera (*Urticaceae*) - Roots, leaves

P
Patchouli: Pogostemon cablin (*Lamiaceae*) - Leaves

R
Rabbit's Paw: Wedelia trilobata (*Asteraceae*) - Leaves
Rosita de Cacao: Quararibea funebris (*Bombacaceae*) - Leaves, flowers

S
Saragundi: Senna reticulata (*Leguminosae*) - Flowers, leaves, seedpods
Sornia: Dicliptera unguiculata (*Acanthaceae*) - Leaves
Sorosi: Momordica charantia (*Cucurbitaceae*) - Whole plant, fruit, seed

T
Tilo: Justicia pectoralis (*Acanthaceae*) - Leaves

V
Verbena: Stachytarpheta frantzii (*Verbenaceae*) - Whole plant, leaf
Vetiver: Chrysopogon zizanioides (Poaceae)

Z
Zorillo: Petiveria alliacea (*Phytolaccaceae*) - Whole herb