

An aerial photograph of a rural landscape. In the foreground, there are several houses with red-tiled roofs and light-colored walls, surrounded by lush green trees. The middle ground shows terraced agricultural fields with rows of crops, interspersed with more trees and vegetation. The background consists of a steep, forested hillside. The overall scene depicts a traditional agricultural setting.

# Climate Resilient Food Systems

An agroecological approach to Climate Resilient Pathways

YLVA LARSSON 2015

MVEN30 THESIS FOR A MASTER DEGREE IN ENVIRONMENTAL SCIENCE  
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# Abstract

Human interference with the climate system imposes a significant threat to the future capacity of ecosystems to sustain ecosystem services vital for food production. Agroecology is increasingly seen a way to meet these challenges. The aim of this study is to investigate if the IPCC conceptual model of Climate Resilient Pathways (CRP) could be adapted to a food system context, by illustrating an agroecological approach to climate resilient development. Furthermore, the purpose is to create a new combined framework for assessing climate resilience in different agricultural systems and food system structures. To do this a literature study and a database search were conducted, investigating the agroecological approach to development of climate resilience in food systems. The results of the literature study motivated the use of Gliessman's (2015) *Levels of conversion* to illustrate the agroecological approach to climate resilient development. A new adapted model was then created by combining Gliessman's *Levels of conversion* with IPCC's *Climate Resilient Pathways*. In this study I argue that the combination of these two concepts can form a new conceptual framework, illustrating the relationship between agroecological integration and climate resilience in food systems, while taking into account climate change complexity where actions and consequences are often separated in both time and space. I also argue that this new framework could be used to facilitate strategic management and choices concerning food system development. The new model could be used to evaluate current state of development, and to create new strategies for the future. It could also be used by farmers and farmer networks to communicate the significance of their work and their need for support from the wider community, as well as the importance of agroecology to build resilience for a sustainable future.

**Key words:** *adaption, agriculture, agroecological integration, agroecology, climate change, climate resilient pathways, food security, food system, levels of conversion, mitigation, resilience, transformation.*

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# I. Definitions

The following list provides definitions, given by the IPCC (2014a), of some of the key technical terms in the scientific area of climate change strategy.

**Adaptation:** The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

- **Incremental adaptation:** Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.
- **Transformational adaptation:** Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

**Adaptive capacity:** The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

**Climate resilient pathways:** Iterative processes for managing change within complex systems in order to reduce disruptions and enhance opportunities associated with climate change.

**Coping capacity:** The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term.

**Food security:** A state that prevails when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development, and an active and healthy life. Food security is said to consist of three components; access to food, utilization of food, and food availability.

**Food system:** A food system includes the suite of activities and actors in the food chain (i.e., producing, processing and packaging, storing and transporting, trading and retailing, and preparing and consuming food); and the outcome of these activities relating to the three components underpinning food security (i.e., access to food, utilization of food, and food availability), all of which need to be stable over time. Food security is therefore underpinned by food systems, and is an emergent property of the behavior of the whole food system. Food insecurity arises when any aspect of the food system is stressed.

**Mitigation (of climate change):** A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

**Resilience:** The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

**Sustainability:** A dynamic process that guarantees the persistence of natural and human systems in an equitable manner.

## II. Abbreviations

**CRP** = "Climate Resilient Pathways"

**CSA** = "Climate Smart Agriculture"

**IPCC** = Intergovernmental Panel of Climate Change

**IPM** = Integrated Pest Management

**AR** = Assessment Report (from IPCC)

**SOM** = Soil organic matter

# 1. Introduction

Modern humans have completely transformed the face of the earth. The impact of humans has been a major driver of biosphere change and the accumulation of greenhouse gases (GHG) in the atmosphere. The magnitude of this change has caused scientists to agree that we have entered a new geological age they call *Anthropocene*. GHG levels are now rising faster than ever before in history, causing climatic changes that will have significant effects on earth's life-support system. We have caused changes that are beyond our control and complete comprehension, that will cause consequences and delayed feed-back effects for centuries to come even after we stop further addition of anthropogenic GHG emissions (Gliessman, 2015; Houghton, 2009; Edwards & Wiseman, 2011). This development is compromising the capacity of ecosystems to sustain ecosystem services in the long term, and thus undermining ecological processes vital for e.g. food production and water availability (Foley, 2005).

Agriculture is the basic activity by which modern humans survive on earth. Sustainable development of agriculture and food systems is therefore vital for the future development of human society. Climate change is projected to cause impacts that will put significant pressure on agriculture and the global food system. Some of the projected biophysical impacts that are threatening the agricultural production are: increased mean temperature; increased frequency and intensity of extreme weather events; variations in water availability; soil erosion; and changes in biodiversity (Gornall et al. 2010; Reddy, 2015; IPCC, 2007). The impacts are expected to be widespread, complex, geographically variable, and profoundly influenced by socioeconomic conditions (Vermeulen et al., 2012). Food systems are intertwined with culture, politics, societies, economies, and ecosystems, which makes climate change issues complex and multidimensional. Climate change is therefore one of the greatest challenges facing agriculture and global food systems today, both ecologically and economically as well as socially (Ericksen, 2008; Reddy, 2015). According to the Intergovernmental Panel of Climate Change (IPCC), climate related disasters are the main drivers of food insecurity. Climate change impacts on agriculture depend to a large extent on when and where adaptation measures are taken. Other links in the food chain are also vulnerable to climate change, but much less well known (Porter et al., 2014). Agriculture is vulnerable to the impacts, but it is also a major contributor to the climatic changes it is threatened by. Agricultural production at field level is estimated to be responsible for at least 13-15% of the total GHG emissions. If the land use change for agricultural expansion is included it is an additional 19% of global GHG (Hoffmann, 2010).

To ensure future food security, food must be available, accessible, and adequate (De Shutter, 2010). The food system must be able to feed an increasing population projected to be approximately nine billions in 2050 (Wezel & David, 2012). This demands sufficient production of food, but also a transformation to an impact-resilient, low-carbon and resource preserving agriculture (De Shutter, 2010). At present, there are possibilities to produce a sufficient amount of calories to feed this increasing population. However, the most pressing issue is how this can be achieved with less contribution to climate change, without eroding the natural resource base on which agriculture depends. Care also has to be taken to avoid further degradation of ecosystems from which other services also are expected, such as: biodiversity use and conservation; bioenergy production; carbon storage; and climate regulation (De Shutter, 2010; Gliessman, 2015; Wezel & David, 2012). *Agroecology* is increasingly seen as a promising way to address these challenges, and as a more sustainable alternative to conventional industrial agriculture.

The science and practice of Agroecology is supported by a wide range of experts within the scientific community and international agencies e.g. *The International Assessment of Agricultural Knowledge, Science and Technology for Development* (IAASTD), *United Nations Food and Agriculture Organization* (FAO), *United Nations Environmental Programme* (UNEP) (De Shutter, 2010). Agroecology as a science and practice aims to assess and improve sustainability in all agricultural modes of production, independent of their current state, and strive to make them more ecologically sound. While industrial agriculture and food systems are both highly contributive and highly vulnerable to climate change impacts, studies show that agroecological systems are more climate resilient (Li Ching & Stabinsky, 2011; Altieri & Nicholls, 2012). The agroecological approach to farming allows farmers to cope with both environmental and social stress in a more efficient way, which is especially important as these phenomena are becoming more frequent and severe (De Shutter, 2010; Swiderska et al., 2011; Altieri and Nicholls, 2012; Altieri et al., 2012). The aim of agroecology is to support sustainable development by improving traditional agricultural method in



combination with new science; providing sufficient food and improving livelihoods for a growing population; and at the same time preserve natural resources and diversity (Wezel et al., 2009; Altieri & Nicholls, 2005; Wezel & David, 2012). Agroecological practices are already successfully applied in places all over the world, but to enhance climate resilience of the global food system the agroecological approach needs to be the base of a paradigm shift. Radical changes are required in the current dominating food system structure (Parmentier, 2014; De Shutter, 2010; Gliessman, 2015).

In the latest report from the *Intergovernmental Panel of Climate Change (IPCC), Assessment Report 5* from 2014, it is confirmed that climate change will have critical impacts on the future prospects of sustainable development (Denton et al., 2014). In parts of the world most vulnerable to climate change, the impacts are already extensive and continuously eroding the basis for sustainable development. As the magnitude of climate change increase, the challenges to sustainable development will grow globally. To turn this situation around we must strive for development pathways that are as resilient to the effects of climate change as possible, i.e. where social, ecological and socio-ecological systems have the ability to anticipate, reduce, accommodate or recover from climate change related hazards and trends in a timely and efficient manner (Denton et al., 2014). As a response to the spatial and temporal dimensions of climate change impacts, the IPCC presents a new approach to sustainable development which they call *Climate Resilient Pathways (CRP)* defined as "sustainable-development trajectories that combine adaption and mitigation to reduce climate change and its impacts"(IPCC, 2014b:25).

In this study I will use the conceptual model of CRP as a theoretical framework, and investigate how it could be adapted to a food system context by integrating an agroecological approach. The literature study showed that there was not yet any study conducted explicitly putting the two concepts of *agroecology* and *CRP* in relation to each other. There was however one article putting CRP in a food production context. This study by Lipper et al. (2014) was based on the concept of *Climate Smart Agriculture (CSA)* and the idea of *sustainable intensification*, which in many ways are incompatible with the agroecological perspective on true sustainability. With this report I therefore wish to add an agroecological perspective to the concept of CRP. This will mainly be done to achieve the following:

- Adapt the original CRP model to a food system context for a more specific and extended practical use.
- To visually illustrate the agroecological view of building resilience for a sustainable future of food systems.
- To create a climate resilience-framework in which agricultural systems can be assessed from an agroecological point of view.
- In a wider context, include agroecology in the CRP debate and in that way make a small contribution to enhancing the connection between agroecology and climate change strategy.

## 1.1 Aim

The aim of this study was to investigate if the IPCC conceptual model of CRP could be adapted to a food system context, by illustrating an agroecological approach to climate resilient development within the model. Furthermore, the purpose is to create a new combined framework for assessing climate resilience in different agricultural systems and food system structures. To reach this aim, the research questions below will be answered to provide a foundation for adapting the IPCC model.

Research questions:

1. What characterizes an agroecological approach to sustainability and resilience in food systems?
2. How can resilience be enhanced with agroecology, and how could this be presented in a development context compatible with CRP?
3. How can the conceptual model of CRP be adapted to a food system context by illustrating the agroecological approach?

## 1.2 Outline

- The thesis will proceed with a presentation of the *Theoretical framework* in chapter 2. This theoretical framework is used as a base for later analysis.
- Chapter 3 explains the *Methodology* used to conduct this analysis.
- Chapter 4 present the *Results from the literature study* and answers research question 1 and 2. Research question 1 will be answered in section 4.1 by conducting a literature study with focus on investigating the characteristics of the agroecological approach to sustainability and climate resilience. Research question 2 will be answered in section 4.2 by connecting the approach to resilience with the agroecological approach to sustainable development.
- Chapter 5 contains the *Analysis*, where results from the literature study will be put in relation to the theoretical framework. The analysis answers research question 3. The aim of this chapter is to create a new combined conceptual model, illustrating the agroecological approach to CRP.
- In chapter 6, a discussion about the study in a wider context is made.

## 2. Theoretical framework

*This chapter presents the theoretical framework that acts as the base for analysis made in chapter 5. The chapter starts with a brief introduction to IPCC as the creator of the framework. Thereafter it continues with a presentation of the theoretical framework Climate Resilient Pathways (CRP), including its associated conceptual model (fig. 1) which provides the base for the new adapted version of the model created in this study.*

### 2.1 Intergovernmental Panel of Climate Change (IPCC)

The IPCC is the leading international body of Climate Change Assessment. The IPCC was established in 1988 by the United Nations Environmental Program (UNEP) and the World Meteorological Organization (WMO). The purpose of the IPCC is to provide a clear and objective scientific view of the current state of knowledge regarding climate change and its related impacts. The IPCC does not conduct any research, but acts instead as an institution that examines the research conducted around the world. Thousands of scientists are working on a voluntary basis in order to make a comprehensive evaluation of the latest research on climate change and its effects. This information is then compiled in Assessment Reports (AR) on the current state of knowledge of climate change, and issued together with the related Synthesis Report and Summaries for Policymakers. The latest Assessment Report (AR5) was finalized in 2014, and the previous report (AR4) was issued in 2007. Work to compile these reports is divided between the three so-called Working Groups. Working Group I (WGI) assesses the physical aspect of the climate change system, Working Group II (WGII) assesses the vulnerability to climate change and the inter-relationship between vulnerability, adaptation and sustainable development, and Working Group III (WGIII) assesses options for mitigation of climate change (IPCC, 2015).

The basis for this study is primarily the work of WGII, chapter 20: *Climate resilient Pathways: adaptation, mitigation and sustainable development* (Denton et al., 2014).

### 2.2 Climate Resilient Pathways (CRP)

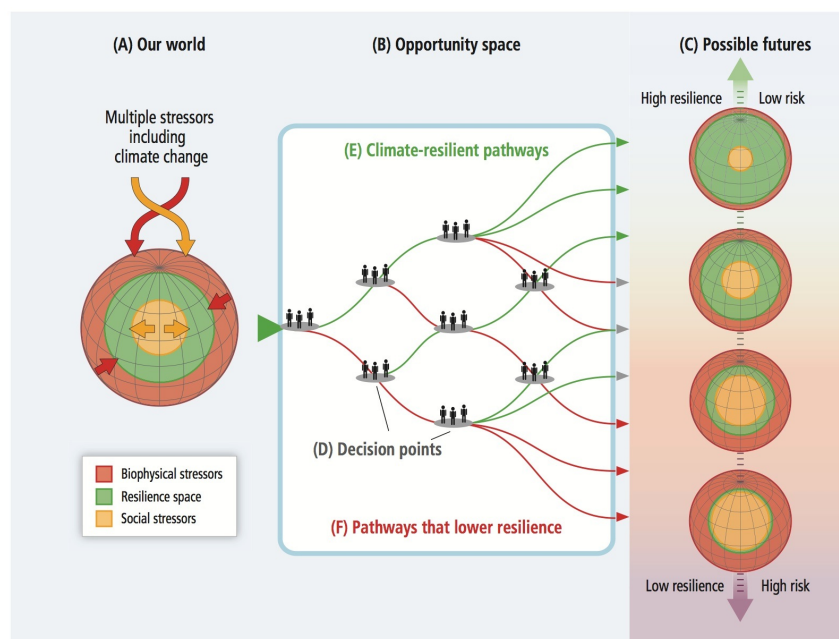
The basis for the analysis in this study is the conceptual framework of *CRP* with its associated model (fig. 1), presented in the IPCC's Assessment Report 5 by WGII in 2014. IPCC describes CRP as "sustainable-development trajectories that combine adaption and mitigation to reduce climate change and its impacts" (IPCC, 2014b:25). CRP take into account the complex interactions between climate and social ecological systems. They can be seen as iterative, continually evolving processes and actions for managing change within these systems to realize the goal of sustainable development. In CRP mitigation is considered a way to limit the contribution of GHG to the atmosphere, and in that way keep climate change moderate rather than extreme, as well as to decrease the speed of change. Adaptation is seen as a necessary response strategy to cope with climate change impacts that cannot be avoided due to already caused anthropogenic interference with the climate system and present failures to mitigate GHG (Denton et al., 2014). Although both mitigation and adaption is essential for climate risk management, the prospects of CRP are related fundamentally to accomplishments of climate change mitigation. Because of that, CRP place emphasis on the need and opportunity to make progress towards the paths of higher resilience now rather than to postpone it into an unknown future. Every delay in action means limited options and reduced possibilities for sustainable development in the future. However, the IPCC has a high agreement that actions towards CRP taken today gives opportunity to implement solutions that can generate co-benefits such as improved livelihoods, social and economical well-being, and responsible environmental management (Denton et al., 2014).

The graphical illustration below, is used by IPCC to illustrate the concept of CRP (fig. 1). It illustrates a decision making process that connects our present with our possible futures. Choices made in this process give us the opportunity to create development trajectories/pathways that will either reduce or increase climate change and its impacts. The pathways are a result of the strategies we choose to support and

how successfully they are implemented, which in its turn determines future prospects for sustainable development. The conceptual framework is general for all sustainable development, and thus not specific for a certain sector. To ensure future prospects of sustainable development, pathways that combine adaption and mitigation leading to higher resilience has to be identified. As such, the process for managing changes is a continuing process of problem identification, innovation, and development (Denton et al., 2014).

In *Assessment Report 5*, IPCC explain the conceptual model of *CRP* and its components as follows;

”(A) Our world is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability, land-use change, degradation of ecosystems, poverty and inequality, and cultural factors. (B) Opportunity space refers to decision points and pathways that lead to a range of (C) possible futures with differing levels of resilience and risk. (D) Decision points result in actions or failures-to-act throughout the opportunity space, and together they constitute the process of managing or failing to manage risks related to climate change. (E) Climate-resilient pathways (in green) within the opportunity space lead to a more resilient world through adaptive learning, increasing scientific knowledge, effective adaptation and mitigation measures, and other choices that reduce risks. (F) Pathways that lower resilience (in red) can involve insufficient mitigation, maladaptation, failure to learn and use knowledge, and other actions that lower resilience; and they can be irreversible in terms of possible futures” (IPCC, 2014b:44).



**Figure 1.** Climate Resilient Pathways (CRP), original conceptual model by IPCC.  
Source IPCC, 2014b:44.

## 3. Methodology

*This chapter presents the mode of procedure and how data was collected, processed, and analyzed. The methods used and the mode of procedure are illustrated in figure 2. The last section in the chapter presents the limitations of the study.*

### 3.1 Data collection method

The initial stage of this study process began with a literature study and database search to collect information about (a) the concept of CRP as a base for the theoretical framework of this study; (b) if there were any previous studies combining the two concepts, or putting CRP in relation to food systems; and (c) investigating the agroecological approach.

Data was gathered from books and the following digital sources:

- LUBsearch: a web based search system to access the digital resources from Lund University Library Network.
- Google Scholar: a search engine from Google focused on scientific information.
- The official website of the Intergovernmental Panel of Climate Change (IPCC).
- The website Agroecology.org.

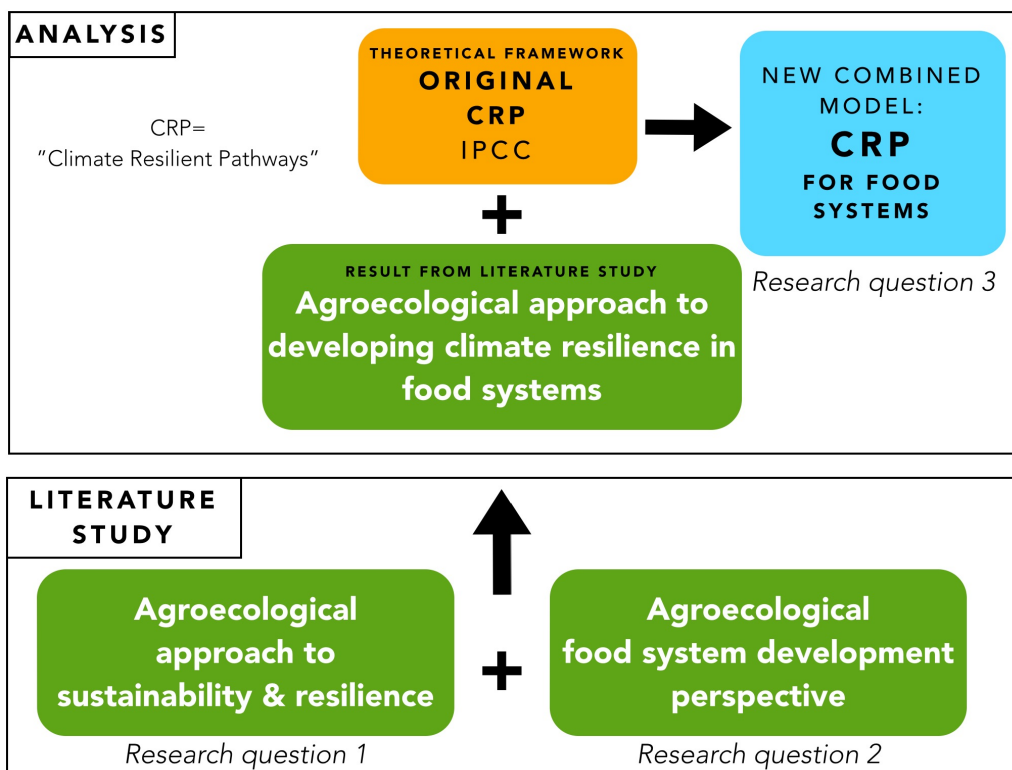
a) The theoretical framework used in this study (see chap. 2) is based on the concept of CRP, as presented in Assessment Report 5 from IPCC (IPCC, 2014b; Denton et al., 2014). Information about this conceptual model was collected solely from the publication database on the official website of IPCC. The information was found in the work of WGII, chapter 20: *Climate Resilient Pathways - adaption, mitigation and sustainable development* (Denton et al., 2014), and in Summary for policymakers; Impacts, Adaptation, and Vulnerability (IPCC, 2014b).

b) To determine if there were any previous studies combining the concepts of CRP with agroecology or food system analysis in general, the following key words used were; *agroecology, agroecosystem, climate resilient pathways, food systems, agriculture, food, food security*. During the data collection period, there were no articles found that explicitly were putting CRP in relation to agroecology. However, there was one scientific article putting the concept of CRP in a food system context. This article written by Lipper et al. (2014) had a focus of Climate Smart Agriculture (CSA), a sustainability concept for agricultural production based on '*sustainable intensification*'. As mentioned earlier, CSA and sustainable intensification are in some sense incompatible with the agroecological perspective on true sustainability and is thus an objective for discussion (Diamond Collins & Chandrasekaran, 2012; Gattinger et al., 2011; Stabinsky, 2012). Because there was no previous literature specifically putting the concepts of CRP and agroecology together, research questions were outlined to see if this connection is possible.

c) To investigate the agroecological approach to CRP, it was necessary to begin with finding the common factors that could make them compatible. Since the key focus of the IPCC concept is *climate resilience* and *development pathways towards sustainability*, these issues also had to be the main focus when determining research questions to investigating the agroecological approach. The process resulted in two research questions based on literature studies, investigating (1) the agroecological approach to sustainability and resilience and (2) how this could be presented in development context compatible with the focus of CRP. The results from the Literature study are presented in chapter 4, and answers research question 1 and 2. These two questions are laying the foundation for further analysis to answer research question 3 (see fig. 2), which will be described further in section 3.2.

The agroecological approach to climate change resilience was investigated by collecting information from books, scientific articles and the website Agroecology.org. Keywords used in the database search were; *agroecology, agroecosystem, resilience, climate change, food system, agriculture, adaption, mitigation, transformation, and food security*. The agroecological approach to increasing sustainability in a system is primarily based on the realization of agroecological principles, using place-specific methods. During the literature study, no comprehensive list of agroecological principles focusing explicitly on enhancing climate change resilience was found. Instead, I compiled a new list of principles relevant to this specific purpose (see

chap 4.2). The new list of resilience-principles was derived from a list of general sustainability-principles found at the website [agroecology.org](http://agroecology.org). The most relevant principles were then selected, re-formulated, and explained in more detail based on information from the literature.



**Figure 2.** Mode of procedure. This figure shows how the study was conducted. The process began with a literature study that investigated the agroecological approach to climate resilience and an agroecological perspective on sustainable development. In the analysis, the results from the literature study was then put in relation to the theoretical framework of Climate Resilient Pathways (CRP), to create a new adapted model that illustrated an agroecological approach to climate resilient development of food systems.

Source: own illustration.

### 3.2 Data analysis method

The previous chapter showed how data was collected and selected in the literature study. This chapter will describe how data was processed and analyzed. The aim of this study was to investigate if the conceptual model of CRP could be adapted to a food system context by adding an agroecological approach to climate resilient development. The concept of CRP was thus used as a theoretical framework for the study. The purpose was also to use the CRP as a foundation to create a combined framework for assessing climate resilience in different agricultural systems and food system structures, from an agroecological point of view.

The agroecological approach was investigated in a literature study. Data from various sources relating to the agroecological view of climate resilience and sustainable food systems development were collected and analyzed to find patterns, connections and common factors that would be possible to integrate with the CRP framework. The analysis showed that it is possible to join agroecological principles and CRP in a combined framework and a common graphical model.

To illustrate an agroecological approach to development of climate resilience in food systems, the literature study motivated the use of Gliessman’s (2015) five *Levels of Conversion* to be integrated with the CRP. These Levels illustrate the conversion process needed to make food systems truly sustainable. They can

serve as a map outlining a stepwise evolutionary conversion process, defining the strategies needed to reach higher levels of sustainability. The Levels are connected to resilience through the concept of *agroecological integration*. Agroecological integration is the degree of realized agroecological principles in a system, which can be used to assess agroecological sustainability. The resilience-principles presented in this study can thus be used to evaluate the agroecological integration in a system with focus on climate resilience. Levels of conversion represent agroecological integration with a concrete development perspective and defined social and ecological goals. Hence, in this study, Levels of Conversion will represent the agroecological perspective on building resilience for a sustainable future of food systems. The analysis continued by putting the results from the literature study in relation to the theoretical framework, answering research question 3 (see fig. 2).

This is a study that puts two existing concepts in relation to each other to create a new combined conceptual framework and model. *CRP* targets sustainable development in general, and is unspecific in its character. The agroecological development strategy *Levels of Conversion* is on the other hand specifically targeting the food system development. Despite the difference in the two concepts appearance and use, this common essence of climate resilient development made them possible to combine. Both concepts are illustrating a process of building resilience for a sustainable future, but with two different but complementary focuses. As such, both concepts were further developed to include new dimensions for an extended use when joined together into a combined framework. The complementary focuses can be explained as follows:

- Gliessman's Levels of conversion is focusing on the outlining of practical management to increase sustainability in food systems. However, the concept is not taking into account the outcome of resilience in a present-future time perspective. In other words, no action and consequence perspective over time.
- CRP focus on how the time factor impact prospects for sustainable development, and how the opportunities and options are related to how and when we implement adaption and mitigation measures. CRP is however not suggesting or specifying any concrete strategies to achieve the goal of sustainability and resilience.
- The two concepts can be joined together based on their common factors, and get an extended use because of their differences.
- In short, it could be explained as Levels of conversion illustrate how resilience can be enhanced in practice, and CRP illustrate why measures has to be taken as soon as possible. The conceptual model stresses that options and restrains are determined by the time factor and achievements to mitigate and adapt to climate change. As climate change increase, a continuous change in conditions demands a continuous improvement of systems to buffer the effects and prevent further contribution to the changes.

When creating the new adapted model, the five Levels of conversion where used as the grading system for "possible futures" (see fig. 6), This grading system can be used to roughly categorize the outcomes of resilience when supporting a certain kind of system designs or strategy. Since all systems look different, the five Levels are not absolute, they are merely pointers towards a sliding spectrum of resilience in which a system or strategy can be placed for evaluation. The Levels of conversion combined with CRP thus acts as framework for evaluating resilience in a certain type of system or to evaluate which development strategies to support. The decision points found in the "opportunity space" can thus be seen as important steps in the decision making process that leads to implementation or failure to implement agroecological resilience-principles. Successful implementation leads to pathways with higher resilience.

### 3.4 Focus and limitations

This study has not the aim to test or verify theories, or to create a new theory based on case studies. Instead this is a study that puts two existing concepts in relation to each other, in the attempt to create a new combined conceptual framework.

As climate change impacts on the food system are complex, multidimensional, interdisciplinary and encompasses a range of institutional, social and ecological components, activities, actors and outcomes (Ericksen, 2008), a complete assessment is not possible to include in the scope of this thesis.

To cover both ecological and socioeconomic dimensions regarding climate change resilience of future food systems, the focus of this report is mainly limited to mitigation and adaptation with the goal of ensuring future sustainability and long term food security. The theoretical approach in this report, conducted as an analysis of the literature study, can only give an overview of possible future outcomes of resilience at different levels of agroecological integration. Likewise, different social, political and cultural circumstances

constitutes a complex reality with a great variety of possibilities and restraints. Urban regions differ from rural, condition in global south differs from global north, and societies in richer countries often have completely different food system cultures than those of the most poor. Therefore, this report only gives a general idea of the situation, wherever the starting point may be. However, there is a clear trend that industrial agriculture and corporate food systems are gaining ground globally, disempowering local communities and undermining local food cultures and traditional knowledge. Following this, there is a need to support the transition to a more sustainable and equitable world, preserving social and environmental integrity.



## 4. Results from the literature study

*This chapter presents the results from the literature study and answers research question 1 and 2. Section 4.1 starts with a brief introduction to the agroecological approach to food systems and continues with the investigation of the approach to sustainability and climate resilience. In section 4.2 the agroecological approach is put in a development context. It presents the agroecological perspective on how food system sustainability and resilience can be increased by introducing the concept agroecological integration and some agroecological principles to enhance resilience. The agroecological development perspective is further conceptualized by the introduction of Gliessman's (2015) five Levels of Conversion to a sustainable food system, as a way of measuring and outlining progress in sustainable development of food systems. It is an agroecological framework to assess and build sustainable food systems, and a way of illustrating the concept of agroecological integration in a development perspective.*

### 4.1 The agroecological approach to sustainability and climate resilience in food systems

#### 4.1.1 Agroecology and food systems

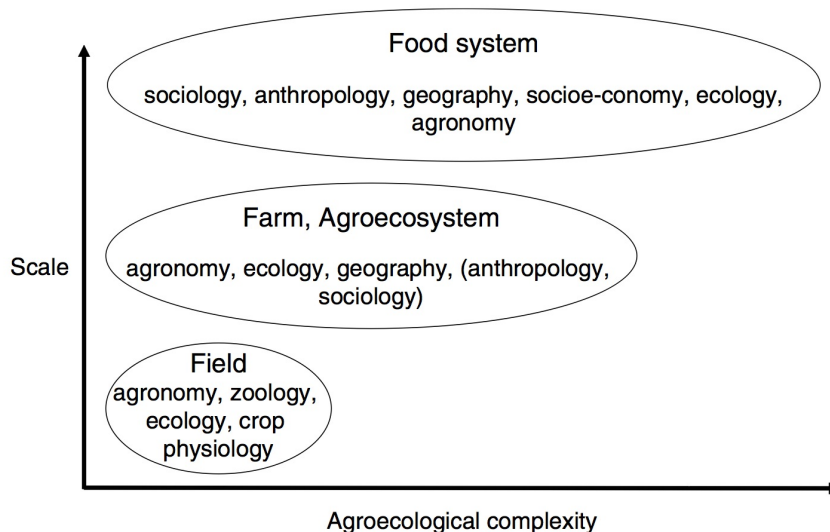
Agriculture has always been evolving and adopting new practices to respond to changed conditions. During the 20th century the agricultural sector responded to new political and economical pressure. New technologies, farm support programs and research development with focus on maximizing profit resulted in fewer and larger farms. This development encouraged highly specialized industrial systems, dependent on chemical inputs and non-renewable resources (Gliessman, 2015). The industrial agriculture that dominates the global food system today has increased both productivity, efficiency and economic growth in the agricultural sector compared to pre-industrial times (Ericksen, 2008). However, this development comes at a high social and environmental price. While achieving short term economic gains, the industrial system is linked to problems that are undermining the capacity of ecosystems to sustain food production in the long term (Gliessman, 2015). The industrial system is built around two main goals; maximization of production and maximization of profit. The emphasis on these goals has transformed agriculture into a manufacturing process resembling the production that occurs in factories. While achieving short term economic gains, the system is continuously destroying the basis for its own production. By its use of industrial practices such as extensive tillage, monoculture cropping, excessive irrigation, application of chemical fertilizers and pest control, the industrial system is linked to problems that are undermining the capacity of ecosystems to sustain food production in the long term (Gliessman, 2015). Additionally, industrial agriculture is a fundamental part of today's globalized food system, which is also a subject to some political, economical and sociological criticism. Modern globalized food systems are, according to Holt-Giménez and Shattuck (2011:111) characterized by; "unprecedented market power and profits of monopoly agrifood corporations". Even though these industrial systems are governed by very powerful corporations, they may be increasingly vulnerable to shocks due to their degree of specialization and homogenization, making it difficult to adapt to changes (McMichael, 2000; Hendrickson & Heffernan, 2002).

In the 1930s, the scientific disciplines of agronomy and ecology where joined together with zoology, crop physiology and botany, and formed the beginning of the trans-disciplinary field of agroecology. In the 1970s, as the industrial agriculture was subject to increased criticism, agroecology gained renewed interest (Wezel et al., 2009; Gliessman, 2015). Today, agroecology is well established all over the world, in both science, practical farm management, and in social-environmental movements.

The term *agroecology* can refer to a scientific discipline, an agricultural movement, or an agricultural management (Wezel et al., 2009). It includes methods for assessing and improving sustainable food systems (Gliessman, 2015). Agroecology as a science is defined as "the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions" (Francis et al., 2003:100). In more practical terms it is defined by Gliessman (2007:18) as "the application of ecological concepts and principles to the design and management of sustainable food systems". Agroecology recognizes the multi-functionality

of agriculture, not just the aspect of production, by the link to e.g. food security, environmental protection, community well-being (Curtis, 2012).

Agroecology as a science can primarily be derived from the concept of *agroecosystems*. An agroecosystem "is a site or an integrated region of agricultural production understood as an ecosystem" (Gliessman, 2015:21). The agroecosystem concept can be used to holistically analyze the food production system through so called *agroecosystemic* thinking, i.e. systemic thinking in an agricultural context. This holistic view takes into account the complexity and ecological components of the food production, as well as the social and economic dimensions and structures under which food production operates (Gliessman, 2015). The agroecological trans-disciplinary complexity in different scales of study are illustrated in figure 3.



**Figure 3.** Illustration of the agroecological trans-disciplinary complexity in different scales of study, indicating the number of disciplines involved to deal with in an increasing complexity of research questions. Source: Wezel & David, 2012:29.

An agroecological approach to food system change can be seen as a way of designing and applying adequate strategies for managing a transition process aiming to make agriculture and food systems more ecologically, socially and economically sustainable (Berton et al., 2012; Parmentier, 2014). The basic feature of these transition strategies is the realization of key agroecological principles through a combination of context-specific practices that are adapted to local environmental and socioeconomic conditions (Altieri and Toledo, 2011; Rosset et al., 2011; Uphoff, 2002; Altieri et al., 2012). Agroecological principles are primarily based on mimicking natural processes to create beneficial biological interactions and synergies among its components (De Shutter, 2010).

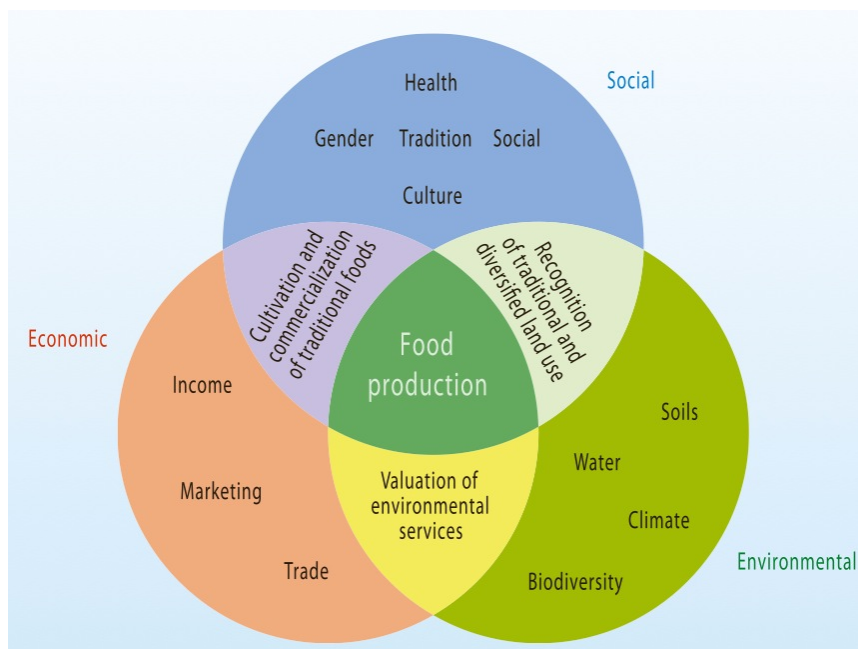
"An agroecosystem that incorporates the natural ecosystem qualities of resilience, stability, productivity, and balance, will better ensure the maintenance of the dynamic equilibrium necessary to establish an ecological basis for sustainability. As the use of external human inputs for control of agroecosystem processes is reduced, we can expect a shift from systems dependent on synthetic inputs to systems designed to make use of natural ecosystem processes and interactions and materials derived from within the system" (Gliessman, 2007:31)

## 4.1.2 Sustainability & resilience

Food systems are complex socio-ecological systems, that depend on ecological variables for its most basic function but are largely driven by social and economic processes (Ericksen, 2008). These components are interconnected and interdependent (fig. 4), which means that to assess and improve sustainability and resilience of food systems both ecological and social, as well as economic factors have to be taken into account.

The term *sustainability* has become increasingly vague and confusing as a result of its extensive use. The label *sustainable* is a desirable feature of almost any product, industry, alternative method or proposal, and it is extensively used for commercial purposes. To clarify the agroecological view of sustainability in food systems the definition from agroecologist Stephen R. Gliessman (2015) could be used. He suggests that a sustainable food system should at least:

- Have minimal negative effects on the environment and release insignificant amounts of toxic or damaging substances into the atmosphere, surface water, or groundwater;
- Minimize the production of greenhouse gases, work to mitigate climate change by increasing the ability of managed systems to store fixed carbon, and facilitate human adaptation to a warming climate;
- Preserve and rebuild soil fertility, prevent soil erosion and maintain the soils ecological health;
- Use water in a way that allows aquifers to be recharged and the water need of the environment and people to be met;
- Rely mainly on resources within the agroecosystem, including nearby communities by replacing external inputs with nutrient cycling, better conservation and an expanded base of ecological knowledge;
- Work to value and conserve biological diversity, both in the wild and in the domesticated landscapes;
- Guarantee equality of access to appropriate agriculture practices, knowledge, technologies, and local control of agricultural resources.
- Eliminate hunger, ensure food security in culturally appropriate ways, and guarantee every human being a right to adequate food;
- Remove social, economic, and political injustices from food systems.

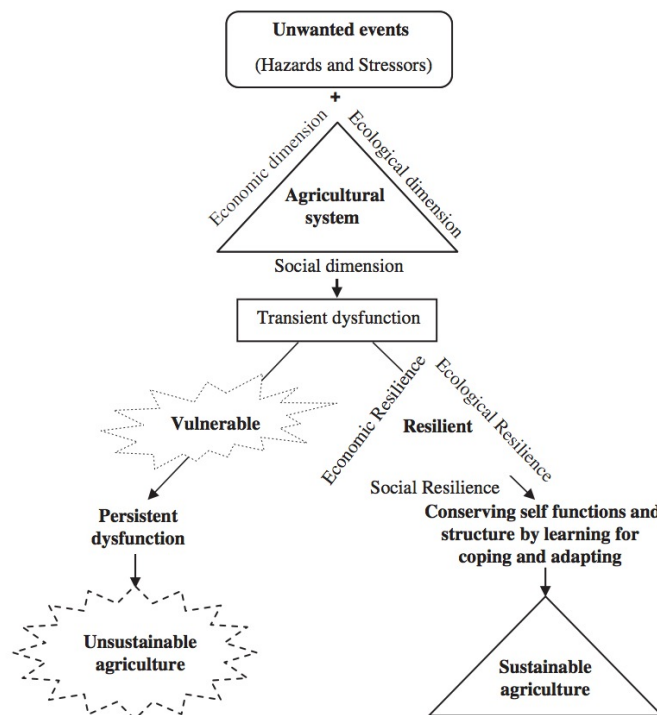


**Figure 4.** Interconnectedness of agriculture and its functions.  
Source: IAASTD, 2009:19.

Just as the term *sustainability*, the term *sustainable development* is used extensively to address a variety of objectives. In agroecology, it could simply be seen as development aiming towards fulfilling the criterion for sustainability listed above.

The strive for resilience is a constant preoccupation in agroecology (Berton et al., 2012). *Resilience* is a multidimensional and complex concept. It is defined and interpreted slightly different across disciplines and contexts (Maleksaeidi & Karami, 2013). A food system is a social-ecological system, and as such explicitly accommodates the social mechanisms behind ecosystem management (Ericksen, 2008). Hence, in agroecology the term *resilience* is preferably used in its social-ecological context. The *ecological* dimensions of resilience is built on the view of multiple stability states and the amount of disturbance that a system can absorb before a change to an alternate state (Holling, 1973). The *social* dimensions of resilience refers to the ability of actors and systems in human society to respond, cope and adapt to disturbances and impacts (Adger, 2000). Thus, “the human element adds to resilience since humans through their ability to visualize, foresee and plan, can enhance the resilience of a system” (Thapa et al., 2010: 7).

Since the agricultural sector is entering a more turbulent phase of increased risk and uncertainty, a sustainable food production system must be able to manage crises, adapt to change, mitigate damage and preserve its long term ability to produce food and ensure food security (Cutter et al. 2008; Milman & Short 2008). Resilience can thus be seen as a necessary precondition for sustainability (Klein et al., 2003; Perrings 2006; Maleksaeidi & Karami, 2013). Maleksaeidi and Karami (2013) have developed a model illustrating the relationship between sustainable agriculture and social ecological resilience (fig. 5). When an agricultural system is stressed or threatened by disturbances, its performance is endangered and may lead to a transient dysfunction. If the system has a sufficient degree of resilience it will be able to preserve its function as a sustainable agricultural system. However, if the system is vulnerable i.e. lacking resilience, the dysfunction will be persistent and the system becomes unsustainable. The degree of resilience determines the rate of recuperation (Maleksaeidi and Karami, 2013).



**Figure 5.** The relationship between social-ecological resilience and sustainable agriculture, as well as between vulnerability and unsustainable agriculture.

Source: Maleksaeidi & Karami, 2013:269.

## 4.2 Enhancing resilience for sustainable food system development

### 4.2.1 Agroecological integration

Like mentioned in previous chapter, agroecological performance does not depend on specific techniques or magic-bullet solutions that will guarantee sustainability wherever the location. Although some particular practices are commonly referred to as *agroecological*, agroecological farming cannot be reduced to a catalogue of techniques (Pérez-Vitoria, 2011). Instead, the realization of principles is linked to interaction between place-specific practices and processes optimized by the whole system (Altieri et al., 2011a). The optimization can be seen as the extent to which a given agroecosystem realizes agroecological principles, i.e. the degree of *agroecological integration*. The degree of agroecological integration in a system can thus be used as a way to assess sustainability, ranging from negligible agroecological integration as in industrial monoculture, to low level of integration such as monoculture-based organic farming with input substitution, to high level of agroecological integration, and thus high sustainability. High agroecological integration can be found in systems with a high degree of diversity and beneficial ecological interaction e.g. complex agroforestry systems with polyculture, annual crops and trees, integration of animals, rotational schemes, and preferably some water elements such as fish ponds for increased biodiversity and the use of pond mud as additional farm-made biological crop fertilizer (Rosset et al., 2011).

### 4.2.2 Principles for increased resilience

As explained earlier in this chapter, the agroecological principles are interconnected, and can thus be seen as overarching goals to guide development and design strategies composed by place-specific practices and methods. Agroecological principles are about valuing ecosystem services, managing beneficial ecological relationships and creating an enabling environment for building and preserving social and natural capital.

”The ultimate goal of agroecological design is to integrate components so that overall biological efficiency is improved, biodiversity is preserved, and the agroecosystem productivity and its self-sustaining capacity is maintained. The goal is to design a quilt of agroecosystems within a landscape unit, each mimicking the structure and function of natural ecosystems.” (Altieri & Nicholls, 2005)

Strategies for improving resilience of food systems to ensure food security include adaption and mitigation measures at both biophysical and socioeconomic levels. Below, some examples of agroecological principles to enhance resilience are presented, (Adapted from Agroecology.org<sup>1</sup>, for complete list see Appendix 1) followed by an explanation of each principle. Since the principles are interconnected they cannot be explained strictly separated from each other, hence some overlap of information will occur in the explanation below.

- I. Diversify farming systems
- II. Build healthy soils
- III. Improve water management
- IV. Conserve energy, use renewable resources and minimize dependence of external inputs
- V. Support local food markets
- VI. Empower people and communities & Integrate local and scientific knowledge

#### **I. Diversify farming systems**

Beneficial relationships among biota can increase yield, replace chemical inputs and increase buffering capacity against damaging impacts and stress, making the system healthier and more resilient than if individual species were kept separated (Gliessman, 2015). Biodiversity is vital to create these emergent properties arising from beneficial relationships among biota, and hence to increase ecosystem resilience. Biodiversity and its benefits can be enhanced in many ways at several levels in the agroecosystem, which all can be seen as strategies to mimic nature. This can include e.g. increased structural diversity, genetic

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<sup>1</sup> [http://agroecology.org/Principles\\_List.html](http://agroecology.org/Principles_List.html)

diversity, intercropping, crop rotations, polyculture, agroforestry, integration of animals and mixed landscapes (Lin, 2011; [agroecology.org](http://agroecology.org)). Since different species have different properties and respond differently to changes, increased biodiversity provides a buffer against environmental and climatic fluctuations and stress. A good example of beneficial ecological relationship to buffer changed biophysical conditions, such as weather events, can be seen in agroforestry systems. Trees in an agroforestry system provide both shade and shelter, enhancing resilience to weather fluctuations. By creating a microclimate it prevents e.g. heat stress, loss of moisture and damage from storms (Lin, 2011). A varied vegetation prevents erosion. Additionally, a greater variety above ground gives greater variety below ground. Improved soil management (see principle 2: *Build healthy soil*) focused on enhancing a healthy soil biota is fundamental for soil health and fertility (Gliessman, 2015).

Another important strategy for resilience through diversification is to enhance the biological synergies between plants and animals, both wild and bred. For example, many plant species are dependent on insects as pollinators for production of a healthy harvest and optimized yield, especially in orchards and agroforestry systems (Bargout, 2012). By enhancing biodiversity and creating favorable environments, these important ecosystem services can be provided. Valuing biodiversity, in terms of beneficial insects and birds in the agroecosystem, can also make it possible to manage pests without using chemical pesticides. Non-crop vegetation, such as flower strips, beetle banks and hedgerows with selected flora, can be used to strategically attract especially beneficial species (Gliessman, 2015). This strategy is called Integrated Pest Management (IPM), and is commonly referred to as a typical agroecological practice, but can also be used in less sustainable industrial systems (Pretty, 2008). The concept of *management* is fundamental in the agroecological paradigm, where biodiversity contributes to suppression of both pests and diseases (Lin, 2011, Gliessman, 2015). *Managing* biodiversity in agroecosystems is replacing the conventional need to *control* it, i.e. seeing biodiversity as a threat to production. The extensive use of chemical pesticides to protect production in conventional systems kills not only the pest but also the beneficial biodiversity, which creates a dependence on continued chemical use (Gliessman, 2015). As climate change increases global temperatures, pests and diseases that previously were geographically restricted by their sensitivity to low temperatures will be able to spread as the climate gets warmer. This could completely change the pest profile of an agroecosystem, which makes beneficial ecological relationships even more important to buffer these impacts.

Integration of farm animals can contribute to resilience in several ways. When integrated in the agroecosystem, livestock can restore soil fertility and quality of vegetation cover. Thus, livestock contribute to carbon sequestration by producing a net increase of soil organic carbon. The increased quality of vegetation cover also prevents erosion, and hence maintains watershed health by promoting functions such as infiltration, percolation and water retention. The on-farm production of manure that comes with integrating livestock reduces dependence on costly purchased industrial fertilizers. By using traditional species and landraces that are adapted to local conditions, and less susceptible to diseases, agrobiodiversity is preserved and resilience increased (Gliessman, 2015).

Another important strategy for resilience is landscape diversity. By creating a mosaic of agroecosystems with maintained natural vegetations in surroundings, field margins and corridors, the biodiversity can be significantly increased. Several studies have shown the importance of natural vegetation as a reservoir of beneficial biota and thereby a more effective biological management of pests and diseases. Corridors with diverse vegetation connect different areas and allow the migration and distribution of plants and animals (Altieri & Nicholls, 2005). The promotion of landscape diversity and agroforestry in agroecological management could, together with increased fertility and productivity, significantly reduce deforestation and land clearing for agricultural expansion (Parmentier, 2014). According to the Technical Centre of Agriculture and Rural Cooperation (CTA, 2012) 75% of the global deforestation has been associated with agricultural expansion.

Increasing biodiversity is multifunctional. In addition to the ecological functions mentioned above, crop diversification and integration of animals in agroecosystems can also increase the social and economic resilience. Diversification of livelihoods decreases vulnerability by creating less dependence on a single produce. With a diversified farming system comes opportunities to rely on a more diverse set of income generating products ([agroecology.org](http://agroecology.org)). It can thus be seen as a safety net for farmers' income and food security, minimizing risk exposure to shocks and stresses (Bargout, 2012).

## **II. Build healthy soils**

Soil is a living, changing, and dynamic component of the agroecosystem. Depending on how it is managed, it can be degraded and barren, or it can be flourishing with an abundance of life. Building healthy soils means

enhancing life in the system through increasing and sustaining soil organic matter (SOM), soil nutrients, and beneficial soil biota. Healthy soil provides ecosystem services that form the basis of sustainable agriculture and increased resilience to climate change (Gliessman, 2015).

SOM-management is at the heart of all efforts to create healthy soil. How SOM is managed, determines the level of biological activity as well as the physical and biochemical characteristics. A high content of SOM enhances both resilience and productivity by improving infiltration, water retention capacity and thereby increasing the tolerance to drought. SOM also improves surface soil aggregation by holding particles together, preventing erosion and loss of nutrients in heavy rains and windstorms (Altieri & Nicholls, 2012). Since harvest deplete SOM, organic matter has to be continually added to replace what has been removed from the system. There are a variety of ways to return or add organic matter to increase SOM. Practices used in agroecological management include e.g. adding crop residues, animal manure and compost, or growing cover crops as green manure. Protecting the soil from disturbance and erosion is an important part of creating healthy soils and increasing resilience. Bare fields are exposed to erosion and drought. Management practices like e.g. reduced tillage or no-tillage methods, use of cover crops and perennial crops together with wind shelter plantations can prevent damage. A protective layer of mulch impede loss of soil moisture due to evaporation, prevent wind erosion, improve water penetration and decrease loss of particles and nutrients from water runoff (Altieri & Nicholls, 2012). Most industrial farming systems are dependent on extensive and repeated tillage. Tillage is used to control weeds, incorporate organic matter and make a compact soil suitable for root growth, but can also have negative effects on the soil structure, organic matter content and deplete soil biota. Tillage is also a costly routine in terms of fuel consumption and labour, and unnecessary tillage should therefore be avoided in agroecological management (Gliessman, 2015).

Ecosystem services that provide fertile soil not only benefit crops and adaption to climate variations, but also helps to regulate the flow of GHG to the atmosphere (Lal, 2004). Soil organisms store carbon in the soil when they are breaking down organic materials creating humus, the key form of SOM. Only the storage of carbon in humus can be called a long term carbon sink. Carbon in plants above ground is only stored short term, since carbon is released back into the atmosphere when plants are decomposing or consumed. Roots that are left in the soil have a greater potential to create humus than the rest of the plant, and are in the sense of carbon sequestration the most important part of the plant (Baker et al., 2007). The capacity to sequester carbon in long term storage of humus gives agriculture a high mitigation potential, that could only be fully realized though ecological management of the soil (Paustian et al., 2006). IPCC presented in their fourth assessment report (AR4) that 89% of the total technical climate mitigation potential of agriculture is related to carbon sequestration (IPCC, 2007). However, sequestering carbon means storing carbon that has formerly been emitted into the atmosphere, and should thus be seen primarily as a complement to the main mitigation efforts seeking to prevent GHG from being emitted in the first place (Parmentier, 2014). But also the long term storage of carbon is reversible. By a decreasing humus content in the soil, carbon is once again released as carbon dioxide into the atmosphere and the soil becomes a carbon source instead of a carbon sink. Adverse agricultural practices that do not regenerate valuable ecosystem services are the primary cause of decreasing humus content in agricultural soils globally (Johnsson et al, 2009). This means that ecological management for soil health is a continuous process that needs to be maintained.

### **III. Improve water management**

Improving water management, moisture conservation and water harvesting is an important aspect of adapting to climate change (Li Ching and Stabinsky, 2011; Sahai, 2011). The aim is to manage and improve soil moisture levels according to crop plant demand. Plants have a continuous flow of water from the uptake in the roots, to the transpiration through the leaves. Therefore a sufficient supply of water for optimum growth is needed. Without adequate water supply to the roots, the plants wilt and die. Water is also the carrier of soluble nutrients vital to the plants. Water management has to take into account; the supply and storage of water; the soil properties such as infiltration, percolation and water retention; as well as direct losses due to evaporation and drainage. This can be done by the use of water harvesting practices; efficient irrigation systems; soil cover and moisture preservation by managing SOM content, and by building favorable microclimates. The water management has to be sustainable and allow aquifers to be refilled. In areas with excessive rainfall, wetland adapted crops, raised-field farming with dikes, ponds and raised bed for farming may be a solution (Gliessman, 2015).

#### **IV. Conserve energy, use renewable resources and minimize dependence of external inputs**

”The agricultural ‘modernization’ of the last several decades has been largely a process of putting ever greater amounts of energy into agriculture in order to increase yields. But most of this additional energy input comes directly or indirectly from nonrenewable fossil fuels. Moreover, the return on the energy investment in industrial agriculture is not very favorable: for many crops, we invest more energy that we get back as food energy. Emissions from this process have also contributed to climate change. Our energy-intensive form of agriculture, therefore, can not be sustained into the future without fundamental changes” (Gliessman, 2015:253)

Sustainable agriculture must strive for independence from external inputs, and effectively generate internal resources through application of agroecological principles (Altieri & Nicholls, 2005). The extensive use of fossil fuels and chemical inputs used to maintain current industrial agriculture and globalized food system, is a major source of GHG (Gliessman, 2013). According to the website [agroecology.org](http://agroecology.org), the main actions to conserve energy and decrease environmental impact are the use of:

- Renewable sources of energy instead of non-renewable sources.
- Biological nitrogen fixation.
- Naturally occurring materials instead of synthetic, manufactured inputs.
- On-farm resources, as much as possible.
- On-farm nutrient recycling.
- Energy efficient technologies.

A major contributor to GHG emission from agriculture is the use of fossil energy and chemical fertilizers, as well as intensive tillage resulting in depletion of SOM. Agriculture can both act as a source and a sink of GHG. An estimated 30% of total anthropogenic GHG emissions comes from agriculture and land use change related to farming. However, agriculture can both emit and sequester carbon, deepening on which agricultural practices that are used (Paustian et al., 2006). An agroecological approach emphasize proactive and strategic management to remove dependence of fossil energy and external inputs, by replacing them with biological functions derived from within the ecosystem (Petty, 2008; Gliessman, 2015). A sustainable and resilient agroecosystem is hence designed to preserve and regenerate resources by the management of ecological processes and ecosystem services (Rosset et al., 2011).

#### **V. Support local food markets**

An agroecological approach encourage the use of local resources and support of local food markets. Local markets shorten the distance between producers and consumers, and enhance knowledge about production, local food culture, and seasonally appropriate food (Gliessman, 2015). In the modern globalized transnational food chains, consumers are often completely separated from the production and the environmental and social context in which it operates. This separation impede the response to negative feedback-effects and indicators of unsustainability in the food system. Sundkvist et al. (2005) argue that the negative social and environmental impacts of food production is a result of current food system structure of the western countries. Main characteristics of this food system structure are identified as; intensification, specialization, distancing, concentration, and homogenization. All of theses characteristics contribute to an increased vulnerability. The development of more local food systems can tighten the feedback loops and increase resilience to crises (Sundkvist et al., 2005). It also shortens food chains, and thus avoiding the high energy needs and related emissions of long-distance transports (Altieri and Toledo, 2011). According to GRAIN (2009), the total GHG emissions can be reduced by 10–12%, by distributing food mainly through local markets.

Another aspect of long-distant food chains is the unawareness of possible consequences from global trade. In developing countries an increasing amount of land is used to grow food and biofuels for export. Cash crops for export contribute very little to local food security of poorer nations (Altieri & Nicholls, 2005). It is estimated that 80% of the worlds hungry lives in rural areas. Economic and political inequality also force the rural population away from their land and cause migration to cities. The farmers that were once able to feed themselves, and sell the surplus to cities, are forces to be dependent on others for their food



security. Applying agroecological principles to the world food trade may be a way of turning the trend, and increase local food security globally (Gliessman, 2015).

## **VI. Empower people and communities & Integrate local and scientific knowledge**

Agroecology is integrating indigenous knowledge from traditional small scale farming with modern science to create a sustainable and resilient way of managing agroecosystems while optimizing yield (De Shutter, 2010). The emphasis on making best use of traditional knowledge is straightforward. This kind of knowledge has been adapted to specific local conditions for generations, and traditional small holder farmers should therefor be acknowledged as experts in their area. Ways of managing harsh environments to meet subsistent needs, have been developed without relying on mechanization, chemical fertilizers, pesticides, or other technologies of modern agricultural science, and can therefor contribute with valuable knowledge to modern science (Altieri et al., 2011b). However, agroecology does not exclude all modern technologies on an ideological basis. If a technology can help farmers to increase productivity without causing harm to the environment, it can be included in a sustainable management (Pretty, 2008).

It is vital that the agroecological knowledge of best practices are spread in the local farming communities, for the development of sustainable food systems. Movements like Campesino a Campesino in Central America and farmer networks like La Via Campesina are vital for spreading agroecological knowledge. The implementation of farmer field schools and workshops are important ways of spreading new information (Degrande, et al, 2010; De Shutter, 2010; Holt Gienenez, 2006; Holt Gienenez, 2010).

”The move towards agroecology should be based on the farmers themselves - its main beneficiaries. Agroecological techniques are best spread from farmer to farmer, since they are often specific to an agroecological zone” (De Shutter, 2010:16)

Education and shared knowledge is a proven way of empowering farmers to organize themselves, and stimulate continued learning and development. Lack of power increases poverty when farmers are marginalized in the communities, which can turn into a negative spiral of disempowerment and inequality. Farmer participation in research and policy making is vital. Co-designed policies have a high degree of legitimacy and are more likely to be carried out in practice. It is essential these policies are regularly tested and reevaluated with the participation of farmers, and the policy process evolving into a process of social learning instead of political decisions being imposed top-down (De Shutter, 2010).

### **4.2.3 Levels of conversion to a sustainable food system**

Gliessman (2015) has defined five Levels of conversions to sustainable agriculture and food systems, based on the integration of agroecological principles. The practical use of these Levels is to characterize the current state of development on a farm or a larger food system scale. It can also be used to outline strategies for progress in sustainability.

Level 1-3 (originating from Hill, 1998) present the changes in management and agroecosystem structure that has to be taken at farm level. Level 4 and 5 present the structural and social change needed at a larger scale in food systems, both locally and globally. All together the five Levels can ”serve as a map for outlining a stepwise, evolutionary conversion process for the entire global system” (Gliessman, 2015:277). This approach can be used as a protocol for converting industrial farming into more sustainable alternatives, determining sustainability and categorizing agricultural research relating to conversion. The concept is based on the fact that rapid conversion from an industrial system to a more sustainable ecological system, incorporating different values and functions, is neither practical nor possible. The process of increasing sustainability is more likely to gradually evolve in slower steps of redesigning structure and management, passing level by level. In practical terms the different stages of conversion means different field practices, day-to-day management, planning, marketing and philosophy (Gliessman, 2015). This conversion process also represent conversion in a broader sense, e.g. a development where farmers that have managed their farms sustainably for a long time will experience an increasing support from a wider community, and where new farms will be able to start at an already higher level of sustainability. According to Gliessman

(2015:278) "The conversion process must be part of ensuring long-term food security for every one in all parts of the world".

### **LEVEL 1: (Agroecosystem)**

*Industrial efficiency.* The goal of the Level 1 is to increase the efficiency and effectiveness of conventional industrial practices in order to reduce the use and consumption of costly, scarce, or environmentally damaging inputs. This means reducing conventional industrial methods and changing how the methods are used. On this level there is still a dependency on external inputs, since the production is working according to industrial principles. However, conversion from resource and input intensive conventional agriculture to this first step of higher precision and efficiency may reduce some of the negative environmental impacts, and lay the foundation for further conversion (Gliessman, 2015).

"This approach has been the primary emphasis of much of the agricultural research of the past four to five decades, through which numerous agricultural technologies and practices have been developed. Examples include optimal crop spacing and density, genomics, improved machinery, pest monitoring for improved pesticide application, improved timing of operations, and precision farming for optimal fertilizer and water placement." (Gliessman, 2015:278)

### **LEVEL 2: (Agroecosystem)**

*Organic substitution.* The goal of the Level 2 is to replace conventional inputs and practices with organic alternatives that are less resource-intensive and less environmentally harmful. In organic farming, conventional inputs may be replaced by applying alternative farming methods to enhance ecological functions such as; biological nitrogen fixation from plants, and pest management by promoting natural predators. Reduced tillage can be used to preserve soil structure (Gliessman, 2015). Substituting inputs and promoting use of local resources were the essence of the original philosophy of organic farming. This philosophy was mainly adopted by small-scale farmers, producing food for local markets. Most organic small scale production is based on this philosophy, and research shows that these systems produce acceptable yields and have a low environmental impact. However, as the demand for organic produce has been growing steadily, multinational food corporations have joined the trend. Hence, organic products are now also produced in large scale industrial monocultures, that do not differ substantially from conventional farms with the use modern machinery, commercial crop varieties and adoption of monocultures (Altieri & Nicholls, 2005). Gliessman (2015) argue that commercial large scale organic farming, generally stays at this Level. In general, certification standards allows this type of large scale industrial food production to fulfill the conditions for *organic* certification.

"Due to their inherent low levels of functional biodiversity, these simplified systems lack natural regulatory mechanisms and therefore are highly dependent on external (organic/biological) inputs to subsidize functions of pest control and soil fertility. Adopting such practices and leaving the monoculture intact does little to move towards a more productive redesign of farming systems. Farmers following this regime are trapped in an input substitution process that keeps them dependent on suppliers (many of a corporate nature) of a variety of organic inputs, some of questionable effectiveness and environmental soundness" (Altieri & Nicholls, 2005)

Even though unsustainable conventional practices are modified to be more sustainable, the production still works according to an industrial framework, similar to Level 1. This means that many of the ecological problems that are present in conventional industrial systems also occur in those with input substitution (Gliessman, 2015). To proceed to the next Level of sustainability, agroecological integration has to be increased and a transition from incremental to transformational changes take place.

### **LEVEL 3: (Agroecosystem)**

*Agroecological redesign.* The goal of Level 3 is to redesign the agroecosystem to make its function based on a new set of ecological processes and relationships. This Level emphasize a high level of diversity and agroecological integration to create synergies among its components. The industrial approach of fighting symptoms of yield limiting factors, that still exist in Level 1 and 2, is replaced by a proactive approach that

manage and prevent the root cause of the problem by redesigning the system. The agroecosystem redesign is based on managing and valuing ecosystem services. In this way the agroecosystem may foster its own soil fertility, natural pest regulation and crop productivity through maximizing nutrient recycling, organic matter accumulation, biological control of pests and reliability of production (Altieri & Nicholls, 2005). Problems such as yield limiting factors are prevented by internal context specific design and management, instead of application of external inputs. Practical examples of this agroecosystem redesign is diversification of farm structure and management through the use of rotations, multiple cropping and agroforestry (Gliessman, 2015).

#### **LEVEL 4: (Local food system)**

*Food citizenship.* The goal of Level 4 is to reestablish a more direct connection between producers and consumers, which has most often been lost with the industrial system of today. This Level connects the production to the food system in which it operates. The goal is to reestablish a culture of sustainability that takes into account the interactions between all components of the food system. The conversion to sustainable agroecosystems occurs within social, cultural and economic contexts. To create sustainable food systems, conversion must be supported by these contexts. This means a change of values at the individual and community level to favor more locally and sustainably grown food, supporting farmers that are striving through the Levels of agroecosystem conversion (1, 2 and 3). In some sense, this means that the food system change of Level 4, may occur in parallel with the agroecosystem change at Level 1, 2 and 3. The essence of this Level is that farmers and consumers are reconnected to establish a mutual beneficial relationship, where both parts can influence and be influenced in a more participatory manner. This relationship turns into what Gliessman (2015) calls a *food citizenship*, where every individual and community becomes a force of food system change. This support will together with other communities contribute to a new kind of food system culture and economy built on sustainability. This fundamental transition is prerequisite to reach Level 5 (Gliessman, 2015).

#### **LEVEL 5: (Global food system)**

*Global transformation.* The goal of Level 5 is to built a new global food system, based on sustainability, equity, participation, and justice. In this level the agroecosystem sustainability gained in conversion from Level 1-3, and the established food citizenship in Level 4, create a foundation for changing the global food system, transforming it into a network of local and regional sustainable food systems. This new food system network is not only sustainable, but helps to restore and protect earth's life-support system (Gliessman, 2015).

#### *Concluding remarks from chapter 4:*

- An agroecological approach can be seen as a way of holistically designing and applying adequate strategies for managing a transition process aiming to make agriculture and food systems more ecologically, socially and economically sustainable.
- Agroecological principles are primarily based on mimicking natural processes to create beneficial biological interactions and synergies among its components, to create a sustainable food system that is resilient and able to maintain a natural dynamic equilibrium.
- In agroecology *resilience* can be seen as a necessary precondition for *sustainability*.
- *Agroecological integration* is the degree of realized agroecological principles in a system. It can be seen as a way of assessing sustainability and resilience, ranging from low to high degree of integration in a sliding spectrum.
- Key agroecological principles for resilience include: Diversify farming systems; Build healthy soils; Improve water management; Conserve energy, use renewable resources and minimize dependence of external inputs; Support local food markets; Empower people and communities & Integrate local and scientific knowledge.

- The concept of agroecological integration can, even if not stated explicitly, be conceptualized through Gliessman's (2015) Levels of conversion to a sustainable food system. All together the five Levels can "serve as a map for outlining a stepwise, evolutionary conversion process for the entire global system" (Gliessman, 2015:277). The agroecological approach to resilience can be connected to the development perspective of *Levels of conversion*, by the concept of *agroecological integration*. With every higher level of conversion, the levels of agroecological integration increases, and thus resilience to climate change.
- Level 1 and 2 take place in the framework of industrial production, including conventional agriculture with increased efficiency and organic production with emphasis on input substitution. Changes to, and operation within, these Levels can thus be seen as a "business as usual" approach with incremental changes towards sustainability. Levels 3-5 needs transformational changes in the "business as usual" approach to fundamentally transform current food system structure to reach deep sustainability.
- The ultimate goal is to reach Level 3 in food production, and Level 4 and 5 in the social and economic food system structure in which food production operates.

## 5. Analysis

*In the previous chapter an agroecological approach to climate resilience and sustainable development of food systems was described. This chapter answers research question 3 by putting the results from the literature study in relation to the theoretical framework in an attempt to adapt the model to illustrating the agroecological approach.*

### 5.1 Creating a new combined framework and conceptual model

The aim of this study is to investigate if the IPCC conceptual model of CRP could be adapted to a food system context, by illustrating an agroecological approach to climate resilient development. Furthermore, the purpose is to create a new combined framework for assessing climate resilience in different agricultural systems and food system structures. By adapting the general model to specifically consider a food system context, the model can hopefully get a more practical application.

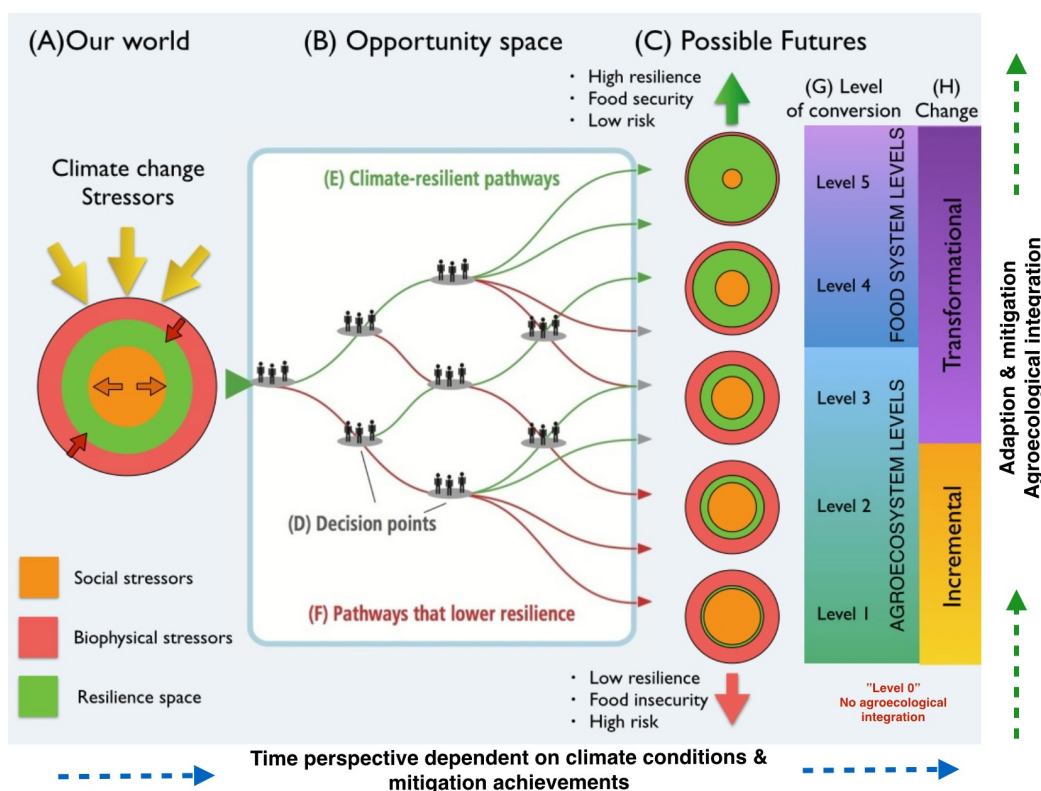
The IPCC concept of CRP (introduced in chap 3. *Theoretical Framework*) can be seen as a framework for development-pathways that combine adaptation and mitigation measures to increase resilience, and thereby also the future prospects of sustainable development. Since the impact of climate change is an increasing threat to the prospects of sustainability in the future, we must strive to find development pathways that are as resilient to the effects of climate change as possible (Denton et al., 2014). Mitigation is considered a way to keep climate change moderate rather than extreme, as well as to decrease the speed of change. Adaptation is seen as a necessary response strategy to cope with climate change impacts that cannot be avoided (Denton et al., 2014).

To create a new adapted model, the agroecological approach to increasing sustainability and resilience in food system had to be investigated. The approach also had to be presented in a framework with development perspective compatible with the sustainable development focus of CRP.

An agroecological approach to food system change can be seen as a way of holistically designing and applying adequate strategies for managing a transition process aiming to make agriculture and food systems more ecologically, socially, and economically sustainable (Berton et al., 2012; Parmentier, 2014). The development strategies are based on the implementation of key agroecological principles. Agroecological principles are primarily based on methods to mimic natural processes and create beneficial biological interactions and synergies among system components. Key agroecological principles for increasing resilience include; Diversify farming system; Build healthy soil; Improve water management; Conserve energy, use renewable resources and minimize dependence of external inputs; Support local food markets; Empower people and communities & integrate local and scientific knowledge (see chap. 4.2). The degree of realized principles can be evaluated in the concept of *agroecological integration*. As the integration of agroecological principles increase, the sustainability and resilience to climate change is enhanced. The process of increasing the agroecological integration in a system can thus be seen as a fundamental part of the agroecological approach to climate resilient development. This can be represented in the development approach *Levels of conversion* presented by Gliessman (2015). This conversion framework categorizes different agroecosystem and food system designs into five sustainability levels, determined by its degree of agroecological integration. It ranges from very low agroecological integration e.g. and industrial monoculture where some action towards resource efficiency has been taken such as precision farming or introduction of IPM, to a very high agroecological integration that includes sustainability measures and realized principles at farm level but also at community and global level. With every higher Level of conversion the agroecological integration increase, as well as the spatial scale of society in which the development process is carried out. Gliessman argues that these conversion Levels can serve as "a map outlining a stepwise, evolutionary conversion process". It conceptualizes the steps that need to be taken when converting from high input industrial agriculture and food systems to alternatives with a higher degree of sustainability. As well as outlining the conversion process, I argue that the Levels can be used to set goals and outline strategies for sustainable development of food systems. However, to take into account the dimension of climate change complexity, where actions and consequences often are separated in both time and space, a present-future perspective has to be added to the framework of Levels of Conversion.

By integrating Gliessman's five Levels of Conversion with the conceptual framework of CRP this could be achieved. In combination the two concepts can form a new conceptual framework illustrating an agroecological approach to developing climate resilience, and thereby adapting the original IPCC model to a food system context. The new adapted version of the IPCC conceptual model is presented in Figure 6. The two conceptual frameworks joined together can complement each other into a new combined model facilitating a more practical use in strategic management of food system development. To ensure future prospects of sustainable development and food security, pathways that combine adaption and mitigation leading to higher resilience has to be identified. The model can provide a general idea of how different decisions and development strategies could either reduce or increase climate change and its impacts. The Levels can be used for categorizing strategies and hereby determine what kind of systems that should be supported for optimal outcome regarding climate resilience, sustainable development and food security. In this way the general state of current development can be analyzed as well as new strategic goals determined for the future.

The new conceptual model illustrate the relationship between different system designs and their degree of integrated agroecological principles, categorized in different Levels, and the degree of climate change resilience. This explanatory model is meant to facilitate the spreading of knowledge and understanding, by in a simple way give a picture of the connection and interactions involved in the process of establishing food security by means of agroecological principles. By characterizing the current situation, it gives a starting point for the process, and outlines possible paths to reach future goals. It illustrates the importance of the time factor as a major parameter when setting the goals for the future. The model can be adapted to serve as a guide in projects of different nature, by the use of project specific options inserted in the decisions points. This conceptual model is not meant to be used as a tool for making mathematical projections for the future, but aims instead to illustrate how different strategies and goals are related to the possibilities when it comes to building resilience. The development process illustrated is not static. It is a continually evolving process with new decision points emerging, depending on and limited by the speed of changing climate conditions.



**Figure 6.** An Agroecological approach to CRP. Illustrating the agroecological approach to development of climate resilience in food systems, and hence future prospects of sustainable development. The new model is a fusion of CRP from IPCC (2014b) and the agroecological 'Levels of conversion' (Gliessman, 2015).

Source: Own illustration, adapted from IPCC (2014b:44)

## 5.3 Components and function of the adapted model

Below follows a description of the components of the new model, adapted from the original text by IPCC (2014b) to encompass the new model components. This text is followed by a more detailed explanation of the three main parts (A, B and C). In the modified version of CRP conceptual model presented here, the components (**G**) and (**H**) have been added, where (G) indicates different Levels of conversion, and (H) marks their incremental or transformation character of change.

”(A) Our worlds food systems are threatened by multiple stressors that impinge on resilience from many directions, presented here simply as climate change related biophysical and social stressors, such as weather events and food insecurity. (B) Opportunity space refers to decision points and pathways that lead to a range of (C) possible futures with differing levels of resilience and risk. (D) Decision points results in actions or failures-to-act throughout the opportunity space, and together they constitute the process of managing or failing to manage risks related to climate change. (E) Climate-resilient pathways (in green) within the opportunity space lead to a more resilient world through adaptive learning, increasing scientific knowledge, effective agroecological adaptation and mitigation measures. (F) Pathways that lower resilience (in red) can involve insufficient mitigation, maladaptation, failure to learn and use knowledge, and other actions that lower resilience. These can be irreversible in terms of possible futures. Possible futures are categorized according to the five Levels of Conversion, illustrating strategies leading to a certain food system change (G). The result of different Levels of food system change can be placed in a sliding spectrum from low to high; resilience, risk and food security. The character of change needed (H) is divided into *incremental* and *transformational* change, where *incremental* change is adjustments of current ”business as usual” strategies, and *transformational* change is a fundamental change in the basic ecological and socioeconomic structure.” (adapted from IPCC, 2014b:29)

### 5.3.1 The three main parts of the model (A, B and C)

**A:** ”Our world” represents the present state of the agricultural system and starting point independent of present Level of sustainability. The globe in this starting point illustrate how the three different indicators (biophysical stressors, social stressors and resilience space) interact and that they are interdependent. If resilience decrease, social and biophysical stressors increase. Likewise, if resilience increase it will result in a lower social and biophysical stress related to the system. It does not necessarily mean that the social and biophysical threats disappear, it only indicates that there is a stress relief and a higher immunity when resilience is enhanced. The degree of resilience depends on at what time and how successfully mitigation and adaptation measures are implemented.

**B:** ”Opportunity space” illustrates the process of decision making as a web of pathways to build climate resilience in food systems. Depending on what choice and actions we take to mitigate climate change and adapt to new conditions, we can build a certain degree of resilience. Those choices and actions are illustrated by the *Decision points*. In the *Decision points* the implementation of agroecological principles are evaluated, determined, and carried out as strategies. If these strategies support a higher implementation of agroecological principles, the pathways (in green) will lead to higher Levels of conversion and higher levels of climate change resilience. If on the other hand implementation of agroecological principles are not supported, the pathways (in red) will lead to a negative development and to lower Levels of conversion, and thereby a decrease in resilience to climate change. Depending on if the model is applied on farm level, community level and regional level, the decision points may concern issues such as; risk management at farm level, community supported food security, and political policy making. The choices of strategies determined in the *Decision points* of *Opportunity space* also affect the amount of time that the different pathways towards higher resilience are ”available” to us. This time is largely dependent on what is achieved concerning climate change mitigation, and hence how effective our strategies are. There is a limited time frame suitable for the implementation of each strategy. If current unsustainable practices proceed, and the magnitude of climate change increase, the challenges to sustainable development will grow (Denton et al.

2014). For that reason, there is a limited window in time where the pathways to the higher levels of resilience are available. As climate change increase, the available options for future sustainability decrease. IPCC therefore stresses the importance of not postponing implementation of effective strategies for climate change mitigation, but instead to take direct actions (Denton et al. 2014).

C: "Possible futures" illustrate the degree of resilience we have the possibility to reach, depending on which strategies we implement. The different "globes" are categorized according to the agroecological development strategy; *Levels of conversion*. With every higher Level of conversion the agroecological integration increases, and thus the resilience to climate change. The different Levels can be seen as a rough categorization of different systems. Within these Levels there is a sliding spectrum of integrated agroecological principles.

The five Levels start at the agroecosystem level, where changes are building the foundation for further conversion into the broader concept of food system level. Level 1-3 represent conversion stages at agroecosystem level. In Level 1 more resource preserving methods of industrial agriculture are adopted. In Level 2 chemical inputs are replaced with more sustainable organic alternatives and methods. In Level 3 transformational redesign of the agroecosystem results in independence of external inputs, and a self-regenerating ecosystem balance is established. The goal is to get more and more farms to convert into Level 3 management, and hereby create a patchwork of sustainably managed farms and regions. This development is connected to Level 4-5 which represents the socio-economic conversion needed at food system level. Level 4 represent the change of relationships needed in the food system at a local and regional scale. In this Level the anonymous nature of corporate food systems is challenged by reconnecting farmers and consumers, forming a so called *food citizenship*. Level 5 represent the global change needed which are made possible by the earlier Levels, transforming the global industrial food system into a network of local and regional sustainable food systems. By every higher Level of Conversion, there is an increase in sustainability and resilience.

### *Concluding remarks of chapter 5:*

- By integrating the concept of *CRP* presented by IPCC, with the five *Levels of conversion* presented by Gliessman (2015), a new model can be created, adapted to a food system context.
- With every higher Level of conversion, the *agroecological integration* of principles increases and thus resilience to climate change.
- In this study it is argued that the Levels of conversion can also be used for categorizing strategies, and hereby determine the general state of current development as well as setting strategic goals for the future.
- By combining *Levels of conversion* with *CRP*, a present-future perspective can be added. The combination of concepts can facilitate management of strategies and actions, while considering climate change complexity, where actions and consequences often are separated in both time and space.



## 6. Discussion

*This chapter puts the result of the study in a wider context. The study is put in a larger perspective and the potential use of the new combined model and framework is discussed. The framework is also put into practical use providing an example of how the agricultural concept of Climate Smart Agriculture (CSA) can be assessed by the new combined framework. By referring to some other reports and case studies, the chapter also discuss food security and the roll of agroecology.*

### 6.1 CRP in a food system context

Climate change will have a significant impact on earth's life-support system. The capacity of ecosystems to sustain ecosystem services vital for food production is endangered. This development is eroding the basis for sustainable development of food systems and future food security. IPCC has identified some key risks of climate change that will compromise prospects of sustainable development. These key risks include; losses of ecosystem services, challenges to land and water management, effects on human health, particular risks of severe harm and loss in certain vulnerable areas, increasing prices of food commodities on the global market, consequences for migration flows at particular times and places, increasing risks of flooding, risks of food insecurity, systemic risks to infrastructures from extreme events, loss of biodiversity, and risks for rural livelihoods (Denton et al., 2014:1109). Many of these, if not all of them, could be related to agriculture and future food security. According to the IPCC there is high confidence that together with an increasing food demand, all aspects of food security will be affected by climate change (IPCC, 2014b).

However, the IPCC also concludes that the actions towards CRP that we invest in today can provide future opportunities to implement solutions that will generate co-benefits. These can under a responsible environmental management improve livelihoods and increase social and economical well-being (Denton et al., 2014). Mitigation and adaptation are at the heart of these actions. This calls for a paradigm shift in the agricultural development, where a holistic and systemic approach has to be applied. In the first stages of this process Parmentier (2014) and Berton (2012) argues that an analysis of the current state of development has to be undertaken, and the preconditions for a truly sustainable future analyzed. The process has to foster public policies that support sustainable agricultural approaches and the realization of future sustainability and food security (De Shutter, 2010).

In this study, a conceptual model for illustrating an agroecological approach to CRP has been developed (See fig. 6). The model presents a way of illustrating the relationship between integration of agroecological principles, and the degree of climate change resilience in food system. Agroecology as a science and practice aims to assess and improve sustainability in all agricultural modes of production, independent of their current state. Because of this, I used the agroecological concept to adapt the CRP to food system context and to create a framework in which agricultural systems and food system structures can be assessed from an agroecological point of view. In this way an agroecological assessment of current state of development can be made and strategies for improvement be outlined.

### 6.1 Thoughts around the practical use

#### 6.1.1 In strategic management

To foster a paradigm shift, an analysis of the current state of development has to be undertaken. In this process, a holistic approach should be applied to future strategies for development and should include identification of expected benefits and constraints in the short, medium and long term; and preconditions for future sustainability analyzed (Parmentier, 2014; Berton, 2012). Public policies that support such sustainable approaches and modes of production, has to be created (De Shutter, 2010). This study shows that *Levels of Conversion* can be used for categorizing strategies, and hereby determine the general state of current development, as well as setting strategic goals for the future. By combining Levels of conversion with CRP into a new framework, a present-future perspective can be illustrated. The combination of concepts can facilitate management of strategies and actions, while taking into account climate change complexity, where

actions and consequences often are separated in both time and space. The two concepts together will create a more concrete way to analyzing food system resilience.

The conceptual model is theoretical in its character, but the connection to concrete agroecological principles realized by hands-on methods gives the conceptual framework a practical application. In this way, the new conceptual model can be used as a tool for agroecological food system development. Using this model to evaluate food production systems and food system structures, could make it possible to classify and describe consequences for climate resilience in those systems. This could be applied at different scales in the food system, from the development of single farms to a wider context when setting goals for the food systems at local, regional or global scale. By illustrating the possibility to enhance resilience in systems, development towards higher sustainability and food security could be promoted in a concrete manner; recommendations can be issued, new practices evaluated, directives carried out, and stimulating measures taken to enhance changes in a more sustainable direction.

### 6.1.2 In communication

The conceptual framework and model could also be used as a tool to communicate the agroecological approach to resilience in a way that might be easier to grasp than if it was explained in written text only. By using the model, the agroecological approach to sustainable development of food systems and its relation to climate change resilience can be presented visually. In this sense the new conceptual framework can provide a contribution to earlier studies of Levels of Conversion as such, by extending its practical use to encompass a more clear connection to climate change resilience and facilitation of knowledge transfer. The new conceptual model could also serve as a foundation for further development of the adapted framework, to improve the concept and refine its practical use.

Furthermore, the new model puts agroecology in a direct context of the specific framework of CRP, presented by IPCC and debated in the scientific community. The model could thus prepare the ground for agroecology to be a more natural part of the public and political debate regarding climate change and future food systems.

Finally, the conceptual model and framework could also be used by farmers and farmer networks to communicate the significance of their work, and their need for support from the wider community. A transition towards sustainability and high food security is not possible without major changes in current industrial production methods and food system structures. By using the IPCC model of CRP and the five Levels of Conversion in combination, an overview of the existing possibilities are made easier. The process of change to achieve the goal of high food security in a changing climate can be outlined, supporting policies developed, and by the application of agroecological principles ultimately be reached.

## 6.2 Putting the combined framework to practical use

During the search for literature that was analyzing CRP in relation to a food system context, only one scientific article could be found. This article called *Climate Smart Agriculture for food security* by Lipper et al. (2014) was published in the scientific magazine *Nature*. It presents the concept *Climate Smart Agriculture* (CSA) as a way of realizing CRP by targeting climate change in agricultural production. CSA is promoted by various actors including the *World Bank*, the *FAO*, the *Consultative Group of International Agricultural Research* (CGIAR) and its *Climate Change Agriculture and Food Security program* (CCAFS), the *UK Department for International Development* (DFID), the *International Food Policy Research Institute* (IFPRI) and the *Rockefeller Foundation*.

However, this concept has also been criticized for e.g. protecting commercial interests rather than environmental, as well as the market power of industrial food corporations. The promotion of *sustainable intensification* and focus on the economic profit from carbon credit offsets on the carbon markets, is criticized to draw attention from the real challenge of reducing GHG emissions at the source (Parmentier, 2014; Diamond Collins & Chandrasekaran, 2012; Gattinger et al., 2011; Stabinsky, 2012).

The *Global Alliance for Climate Smart Agriculture* (GACSA) is a well established organization with a long list of prominent members, including agricultural organizations, chemical companies and business agencies (See member-list in GACSA, 2015). GACSA is linking climate to agricultural financing, and members like e.g. the World Bank have economical interests in the carbon market. Other members have economical interests in the chemical industry and fertilizer manufacturing (Parmentier, 2014; GACSA,

2015). CSA is a widely accepted concept, and promoted by GACSA with its major global members. CSA is seen as a production framework to support food security while adapting to climate change. Advocates of CSA states that; "CSA differs from 'business-as-usual' approaches by emphasizing the capacity to implement flexible, context-specific solutions, supported by innovative policy and financing actions" (Lipper et al., 2014:1068). *Sustainable intensification* is a corner stone in CSA. Lipper et al. (2014:1069) argues that; "Sustainable intensification on existing agricultural land has considerable mitigation potential by reducing the conversion of forest and wetlands, although additional protection measures may be required". This sustainable intensification is made possible by use of chemical inputs. Inputs are argued to enable maximization of yields in industrial systems, and are according to CSA a way to mitigate GHG by limiting further expansion of farmland and thus contribute less to deforestation.

However, I argue that the use of chemical inputs in agricultural systems to mitigate GHG in other location, such as forests, can be seen as contradictory. CSA is using chemical fertilizers to increase sustainability and mitigate GHG. Today's industrial agriculture is relying on energy from fossil fuels, which are known to be highly contributive to GHG emissions as described by Woods et al. (2010):

"Modern agriculture is heavily dependent on fossil resources. Both direct energy use for crop management and indirect energy use for fertilizers, pesticides and machinery production have contributed to the major increases in food production seen since the 1960s [...] Although fossil fuels remain the dominant source of energy for agriculture, the mix of fuels used differs owing to the different fertilization and cultivation requirements of individual crops. Nitrogen fertilizer production uses large amounts of natural gas and some coal, and can account for more than 50 percent of total energy use in commercial agriculture" (Woods et al. 2010:2991)

CSA promotes the use of conventional industrial no-till systems, which according to Gattinger et al. (2011) often comes in a combination with monocultures, GMO and an extensive use of herbicides. In this sense, Parmentier (2014) argues that CSA is incompatible with the agroecological approach to sustainability, and also criticizes CSA for missing the real target of eliminating carbon emissions at the source by instead focusing on the financial side of the carbon market. Because of the wide acceptance of such farming methods and continued dependence on external inputs, the CSA concept will not be considered sustainable according to agroecological principles.

In Assessment Report 5 from IPCC, it is declared that; "Enhancing resilience to respond to effects of climate change includes adopting good development practices that are consonant with building sustainable livelihoods and, in some cases, *challenging current models of development*" (Denton et al., 2014:1110, *emphasis added*).

To challenge the CSA view of sustainability and how to reach CRP, the CSA concept could be evaluated within the new framework of CRP for food systems created in this study. As a result of CSA acceptance and use of monocultures, chemical inputs and GMO, the CSA management strategies does not differ substantially from conventional agriculture. Thereby it will not reach higher than Level 1 in Gliessman's Levels of Conversion. According to this study it is therefore possible to argue that CSA, promoted as a way to realize CRP by Lipper et al. (2014), should not be seen as the ultimate goal. CSA should instead be seen as an initial step towards sustainability, provided that future development to higher Levels of Conversion is not restricted. The conclusion of this short evaluation is that the development of food systems has to go beyond the incremental goals of *Climate Smart Agriculture*, to become climate resilient, truly sustainable, and enhance food security. This conclusion is in line with the statement of IPCC in the fifth assessment report, which declares that; "Because climate change challenges are significant for many areas, systems, and populations, climate-resilient pathways will generally require transformations - beyond incremental approaches - in order to ensure sustainable development" (Denton et al., 2014:1106).

In October 2014, an article in *The Guardian* written by Anderson (2014) describes how more than 100 civil society organizations signed a letter rejecting the concept of CSA, and how the world's largest peasant farmers' movement, La Via Campesina, described the launch of GACSA as a way to put a green label on unsustainable agriculture. The article also emphasizes that:

"We must avoid opening the door to false solutions under vague 'climate-smart' rhetoric. Instead, we must be specific about investing in real resilience through agroecological adaptation solutions to climate change [...] Above all, we need systemic change. But it is hard to envision

that the corporations leading the climate-smart change are really aiming for localized, low-input, agroecological food systems that they would no longer control.” (Anderson, 2014)

## 6.3 Ecological agriculture and Food security

To ensure future food security, food must be available, accessible and adequate. At present, it is possible for industrial agriculture to produce a sufficient amount of calories to feed the world's population with the support of external inputs (De Shutter, 2010). However, a major weakness of such a system is the highly specialized production carried out in homogenous landscapes. These factors make it dependent on external inputs for production (Gliessman, 2015). Commodities like fossil fuels and chemical fertilizers are affecting the environment negatively, and the system is economically sensitive to price variations and availability of oil, gas and coal. As long as the availability of arable land, water and external inputs is sufficient, and the climate is suitable for the desired crops, an industrial agricultural system can be stable, resilient to change and ensure food security. Nevertheless, because of the environmental impacts of industrial agriculture, this will not be achievable in the long term (De Shutter, 2010; Gliessman, 2015; Wezel & David, 2012). Agriculture and the global food system are now facing significant challenges to feed an increasing population while at the same time target climate change and stop further degradation of ecosystems (De Shutter, 2010).

A transition towards sustainability and high food security is not possible without major changes in production methods and food system structure. Agroecology is increasingly seen as a promising alternative to industrial agriculture. The environmental benefits of supporting agroecological development and the scaling up of ecological agriculture are widely acknowledged. But a key question is whether ecological agriculture can be productive enough to feed the world's increasing population.

An extensive review of scientific studies investigating the productiveness of agroecological farming systems can be found in the report *Agroecology and the right to food* by Oliver De Shutter (2010), United Nations Special Rapporteur on the right to food. In the press release of this report at the United Nations Human Rights Council (2011), De Shutter states that;

”To feed 9 billion people in 2050, we urgently need to adopt the most efficient farming techniques available. [...] Today’s scientific evidence demonstrates that agroecological methods outperform the use of chemical fertilizers in boosting food production where the hungry live - especially in unfavorable environments. [...] A large segment of the scientific community now acknowledges the positive impacts of agroecology on food production, poverty alleviation and climate change mitigation - and this is what is needed in a world of limited resources. [...] We won't solve hunger and stop climate change with industrial farming on large plantations. The solution lies in supporting small-scale farmers' knowledge and experimentation, and in raising incomes from smallholders so as to contribute to rural development. [...] The approach is also gaining ground in developed countries such as the United States, Germany or France. However, despite the impressive potential in realizing the right to food for all, agroecology is still insufficiently backed by ambitious public policies and consequently hardly goes beyond the incremental stage. [...] Agroecology is a knowledge-intensive approach. It requires public policies supporting agricultural research and participative extension services”. (De Shutter in United Nations Human Rights Council, 2011)

In De Shutter's report (2010), some examples demonstrating the productiveness of agroecological approaches are documented. One of the largest systematic studies conducted on the subject is Pretty et al. (2006). This study compared 286 projects in 57 developing countries covering an area of 37 million hectares. The results showed that the introduction of agroecological practices increased productivity with a global average crop yield increase of 79%. Projects located in Africa were reanalyzed by UNEP-UNCTAD, which showed that African projects had an average yield increase of 116%, and 128% increase in the projects located in East Africa (UNEP-UNCTAD, 2008).

In Tanzania, 350,000 hectares were rehabilitated in two decades, after introducing agroforestry techniques and participatory processes in the area (Pye-Smith, 2010). Similar large scale projects can be found in e.g. Malawi, Mozambique and Zambia (Garrity et al., 2010). Malawi launched a fertilizer subsidy program in 2005-2006 as a response to a severe food crisis caused by drought the year before. However, to

ensure sustained production even after subsidies were scaled back or withdrawn, agroforestry systems with nitrogen fixing trees were established to phase out the need for chemical fertilizers. The results from research shows that these systems can increase yields from 1-3 tons per hectare (Garrity et al., 2010).

When it comes to the impacts of climate change, agroecological approaches has also been proven to make farms more resilient to extreme events. This could e.g. be studied by following the impacts of Hurricane Mitch in 1998. A large scale study (Holt-Giménez, 2002) on 180 communities of smallholders in Nicaragua shows that fields and plots where simple agroecological methods<sup>2</sup> were used, had a higher resilience to this extreme event than conventional control plots. The study showed that areas where agroecological methods were practiced had an average of 40% more topsoil left after the hurricane, compared to areas where conventional methods were used. The agroecological plots/fields lost 18% less arable land in landslides, and had 69% less gully erosion (Holt-Giménez, 2002). Hence, the study shows that the use of agroecological methods helped farmers in Nicaragua to be more resilient to destructive environmental, social and economical consequences of Hurricane Mitch.

The agroecological development is of global importance to feed an increasing population in a world with changing climate and limited resources. Agroecological principles are realized by place-specific practices based on the most efficient and functional design to support ecological functions and services on that specific place, which makes them possible to implemented in most geographical regions. Most often, it is also independent of advanced technology which makes is accessible even for those with low economical resources. Agroecology also provides an important systemic approach that could balance today's dominating focus on maximized economical growth. Holistic thinking has to be reintroduced where it has been lost. It is only a holistic approach that can restore and maintain ecosystems in balance, and it is only an ecosystem in balance that can endure over time, and make it possible to sustain food production in the along term.

## 6.4 Further studies

The study conducted here is of theoretical character. It is however based on agroecological concepts that are well established and widely practiced all over the world. To really connect this theoretical study with the practical reality, I would suggest that further studies were made to verify or refute the statements I put forward when presenting the idea of a combined model. My opinion is that the CRP gets more useful when connecting it to concrete practical management. This study is the first step in doing this, by connecting it to agroecology that is deeply rooted in practical management. Studies at farm and community level could contribute to further developing the new framework for practical use. Case studies could be used to strengthen the connection between theory and reality, and provide examples of how the model could be used, as well as identifying strengths and weaknesses within the framework that are difficult to detect in theory.

First of all, "*...it is appropriate action, and not further studies or discussion, that is most required; and certainly not a perpetuation of any of the present unsustainable practices*" (Hill, 1998:391). I find this quote as true today as it was 17 yeas ago. However, appropriate actions needs to be carried out along with a constant search and reevaluation of best practices and solutions. Some suggestions of further studies are presented below:

### *Food systems*

- Further studies of the food system perspective of agroecology and the holistic approach applied to strategies for sustainable food security.
- Connection and links between rural and urban areas, and its social and environmental impacts on food security.
- A holistic view of exports and imports; feed-back effects and consequences for sustainability. How will locally based food systems affect food security and global trade?
- Connecting studies of agroecology with climate change strategies.
- New ways of structuring markets and supply chains. Also regional specific strategies for food system change, as well as local strategies to improve linkages between farmers and consumers.

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<sup>2</sup> Such as rock bunds or dikes; green manure; crop rotation and the incorporation of stubble; ditches; terraces; barriers; mulch; legumes; trees; plowing parallel to the slope; no-burn; live fences; and zero-tillage (Holt-Giménez, 2002))

### *Climate Smart Agriculture (CSA)*

- For further studies I suggest evaluation of CSA and the influence of GACSA members. How are the private economical interest affecting the policies created? How will these policies affect small scale farmers socially and economically? I also suggest a holistic evaluation of how CSA affect the responsibility of large scale farmers, companies and corporations to mitigate GHG.

### *Certification Labels*

- What requirements are fulfilled by which certification standards, and how are they controlled? Can the labels be trusted to ensure environmental and social well-being? At what Levels of conversion are different certifications? Can the Levels presented by Gliessman (2015) be used in a classification system specifying how products are produced and how the production and consumption of these products take into consideration the aspects of resource use, environmental wellbeing, and social responsibility of local and global trade? Could this be a more simple way for consumers to choose what future they want to support by looking at labels? Is there a need for refined certification standards, separating food production of Level 2 and 3, and integrating information about Level 4 for the support of local food production and Level 5 for sustainability and justice in global trade?

## 7. Conclusion

*The aim of this study is to investigate if the IPCC conceptual model of CRP could be adapted to a food system context, by illustrating an agroecological approach to climate resilient development. Furthermore, the purpose is to create a new combined framework for assessing climate resilience in different agricultural systems and food system structures.*

*Research questions:*

*1. What characterizes an agroecological approach to sustainability and resilience in food systems?*

An agroecological approach can be seen as a way of holistically designing and applying adequate strategies for managing a transition process, aiming to make agriculture and food systems more sustainable. A food system is a social-ecological system, and as such explicitly accommodates the social mechanisms behind ecosystem management. The holistic approach in agroecology takes into account the complexity ecological components and functions in food production, as well as the social and economic dimensions and structures in which food production operates. The strive to enhance resilience is a constant preoccupation in agroecology, and can be seen as a necessary precondition for sustainability. When an agricultural system is stressed or threatened by disturbances, its performance is endangered and may lead to a transient dysfunction. If the system has a sufficient degree of resilience it will be able to preserve its function as a sustainable agricultural system.

*2. How can resilience be enhanced with agroecology, and how could this be presented in a development context compatible with CRP?*

Enhancing resilience with agroecology means to increase the integration of agroecological principles. Agroecological principles are primarily based on mimicking natural processes to create beneficial biological interactions and synergies among system components. They are realized by place-specific methods. Sustainability and resilience can be assessed by the degree of *agroecological integration* in a system, i.e. the degree of realized key principles. The literature study motivated the use of Gliessman's (2015) Levels of Conversion to represent the concept of agroecological integration applied to a concrete development perspective, compatible with CRP. With every higher Level of conversion, the *agroecological integration* increases, and thus the resilience to climate change.

*3. How can the conceptual model of CRP be adapted to a food system context by illustrating the agroecological approach?*

By combining the IPCC conceptual framework of CRP with the agroecological development perspective of Gliessman's Levels of conversion, the original model can be adapted to a food system context by illustrating the agroecological approach. The two concepts could be joined together by their common factors, and got an extended use because of their different but complementary focuses. Levels of conversion connects theory to reality with a strong link to practical management and system development with defined principles and goals. CRP contributes with the time perspective that connects *present* with *future*, and take into account climate change complexity where actions and consequences often are separated in both time and space. It could be explained as the agroecological view define how higher resilience can be achieved, and CRP put this development work in a time perspective.

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## 7. References

Adger, W.N. 2000. Social and ecological resilience; are they related? *Progress in Human Geography* 24: 347–364.

---

Agroecology.org (n.d). Principles of Agroecology and Sustainability. Access: [http://www.agroecology.org/Principles\\_List.html](http://www.agroecology.org/Principles_List.html)

---

Altieri M.A., Lana M.A., Bittencourt H.V., Kieling A.S., Comin J.J., Lovato P.E. 2011a. Enhancing Crop Productivity via Weed Suppression in Organic No-Till Cropping Systems in Santa Catarina, Brazil. *Journal of Sustainable Agriculture*, 35:8, 855-869.

---

Altieri M.A., Nicholls C.I. 2012. Agro-ecological approaches to enhance resilience. *Farming Matters*, 28, pp.14-17.

---

Altieri, M.A. & Nicholls, C.I. 2005. Agroecology and the search for a truly Sustainable agriculture. Colonia Lomas de Virreyes: United Nations Environment Program.

---

Altieri, M.A., Funes-Monzote, F.R., Petersen, P. 2011b. Agroecologically efficient agricultural systems for smallholder farmers: contributions to food security. *Agronomy for Sustainable Development*, Official journal of the Institut de la Recherche Agronomique (INRA)

---

Altieri, M.A., Kang Bartlett, A., Callenius, A., Campeau, C., Elsasser K., Hagerman, P., Kenny, G., Lambrechts, K., Miga, W., Prado, J.P., Prove, P., Saracini, N., Ulmer, K. 2012. Nourishing the world sustainably: scaling up agroecology, EEA (Ecumenical Advocacy Alliance).

---

Altieri, M.A., Toledo, V.M. 2011. The agroecological revolution in Latin America: rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies*, 38:587–612. DOI:10.1080/03066150.2011.582947

---

Anderson, T. 2014. Why ‘climate-smart agriculture isn’t all it’s cracked up to be. *The Guardian*. Accessed: 2015-12-20, at: <http://www.theguardian.com/global-development-professionals-network/2014/oct/17/climate-change-agriculture-bad-isnt-good>

---

Baker, J. Ochsner, T. Venterea, R. and Griffis, T. 2007. Tillage and soil carbon sequestration - What do we really know?. *Agriculture, Ecosystems & Environment* 118, 1-5.

---

Bargout, R.N. 2012. Ecological Agriculture and Sustainable Adaptation to Climate Change: A Practical and Holistic Strategy for Indian Smallholders. *Consilience: The Journal of Sustainable Development*, Vol.9, Iss.1, pp.132-159.

---

Berton, S., Billaz, R., Burger, P., Lebreton, A. 2012. Agroécologie, une transition vers des modes de vie et de développement viables. *Paroles d’acteurs*, Agrisud International.

---

CTA (Technical Centre for Agricultural and Rural Cooperation). 2012. Climate change, agriculture and food security: proven approaches and new investments. Brussels Policy Briefing no.29, Brussels, 27 September 2012, European Commission, Charlemagne Building.

---

Curtis, M. 2012. Asia at the Crossroads, Prioritizing Conventional Farming or Sustainable Agriculture?. *ActionAid*.

---

Cutter, S. L., Barnes, L., Berry M., Burton, Evans, E., Tate E., and Webb J. 2008. A place-based model for understanding community resilience to natural disasters. *Global Environmental Change* 18: 598–606.

---

De Schutter, O. 2012. Report submitted by the Special Rapporteur on the right to food. Womens rights and the right to food. A/HRC/22/50. Human Rights Council. United Nations.

---

Degrande, A., Kanmegne, J., Tchoundjeu, Z., Mpeck, M. L., Sado, T., & Tsobeng, A. 2006. Mechanisms for scaling-up tree domestication: how grassroots organisations become agents of change.

---

---

Denton, F., T.J. Wilbanks, A.C. Abeyasinghe, I. Burton, Q. Gao, M.C. Lemos, T. Masui, K.L. O'Brien, and K. Warner. 2014. Climate-resilient pathways: adaptation, mitigation, and sustainable development. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1101-1131.

---

Diamond Collins E., Chandrasekaran K. 2012. A wolf in Sheep's Clothing? An analysis of the 'sustainable intensification' of agriculture. Friends of the Earth International.

---

Edwards. T & Wiseman. J. 2011. Climate Change, Resilience and Transformation: Challenges and Opportunities for Local Communities : in Weissbecker. I (2011). Climate Change And Human Well-Being. [Electronic Resource] : Global Challenges And Opportunities, n.p.: New York, NY : Springer New York, 2011.

---

Ericksen, P.J. 2008. What Is the Vulnerability of a Food System to Global Environmental Change?. Ecology & Society, 13, 2, pp. 1-18.

---

Foley, J, DeFries, R, Asner, G, Barford, C, Bonan, G, Carpenter, S, Chapin, F, Coe, M, Daily, G, Gibbs, H, Helkowski, J, Holloway, T, Howard, E, Kucharik, C, Monfreda, C, Patz, J, Prentice, I, Ramankutty, N, & Snyder, P. 2005. Global Consequences of Land Use. Science, 5734, p. 570, JSTOR Journals.

---

Francis, C., Lieblein, G., Gliessman S., Breland T.A., Creamer, N., Hardwood, R., Salomonsson, L., Rickerl, D., Salvador, R., Wiedenhoft, M., Simmons, S., Allen, P., Altieri, M., Flora, C. 2003. Agroecology: The ecology of food systems. Journal of sustainable agriculture, vol 23, pp 99-118

---

GACSA. 2015. Global Alliance For Climate-Smart Agriculture. Member List Version 08:8 June 2015. Addendum to the Framework Document (GACSA 1). GACSA Series Document 3 (GACSA3). Accessed: 2015-06-13. Available: <http://www.fao.org/3/a-ax295e.pdf>.

---

Garrity, D. Akinnifesi, F. Ajayi, O. Weldesemayat, S. Mowo, J. Kalinganire, A. Larwanou, M. & Bayala, J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security, 2, 3, p. 197.

---

Gattinger A., Jawtusich J., Muller M., Mäder P. 2011. No-till agriculture - a climate smart solution?. Climate change and agriculture, report No.2, Misereor.

---

Gliessman S.R. 2007. Agroecology: the ecology of sustainable food systems. 2nd ed. Boca Raton FL. Taylor and Francis group LLC.

---

Gliessman S.R. 2010. The framework for conversion. In: Gliessman Stephen R & Rosenmeyer, Martha. (red) The conversion to sustainable agriculture Principles, Processes and Practices. Boca Raton FL: Taylor and Francis Group, pp 3-9

---

Gliessman S.R. 2013. Agroecology and Climate Change Mitigation. Agroecology and Sustainable Food Systems, 37:3, 261-261, DOI: 10.1080/10440046.2012.751954.

---

Gliessman. S.R. 2015. Agroecology: the ecology of sustainable food systems. 3rd ed. Boca Raton FL. Taylor and Francis group LLC.

---

Gornall J., Betts R., Burke E, Clark R., Camp J., Willett K., Wiltshire A. 2010. Implications of climate change for agricultural productivity in the early twenty-first century. Philos Trans R Soc B Biol Sci 365:2973–2989.

---

GRAIN. 2009. The climate crisis is a food crisis. Small farmers can cool the planet. A way out of the mayhem caused by the industrial food system.

---

Hendrickson, M.K., and Heffernan W.D. 2002. Opening spaces through relocalization: locating potential resistance in the weaknesses of the global food system. *Sociologia Ruralis* 42(4):347-369.

---

Hill, S.B. 1998. Redesigning agroecosystems for environmental sustainability: a deep systems approach. Systems Research and Behavioral Science 15, 391-402.

---

---

Hoffmann, U. 2010. Assuring food security in developing countries under the challenges of climate change: key trade and development issues of a profound transformation of agriculture.

---

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4, 1–23.

---

Holt Giemenez, E. 2010. Linking farmers movements for advocacy and practice. *Journal of Peasant Studies*, 37:1, 2010, pp. 203-236.

---

Holt Gimenez, E and Shattuck, A. 2011. Food crises, food regimes and food movements: rumblings of reform or tides of transformation?. *Journal Of Peasant Studies*, 38, 1, pp. 109-144.

---

Holt-Giménez, E. 2002. Measuring Farmers' Agroecological Resistance After Hurricane Mitch in Nicaragua: A Case Study in Participatory, Sustainable Land Management Impact Monitoring. *Agriculture, Ecosystems and the Environment*, 93:1-2, 2002, pp. 87-105.

---

Holt-Giménez, E. 2006. *Campesino a campesino: voices from Latin America's farmer to farmer movement for sustainable agriculture*, Oakland, Food First Books.

---

Houghton, J.T. 2009. *Global Warming : The Complete Briefing*, n.p.: Cambridge : Cambridge University Press.

---

International assessment of agricultural knowledge, science and technology for development (IAASTD). 2009. *Agriculture at a Crossroads: Synthesis report with executive summary*. Available: [http://www.unep.org/dewa/agassessment/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads\\_Synthesis%20Report%20\(English\).pdf](http://www.unep.org/dewa/agassessment/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Synthesis%20Report%20(English).pdf)

---

IPCC, 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

---

IPCC, 2014a: Annex XX: Glossary [Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, K.R. Smith, A.L. St. Clair, K.J. Mach, M.D. Mastrandrea, and T.E. Bilir (eds.)]. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1757-1776.

---

IPCC, 2014b. Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

---

Johnston, A.E., Poulton P.R., Coleman, K., Chapter 1 Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes. 2009. In: Sparks D. L. (ed). *Advances in Agronomy*, Academic Press, 2009, Volume 101, Pages 1-57.

---

Klein, R. J. T., Nicholls R. J., and Thomalla F. 2003. Resilience to natural hazards: how useful is this concept? *Environmental Hazards* 5: 35–45.

---

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* 304, 1623-1627.

---

Li Ching, L. and Stabinsky, D. 2011. Ecological agriculture is climate resilient. Briefing Paper 1, UN Climate Change Conference 28 Nov – 9 December 2011 Duran, TWN.

---

Lin, B. 2011. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change, *BioScience*, 3, p. 183, JSTOR Journals.

---

---

Lipper, L, Thornton, P, Campbell, B, Baedeker, T, Braimoh, A, Bwalya, M, Caron, P, Cattaneo, A, Garrity, D, Henry, K, Hottle, R, Jackson, L, Jarvis, A, Kossam, F, Mann, W, McCarthy, N, Meybeck, A, Neufeldt, H, Remington, T, & Sen, P 2014, 'Climate-smart agriculture for food security', *Nature Climate Change*, 4, 12, p. 1068.

---

Maleksaeidi, H. and Karami, E. 2013. Social-Ecological Resilience and Sustainable Agriculture Under Water Scarcity, *Agroecology and Sustainable Food Systems*, 37:3, 262-290, DOI: 10.1080/10440046.2012.746767

---

McMichael, P. 2000. The power of food. *Agriculture & Human Values*, 17, 1, p. 21, Publisher Provided Full Text Searching File, EBSCOhost, viewed 26 May 2015.

---

Milman, A. and Short, A. 2008. Incorporating resilience into sustainability indicators: an example for the urban water sector. *Global Environmental Change* 18: 758–767.

---

Parmentier, S. 2014. Oxfam-Solidarity. Scaling-up agroecological approaches: what, why and how?. Oxfam-Solidarity, Belgium. Accessed: 2015-06-14. Available at: [http://futureoffood.org/pdfs/OXFAM\\_2014\\_Scaling\\_Up\\_Agroecological\\_Approaches.pdf](http://futureoffood.org/pdfs/OXFAM_2014_Scaling_Up_Agroecological_Approaches.pdf)

---

Paustian, K., Antle, J.M., Sheehan, J., and Paul, E.A. 2006. Agriculture's Role in Greenhouse Gas Mitigation. Arlington: Pew Centre on Global Climate Change.

---

Perez-Vitoria, S. 2011. L'Agroécologie, une approche multidimensionnelle de l'agriculture.

---

Perrings, C. 2006. Resilience and sustainable development. *Environment and Development Economics* 11: 417–427.

---

Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso, 2014: Food security and food production systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533.

---

Pretty, J. 2008. Agricultural sustainability: concepts, principles and evidence, *Philosophical Transactions of The Royal Society B*, 363, p.447-465.

---

Pretty, J. Noble, A. Bossio, D. Dixon, J. Hine, R. De Vries, F. & Morison, J. 2006. Resource-Conserving Agriculture Increases Yields in Developing Countries. *Environmental Science & Technology*, 40, 4, pp. 1114-1119.

---

Pye-Smith, C. 2010. A Rural Revival in Tanzania: How agroforestry is helping farmers to restore the woodlands in Shinyanga Region. *Trees for Change No. 7*, Nairobi, World Agroforestry Centre (ICRAF), 2010, p. 15.

---

Reddy, P.P. 2015, *Climate Resilient Agriculture For Ensuring Food Security*. [Electronic Resource], n.p.: New Delhi : Springer India : Imprint: Springer, 2015.

---

Rosset P.M., Sosa B.M., Roque Jaime A.M.R., Ávila Lozano R.A. 2011. The Campesino- to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. *Journal of Peasant Studies* 38(1), 161-191.

---

Sahai, S. 2011. Climate Resilient Sustainable Agriculture: Adapting for Change in India. *Food Files, Issue 4, IFSN (International Food Security Network), ActionAid*, pp.36-37.

---

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Maser, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

---

---

Stabinsky, D. 2012. Soil Carbon and the Offset Market: Practices, Players and Politics. IATP (Institute for Agriculture and Trade Policy).

---

Sundkvist, A., Milestad, R., and Jansson, A. 2005. On the importance of tightening feedback loops for sustainable development of food systems. *Food Policy* 30(2):224-239.

---

Swiderska, K., Song, Y., Jingsong, L., Reid, H., Mutta, D. 2011. Adapting agriculture with traditional knowledge, briefing. IIED.

---

Thapa, S., Marshall, F., and Stagl, S. 2010. Understanding peri-urban sustainability: The role of the resilience approach. Working Paper, STEPS Centre, Brighton, UK.

---

UNEP-UNCTAD. 2008. Capacity Building Task Force on Trade, Environment and Development (CBTF), *Organic Agriculture and Food Security in Africa*, New York/Geneva, United Nations, 2008, p. 16.

---

United Nations Human Rights Council. 2011. Eco-Farming can double food production in 10 Years, says new UN report. Press release March 8 2011. Accessed 2015-09-11, at: <http://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=10819&LangID=E#sthash.SDVoidle.dpuf>

---

Uphoff, N. 2002. *Agroecological Innovations: Increasing Food Production with Participatory Development*. Earthscan, London.

---

Vermeulen, S.J., Campbell, B., and Ingram J. 2012. Climate change and food systems. *Annual Review of Environment and Resources*, 37, 195-222.

---

Wezel, A, S., Bellon, S., Doré, T., Francis, C., Vallod, D., David, C. 2009. Agroecology as a science, a movement and a practice. *A review. Agronomy for sustainable development*, vol.29, pp 503-515

---

Wezel, A. and David, C. 2012. Agroecology and the Food System: in Lichtfouse. E (ed.), *Agroecology and Strategies for Climate Change*, 17 *Sustainable Agriculture Reviews* 8, Springer Science and Business Media B.V. 2012. DOI 10.1007/978-94-007-1905-7\_2.

---

Woods, J, Williams, A, Hughes, J, Black, M, & Murphy, R. 2010. Energy and the food system. *Philosophical Transactions: Biological Sciences*, 1554, p. 2991, JSTOR Journals.

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# Appendix 1. Agroecological principles

Below, the complete list of agroecological principles from the web site [agroecology.org](http://agroecology.org) are presented. (Source: [http://www.agroecology.org/Principles\\_List.html](http://www.agroecology.org/Principles_List.html))

## Use Renewable Resources

- Use renewable sources of energy instead of non-renewable sources.
- Use biological nitrogen fixation.
- Use naturally-occurring materials instead of synthetic, manufactured inputs.
- Use on-farm resources as much as possible.
- Recycle on-farm nutrients.

## Minimize Toxics

- Reduce or eliminate the use of materials that have the potential to harm the environment or the health of farmers, farm workers, or consumers.
- Use farming practices that reduce or eliminate environmental pollution with nitrates, toxic gases, or other materials generated by burning or overloading agroecosystems with nutrients.

## Conserve Resources

### Conserve Soil

- Sustain soil nutrient and organic matter stocks.
- Minimize erosion.
  - 1 use perennials
  - 2 use no-till or reduced tillage methods.
  - 3 mulch.

### Conserve Water

- Dry farm.
- Use efficient irrigation systems.

### Conserve Energy

- Use energy efficient technologies.

### Conserve genetic resources

- Save seed.
- Maintain local landraces.
- Use heirloom varieties.

### Conserve Capital

- Keep bank debt to a minimum.
- Reduce expenditures.

### Manage Ecological Relationships

- Reestablish ecological relationships that can occur naturally on the farm instead of reducing and simplifying them.
- Manage pests, diseases, and weeds instead of “controlling” them.
- Use intercropping and cover cropping
- Integrate Livestock
- Enhance beneficial biota
  - 1 In soils
    - mycorrhizae
    - Rhizobia
    - free-living nitrogen fixers

- 2 Beneficial insects
  - Provide refugia for beneficials.
  - Enhance beneficial populations by breed and release programs.
- Recycle Nutrients
  - 1 Shift from through flow nutrient management to recycling of nutrients.
  - 2 Return crop residues and manures to soils.
  - 3 When outside inputs are necessary, sustain their benefits by recycling them.
- Minimize Disturbance
  - 1 Use reduced tillage or no-till methods.
  - 2 Use mulches.
  - 3 Use perennials

### **Adjust to Local Environments**

- Match cropping patterns to the productive potential and physical limitations of the farm landscape.
- Adapt Biota
  - 1 adapt plants and animals to the ecological conditions of the farm rather than modifying the farm to meet the needs of the crops and animals.

### **Diversify**

- **Landscapes**
  - 1 Maintain undisturbed areas as buffer zones.
  - 2 Use contour and strip tillage.
  - 3 Maintain riparian buffer zones.
  - 4 Use rotational grazing.
- **Biota**
  - 1 Intercrop.
  - 2 Rotate crops.
  - 3 Use polyculture.
  - 4 Integrate animals in system.
  - 5 Use multiple species of crops and animals on farm.
  - 6 Use multiple varieties and landraces of crops and animals on farm.
- **Economics**
  - 1 Avoid dependence on single crops/products.
  - 2 Use alternative markets.
  - 3 Organic markets.
  - 4 Community Supported Agriculture
  - 5 "Pick your own" marketing.
  - 6 Add value to agricultural products.
  - 7 Process foods before selling them.
  - 8 Find alternative incomes.
  - 9 Agro-tourism
  - 10 Avoid dependence on external subsidies.
  - 11 Use multiple crops to diversify seasonal timing of production over the year.

### **Empower People**

- Ensure that local people control their development process.
- Use indigenous knowledge
- Promote multi-directional transfer of knowledge, as opposed to "top-down" knowledge transfer.
  - 1 Teach experts and farmers to share knowledge, not "impose" it.
- Engage in people-centric development.
- Increase farmer participation.
  - 1 Link farmers with consumers

- Strengthen communities.
  - 1 Encourage local partnerships between people and development groups. Ensure intergenerational fairness.
- Guarantee agricultural labor.
  - 1 Ensure equitable labor relations for farm workers.
- Teach principles of agroecology & sustainability.

### **Manage Whole Systems**

- Use planning processes that recognize the different scales of agroecosystems.
  - 1 Landscapes
  - 2 Households
  - 3 Farms
  - 4 Communities
  - 5 Bioregions
  - 6 Nations
- Minimize impacts on neighbouring ecosystems.

### **Maximize Long-Term Benefits**

- maximize intergenerational benefits, not just annual profits.
- maximize livelihoods and quality of life in rural areas.
- facilitate generational transfers.
- Use long-term strategies.
  - 1 develop plans that can be adjusted and reevaluated through time.
- Incorporate long-term sustainability into overall agroecosystem design and management.
- Build soil fertility over the long-term.
  - 1 build soil organic matter.

### **Value Health**

- Human Health
- Cultural Health
- Environmental Health
  - 1 Value most highly the overall health of agroecosystems rather than the outcome of a particular crop system or season.
  - 2 Eliminate environmental pollution by toxics and surplus nutrients.
- Animal Health
- Plant Health