

Towards a Complex Adaptive Systems Paradigm of Disaster Resilience: A study of Southern African subsistence agriculture communities

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COMMENTS

The reader is reminded of the following:

- The thesis is submitted in article format consisting of 4 research articles
- The student was main author on all articles with supervisors serving as co-authors in relation to the study leading input they provided.
- Two of the articles have already been published in academic journals. These are article 1 in *Disaster Prevention and Management* and article 3 in *International Journal for Disaster Risk Reduction*. Article 2 and Article 4 have been submitted to *Natural Hazards* (article 4) and *International Journal of Disaster Risk Science* (article 2)
- Attached as appendix B, a letter of conformation by co-authors that that the articles that contained here may be submitted as part of the PhD thesis
- Attached as appendix C, letters from editors of academic journals confirming the use of the articles in the thesis

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“Two years ago, I was afraid of wanting anything. I figured wanting would lead to trying and trying would lead to failure. But now I find I can’t stop wanting. I want to fly somewhere in first class. I want to learn about the world. I want to surprise myself. I want to be important. I want to be the best person I can be. I want to define myself instead of having others define me. I want to win and have people be happy for me. I want to lose and get over it. I want to not be afraid of the unknown. I want to grow up and be generous and big hearted, the way people have been with me. I want an interesting and surprising life. It’s not that I think I’m going to get all these things, I just want the possibility of getting them. The possibility that things are going to change. I can’t wait.” FNL

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ABSTRACT

Title: Towards a Complex Adaptive Systems Paradigm of disaster resilience: A study of Southern African subsistence agriculture communities

Keywords: Resilience, Complex Adaptive Systems Theory, Information feedback, Emergent behaviour, non-linearity

Disasters have affected human lives, livelihoods, infrastructure, biodiversity and linked socio-ecological systems since the beginning of time. These impacts have been amplified since the 1970s thereby causing society to consider pro-active approaches to reducing the threat posed by disasters. To this end, international organisations, national governments and academia have created and introduced a vast array of disaster reduction theories, concepts, models and policies to provide theoretical and practical tools for addressing disasters risk. A contemporary disaster risk management concept that has risen to prominence over the last decade is the concept of disaster resilience. However, despite its prominent position in contemporary disaster risk management discourse and practice, confusion still exists on what exactly resilience pertains to on a theoretical level, and how to go about building resilience in practice. The thesis makes the argument that resilience is often not well understood due to the mechanistic nature of most resilience theories, models and policies currently informing our understanding of the concept. This mechanistic approach of explaining disaster resilience often leads to a very linear and shallow understanding of the processes and elements that subsume disaster resilience building processes. In practice, the shallow understanding leads to a practical implementation of resilience building projects that are based upon “one size fits all” approaches which do not address the dynamic nature of resilience within different geographic contexts. The thesis contends that understanding and building disaster resilience is an infinitely more complex process than what is observable in the current discourse. To understand such complexity, the thesis introduces Complex Adaptive Systems Theory (CAST) as a possible new paradigm through which disaster resilience can be understood. CAST is an appropriate choice as it is specifically designed to understand complex human-environmentally linked processes such as disaster resilience

The theoretical discussion on CAST and its associated concepts is tested within the context of subsistence agriculture within the Southern African countries of Madagascar, Malawi and Mozambique. The specific context was selected due to the large dependence

of these countries upon subsistence agriculture for income and food security, and the subsequent need for improved resilience in the face of disaster risk. To gain a greater insight into the underlying dynamics that encompass resilience in the different country contexts, the thesis employed a secondary data analysis methodology on the existing data set collected on behalf of the UN's Food and Agricultural Organisation (FAO). A combined total of 1110 respondents formed part of the study, of which Mozambique represented 40.3% (N=447) of participants, Madagascar 30.4% (N=337) and Malawi 29.4% (N=326). The data collected from these respondents was scrutinised in greater depth through the application of correlation and descriptive statistical analysis. This statistical analysis gives insight into concepts of non-linearity, aggregation, emergent behaviour, feedback loops, adaptation and context-based responses and how the aid in explaining resilience within subsistence agriculture communities in the identified countries. The results of the analysis are presented in four research articles.

Results from Research Article 1 focused upon establishing whether there were theoretical synergies between the concept of resilience and CAST. It was found that there are inherent similarities between the concept of resilience and CAST, which provide ample practical and theoretical contributions to the field of disaster risk studies. Article 2 explored the role of information feedback loops in stimulating interaction between internal and external system elements, and whether these interactions lead to complex emergent system behaviours such as disaster resilience with farming communities. The paper found that information feedback loops and interaction are key drivers for disaster resilient behaviour, as information feedback stimulates improved disaster recovery and coping capacity for subsistence farmers. Through the application of the systems concept of emergence, Article 3 attempted to illustrate how complex emergent behaviours such as disaster resilience at a macro systems level are created through the interaction between micro level system components. Results showed that the use of a combination of agricultural interventions, including small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, and cropping techniques at a micro systems level could lead to coping strategies and hazard avoidance strategies that contribute to the overall resilience of farming communities at a macro systems level. Article 4 explored the notion that emergent behaviours such as those discussed in Article 3 are often non-linear in nature. Results from the analysis of subsistence agriculture communities illustrated that community resilience profiles are uniquely different from context to context. This has implications for the theory and practice of disaster resilience, as it would mean that

resilience and the building thereof could not be understood by means of one size fits all approaches, and that there should be a move towards more flexible and context specific resilience building tools and methodologies.

The research showed that CAST is a useful tool for understanding resilience on two levels - theory and practice. On a theoretical level the study showed that CAST is an appropriate tool to explore disaster resilience, as it is ideally suited to provide insight into systems that are subject to constant change, learning and adaptation. This capability of CAST is consistent with the operational definition of resilience presented in the thesis, and the contemporary thinking of disaster resilience as a process of “building back better” or “bouncing forward”. On a practical level the thesis showed that systems tools such as information feedback loops, emergent behaviour and non-linearity provide disaster scientists with a means to explore deeper dynamics and processes that underlie resilience behaviour in at-risk communities. To this end, information feedback loops aid our understanding of interactions that drive adaptive behaviour, emergence allows us to understand micro level systems interactions and how these interactions lead to resilience in different contexts, and finally, non-linearity places an emphasis upon resilience and the building thereof as something that should be treated as a flexible concept and interventions that should be tailor-made to each community. Importantly, the system tools identified in the thesis are inherently flexible, making them generalisable to all contexts. This is because systems tools aim to understand the process of resilience building, instead of providing an idealised version of what resilience should be. A CAST perspective on resilience accepts therefore that resilience profiles will differ from context to context, but that is crucial to understand the dynamics and underlying process that drive resilience building.

The thesis also demonstrated that the CAST perspective on building disaster resilience is not only applicable to our theoretical understanding of resilience, but that it can make a contribution to understanding resilience as it pertains to different contexts and settings. As such it was shown that within the context of subsistence agriculture in Southern Africa, CAST could reveal the composition and extent of resilience profiles within different communities. Understanding the underlying dynamic associated with the resilience profiles of individual communities is crucial, as it would allow for more appropriate resilience building and development programmes to be implemented by local and international development agencies. The addition of CAST perspectives into resilience building projects

in Southern African subsistence agriculture will also contribute to introducing the notion that building resilience is not a static outcome that can be achieved within a pre-determined time scale. Instead, it should be treated as a dynamic process, independent of set time and funding schedules. This could have major implications for how governments and international donor agencies should go about formulating, funding, implementing and monitoring future agricultural resilience building and disaster risk reduction projects within the region. CAST implies that future resilience building endeavours should be more flexible in their implementation and funding procedures, and place greater emphasis upon the bottom-up formulation (community centred approaches) of resilience building in agricultural settings, rather than donor-government driven approaches that are often top-down in their implementation and understanding of community needs.

Through the application of CAST tools it is apparent that a Complex Adaptive Systems paradigm of disaster resilience is useful, as it provides a means to focus upon the underlying drivers and dynamics associated with resilient behaviour. This is a departure from traditional paradigms of resilience which often spoke only to the capacities needed to build resilience in isolation. Introducing a Complex Adaptive Systems paradigm to our understanding of resilience is a recognition of the basic systems principle of "the whole is more than the sum of its parts," or there is more to understanding a system than merely understanding the individual components.

CHAPTER 1

INTRODUCTION

This thesis focuses on establishing a complex adaptive systems theory paradigm of disaster resilience by focussing on subsistence agriculture communities in Southern Africa.

As a point of departure chapter 1 will attempt to give an insight into the research problem that gave rise to the subject of the thesis. This contextualisation of the research problem is followed by an explanation of the research objectives and questions identified to guide the research process. A discussion on aspects pertaining to research design including, context and research sample, philosophical underpinnings of the study, secondary data analysis as research method and empirical data collection is discussed. The chapter concludes by giving an outline of the chapters the comprise the thesis.

1.1. PROBLEM STATEMENT

On an annual basis thousands lose their lives or livelihoods due to natural and human-made hazards (IFRC, 2014). According to Pelling (2003), from the 1950s to the 1990s the number of people affected by disaster globally tripled, while the economic cost of disaster increased by a factor of 14 over the same period. Additionally, during the period of 2004-2013 disaster losses have been calculated at US\$ 1,669,626 billion in spite of a part of the decade (2000-2010) serving as the international decade for disaster risk reduction (IFRC, 2014:231; Pelling, 2003). The recurrent and accumulating human and capital costs of disaster, has fostered the realisation that there must be more efficient ways of managing, mitigating and preventing disasters than merely responding to impacts (UN, 1989; Oliver-Smith, 2009:13). The introduction of the concept of disaster risk management signalled the shift to a more pro-active approach to the management of disasters. The term introduced the notion that humanity can actively manage and address the risks (hazards and social vulnerabilities) that lead to disasters. The management of disaster risk would be guided by administrative directives, policy, organisational structures, operational skills and capacities to implement strategies to lessen the adverse impacts of hazards and possible disaster impacts (UNISDR, 2009; Twigg, 2015:23). Disaster risk management therefore focuses on establishing the structural means whereby governments can start to address disaster risk. As a practical implementation of the disaster risk management function, disaster risk reduction was formulated as a broad concept to encapsulate all activities to reduce or eliminate the possible impact of disaster including reducing exposure to hazards, lessening vulnerability of people and property, improved environmental and urban planning, improved preparedness and early warning systems and fostering adaptive capacity and disaster resilience of at risk communities (Twigg, 2015:24; Mercer et al, 2010:215). Thus pre-disaster planning has emerged as a practical and necessary component to compliment traditional disaster response thinking (Lewis et al., 1976:2).

Since the early 1970 time a plethora of disaster risk management theories, tools and policies have been formulated to aid our disaster risk reduction efforts. These include (but are not limited to) the disaster management cycle (Baird, O'Keefe, Westgate and Wisner, 1975), pressure and release model (PAR) (Wisner et al.et al., 2003) and international policy measures such as the Yokohama Protocol (1994), the International Decade for Natural Disaster Reduction (1990-2000), and the International Strategy for Disaster Reduction (2001-2010), all of which aimed to contribute to curbing disaster losses. During this genesis of new ideas and protocols on proactive ways of dealing with disaster, disaster resilience also emerged into the lexicon of disaster management (Miller et al., 2010:10; Cimellaro et al., 2010:3639).

The concept of resilience remains one of the most contested in the field of disaster risk studies (Manyena, 2006:433; Gaillard, 2010:220; McEntire, 2005:209). Compared to other disaster risk reduction terminology, academics and practitioners are still arguing the merits of the concept of resilience (Manyena, 2006:434; Gaillard, 2010:220; Klein et al.et al., 2003:40; Zobel, 2011:395). Some of the confusion around the concept of resilience and how it should be applied can be said to lie with three issues: a confusion around how disaster resilience should be defined; how it can be measured and the subsequent practical orientation to how resilience should be increased (resilience is often viewed as an outcome to produce an equilibrium, and not a continuous process of adaptation) (Klein et al. 2003; Manyena, 2006; Renschler et al. 2010; Alexander, 2013, Zhou et al, 2010). These theoretical and practical complications have caused disaster risk scientists and practitioners to often take a narrow or linear view on how disaster resilience can be quantified and explained (Maru, 2010). The linear reasoning contained in both the existing theory and policies has placed a lesser importance on gaining a holistic understanding of a social contexts and interactions within the society (between group members, capacities, external stakeholders) that underlies resilient behaviour and instead emphasises is placed on the need to identify generic categories and goals that are perceived to contribute most to reducing disaster risk and building disaster resilience (Matthews et al. 1999 Turner et al. 2004). This, however, ignores the reality that very little of the world or even regions within the same country is the same (Cutter et al. 2008; Cordona 2004; Zhou et al, 2010).

Linear thinking about building disaster resilience as contained in policy and theory has been problematic because without taking into account a society's complex context-specific variables (social, economic, political, physical, ecological) there can be very little success in building resilience and reducing disaster losses. This is supported by Cardona (2004) and Alexander (2013) who indicate that there has been limited success in building adaptive resilience within at-risk communities over the past 25 years (since the declaration of the International Decade for Natural Disaster Reduction in 1990). The limitations of current policies and theoretical tools in building disaster resilience is further reiterated in both the Hyogo Framework for Action and the Sendai Framework for DRR:

“Disaster loss is on the rise with grave consequences for the survival, dignity and livelihood of individuals, particularly the poor, and hard-won development gains. In the past two decades, on average more than 200 million people have been affected every year by disasters” (UN/ISDR, 2005).

and

“Over the same 10-year time frame (the period of implementation for the Hyogo Framework, 2005-2015), however, disasters have continued to exact a heavy toll, and as a result the well-being and safety of persons, communities and countries as a whole have been affected. Over 700 thousand people lost their lives, over 1.4 million were injured and approximately 23 million were made homeless as a result of disasters. Overall, more than 1.5 billion people were affected by disasters in various ways. Women, children and people in vulnerable situations were disproportionately affected. The total economic loss was more than \$1.3 trillion. In addition, between 2008 and 2012, 144 million people were displaced by disasters “(UN/ISDR, 2015).

In light of the above Mayunga (2007:3-5) and Hufschmidt (2011) both agree that new conceptualisations of disaster resilience is needed. These should place more emphasis on the intimate connections between resilience of communities and capacities available to them, to not only cope with, but continuously adapt, learn and change their behaviour to perceived future disaster impacts. This conceptualisation of resilience opens up many possibilities for the way disasters are managed and understood. Specifically, it contributes to the idea that, as with any other social system, building community resilience to disasters is inherently a non-linear, open system process where new information can continuously flow in and out of, thereby changing the system dynamics - or in this instance, the composition of community resilience profiles. This would be a dramatic departure from the approach followed by contemporary disaster policies and theories which often treat disaster resilience and the building thereof as a linear, closed-system process (Sawyer, 2004). Importantly, the open system process of building community resilience implied by the above-mentioned definition opens up the possibility of applying theoretical tools such as Complex Adaptive Systems Theory (CAST) which is specifically designed to provide a holistic perspective on the dynamic complexity and interactions that form part of the functioning of open systems such as the building of disaster resilience (Kast and Rosenzweig, 1972; Levin, 1998. Von Bertalanfy, 1972; Skyttner, 2005).

In light of the above discussion the purpose of the thesis is therefor to provide a paradigm shift away from the notion that disaster resilience can be built within disaster affected communities by the application “one size fits all” models and policy frameworks that are based on a linear understanding of how societies function. Instead the thesis proposes moving towards a more holistic systems-based understanding of disaster resilience as a possible paradigm shift away from the traditional linear approach through the application of CAST and its associated concepts. With

this in mind the thesis identifies the potential contribution of CAST in understanding disaster resilience and identifies specific elements such as non-linearity, emergent behaviour and feedback loops as key drivers understanding in gaining a more in depth understanding of resilience in social systems.

CAST will now be elaborated on as the central theory that would guide the study.

1.2 CENTRAL THEORETICAL STATEMENT

The complexity presented by the influence of different contexts on the make-up of resilience profiles for different communities compels us to use theoretical analysis tools that could assist in examining the associated complexity. A theoretical tool that provides possible avenues for exploration is complex adaptive systems (CAST) theory.

1.2.1 Complex Adaptive Systems Theory

Systems theory has been formulated to give scientist an insight into complex systems of all types, be it human, environmental or mechanical (Boulding, 1956; Ashby, 1960; Buckley, 1968; Becker, 2009:14; Skyttner, 2005:49-108; Richardson, 2005). Systems science makes the argument that systems can only be understood by recognising that systems are shaped by their interaction with one another i.e humans by their environment and vice-versa (Skyttner, 2005:3; Von Bertalanffy, 1972:417; Whitchurch and Constantine, 1993:325). It also aims to facilitate an understanding of the emergent behaviours that result due to interactions and how these constantly change over time (Skyttner, 2005:3; Meadows, 2008:2; Boulding, 1956:197). Systems theory therefore provides an avenue for disaster scientist to explore the deeper interactions between system components that would lead to the emergence of disaster resilience (Kast and Rosenzweig, 1972:450; Von Bertalanffy, 1972:415). A specific variation of systems theory, referred to as Complex Adaptive System (CAST) theory, presents an interesting tool for studying a dynamic concept such as resilience (Holland, 1992; Hartvigsen, 1998)

CAST is a variation of traditional systems theory that emerged in the natural science fields of ecology and biology to try and explain non-linear adaptation on micro and macro scales in the natural environment (Hartvigsen, 1998:427; Holden, 2005:652; Ahmed et al., 2005:2; Levin, 1999:432). Holland (1992:17) states that CAST was created as a means to comprehend inherently non-linear systems such as economies, brain biology and immune systems that are impossible to accurately simulate using linear diagnostic tools such as computers. Railsback (2001:47) adds that at the core of CAST analysis is an attempt to show how the simple interaction between individual elements at a micro level lead to very complex behaviours at a macro level. For all its potential in explaining complexity in systems behaviour, the social sciences have been very slow to adopt CAST as possible means of analysing human behaviour and larger social systems (Innes and

Boomer, 1999: 416-417; Holden, 2005:652). This in spite of the fact as iterated by Lansing (2003:183), that CAST concepts such as systems emergence (“the idea that larger patterns with new properties can emerge from local interactions”) could contribute significantly to our understanding of how micro level decision making impacts positively or negatively on larger social system dynamics. Hartvigsen et al. (1998:428) also highlights the potential of CAST in social research in stating that CAST provides us with a means of analysing and understanding social dynamics as an aggregate of interacting and diverse set individual behaviours. The benefit of analysing society in this way is that it would give us more accurate impressions of population-level and community-level behaviour (Railsback, 2001:48; Hartvigsen, 1998).

Rammel (2007:10) conceptualises the key tenants of CAST, which are: (1) CAST aims to understand complex emergent behaviour at a macro level by looking at interactions between heterogeneous components at a micro level; (2) All CAST systems are characterised by their ability to learn from their environment; and (3) this learning aims to bring about adaptation or change to the system that helps it survive or absorb shocks to the system. Consequently, complex adaptive systems can be said to be inherently characterised by panarchy, or the ability to be dynamically influenced or adapt to changes that emerge within or from outside the system (Gunderson and Holling, 2002; Folke et al., 2004:558).

1.2.2. Synergy between CAST and Disaster resilience

The key tenants of CAST expounded above highlights the importance of studying disaster resilience through the theoretical lens of complex adaptive systems theory. Disaster resilience is currently not fully understood or even measurable because the contextually based capacities lead to communities showing differing resilience profiles, often within the same regions (Plsek, 2001:311). Holland (1999:18), Rammel (2007:10) and Innes and Booher (1999: 416) all emphasise that CAST is an excellent tool for analysing systems that are constantly changing (“functioning at the edge of chaos”) and that constitute what can be described as “moving targets” or anarchy (Cutter et al., 2008:601). Addressing disaster resilience as a CAST places the emphasis on understanding individual capacities and how these interact to generate resilience (Hartvigsen et al., 1998:427). This might provide insight into those capacities that most likely contribute to positive emergent behaviour and improved disaster resilience within a specific context (Holden, 2005:654; Rommel, 200:10; Zhou et al., 2010:29). Importantly, basing the analysis of resilience and the formulation of subsequent models for understanding resilience on CAST means that there is an inherent understanding that resilience is not the end-point for a society to achieve, but rather a journey that will lead to constant adaptive change (Norris, 2008:130; Rose, 2007:87). This philosophical orientation significantly increases our chances of gaining a holistic impression of societal resilience (Holland, 1992:20). A disaster resilient system is inherently an open system that is able to learn from previous disaster impacts and that makes creative adaptation (from information feedback loops) possible (Ahmed et al., 2005:3; Holden, 2005:656; Lansing 2003:183).

Additionally, CAST will allow the tracking of so-called “second and third order” effects brought about in a society because of improved disaster resilience (Innes and Booher, 1999:416).

On a theoretical level, the underlying principles of disaster resilience and CAST are very similar, warranting the use of CAST as the main theoretical analysis tool for the proposed study. Due to its contribution in deciphering complexity as it pertains to disaster resilience, CAST would greatly assist in gaining a better understanding of resilience in all contexts. One such context that could benefit from the application of a CAST perspective on resilience in subsistence agriculture in Southern Africa. Subsistence agriculture is a large source of income and food security for communities throughout the region. However, this crucial livelihood is constantly threatened by the impact of disasters. A greater understanding of how resilience is constituted through the application CAST could provide practical insights on how best to build disaster resilience in order to protect livelihoods of subsistence farmers throughout the region.

1.2.3 CAST concepts: possible contribution in explaining disaster resilience

An extensive review of literature sources highlight certain key characteristics of complex adaptive systems theory. These key characteristics include the concepts of non-linearity, aggregation, emergent behaviour, feedback loops and adaptation and context based responses. The theoretical base of each of these elements have been extensively developed (although not applied to disaster resilience contexts) and the use of the elements is seen as indispensable to the understanding of the functioning of complex adaptive systems by (Boal and Schultz, 2007; Innes and Booher, 1999:417; Rammel et al., 2007). The integral nature of the elements to understanding the functioning of complex adaptive systems therefore serves as a rationale for their use to guide the theoretical arguments and analysis within the thesis. Although the discussion is by no means an extensive listing of possible synergies between CAST and disaster resilience, some of the key characteristics and their possible application to understanding disaster resilience is listed below.

1.2.3.1 Non-linearity

The basic premise of non-linearity in CAST is that the size of inputs into a system might not be proportional to expected outputs (Boal and Schultz, 2007; Railsback, 2001). Specifically, small seemingly insignificant variables or inputs in a system might fundamentally change the operation of a system whilst major inputs or variables might have no impact in changing the system (Schneider and Somers, 2006; Plsek, 2001). This notion is in line with the work of Lorenz (1963) and Chaos Theory. By viewing disaster resilience through the lens of non-linearity it might be possible to determine or track impact of individual variables on the overall generation of disaster resilience in a society. This element is discussed in article 4 of the thesis.

1.2.3.2 Aggregation

According to Levin (1998:432), aggregation is the process whereby individuals in complex systems arrange themselves into sub-groups or hierarchal organisation that have similar interests, needs and practices they have. Once sub-groups are formed they do not remain isolated. Instead, multiple interactions are established between different sub-groups that allows for dynamic development and adaptation to changing environments (Railsback, 2001; Boal and Schultz, 2007). The concept of aggregation provides interesting avenues of exploration within the field of disaster resilience, as it would help to focus some attention on the role, correlation and total contribution of social coping mechanisms to the overall resilience of a society. This element is not discussed directly with an article of its own but does form part of the discussion role of farmers' associative mechanism in stimulating information feedback towards generating disaster resilience. See article 2.

1.2.3.3 Emergent behaviour

According to Innes and Booher (1999, p. 417) emergent behaviour is one of key characteristics of CAST. Emergence refers to how system-level properties, characteristics and patterns emerge from interaction between individual elements at a micro level, even though the individual elements bare no similarity the final wider system characteristics (Railsback, 2001; Schneider and Somers, 2006; Hartvigsen et al., 1998). The concept of emergence could be useful in the exploration of disaster resilience as it will allow for the investigation into how an aggregation of smaller variables could lead to improving resilience profiles of disaster effected communities. This element is discussed in article 3 of the thesis.

1.2.3.4 Feedback loops and adaptation

According to Walker et al. (2012) and Holden (2005) feedback loops play a crucial role in the development of CAST by either enhancing, stimulating, detracting or inhibiting elements within the existing system. Through these processes feedback loops allow for learning and adaptation within a dynamic environment thereby preventing the extinction of a system (Begun et al., 2003; Rammel et al., 2007; Innes and Booher, 1999). The study of feedback loops allows for greater insight into how communities learn from past events to improve their overall level of disaster resilience. It could also provide insight into the second and third order knock on effects of building disaster resilience within a specific community Innes and Booher (1999). This element is discussed in article 2 of the thesis.

1.2.3.5 Context-based responses

A crucial aspect of CAST is its emphasis on the importance of context on the functioning of a system (Boal and Schultz, 2007). According to Holden (2005) and Holland (1992) any complex system is inseparable from the context and history that it finds itself in. The influence of context on CAST is so extensive that it contributes to making each CAST unique (Begun et al., 2003; Hartvigsen et al., 1998). However, the context of a CAST is not static and can also be altered due

to the dynamic interaction between interconnected elements (Holden, 2005). For instance, dramatic events at a local level (i.e. disaster in a community) does not only change of the context of the community itself, but could also cause changes at national and regional level (e.g. changes in disaster risk management policies), which in turn would impact once again on the context of the community (Zhou et al., 2010; Schneider and Somers, 2006). The emphasis on understanding of the context provides an opportunity of not only studying the aggregation of unique element's that make a community resilient on a case to case basis but also allows form the exploration of the interconnectedness of elements and how changes at lower levels of a system can change the wider context of resilience. This element is a cross-cutting issues within the thesis. The theoretical need for considering context based responses is established in article 1 and practical applications are considered in articles 2-4.

The various characteristics highlighted above was applied to the context of subsistence agriculture communities in Southern Africa. The rational for selecting the community will be briefly highlighted.

1.2.4 Resilience building in the context of Southern African subsistence agriculture

Morton (2007:19680) characterises subsistence agriculture as a livelihood strategy where the majority of agricultural output produced is for household consumption, and only a fraction of the produced is marketed to augment household income. Subsistence agriculture is also characterised by minimal access by farmers to productive inputs such as land, equipment water and fertiliser (Cooper et al, 2008:26; Conway, 2008:31; IFAD, 2011). Consequently subsistence farmers in many parts of the globe, including those in Southern Africa, mostly depend on stability of weather patterns and rainfall to produce food to support their livelihood strategy (Davies et al, 2009:3; Cooke, 2015:37;UN ECA-SA, 2013:4). According to Clay (2003:18) this dependance on erratic and ever changing weather patterns increases the overall vulnerability of subsistence farming population, especially in terms of levels of poverty and food security. Increasing vulnerability of subsistence farming communities is concerning in the context of Southern Africa.

Currently, subsistence agriculture is one of the most common livelihood strategies in Southern Africa and contributes significantly to the regions economy (Davies et al, 2009:11; IFAD, 2011). According to Abdalla (2007:52) and UN ECA-SA (2013:2) between 80-85% of the population of the region are dependant on subsistence agriculture as their primary livelihood strategy (including for substance, income and employment). This sector is however severely threatened by two overarching constraints, i.e. weather related risk and structural constraints, both of which could increase vulnerability and reduce resilience to disasters for subsistence agricultural communities (Morton, 2007:19683). The first constraint, weather related risk, has in the past severely affect the region. According to Clay et al (2003:17) and Abdalla (2007:21) droughts are the most common hazard in the region with major drought occurring in 1991/1992 (region wide), 1993/1994 (Malawi, Mozambique, Zambia), 1997/1998. These droughts severely affected food production on household and country levels, with the greatest impact being felt by poor, subsistence farming communities (Clay et al, 2003:17; Abdalla, 2007:21). Flooding also occurred in the region with

prominent flood events occurring in 1999/2000 (region wide), 2001 (Mozambique). The impact of drought and flood events have continued to cause large scale devastation, with UNOCHA-ROSA (2015) estimating a total number of 27 million and 6,7 million people affected by droughts and floods in the region for the period between 2005-2015. Various scholars observe that the impact of droughts and floods on subsistence agriculture in the region is in all likelihood going to increase with the influence of climate change in decades to follow (Cooper et al, 2008:25; Clay et al, 2003:18; Morton, 2007:19684, Davies et al, 2009:3 IFAD, 2011). This change in the normal climate regime provides special challenges to subsistence farmers in Southern Africa as they often do not have the structural means to adapt to rapid changes in their environment. Morton (2007:19682-1683), Conway (2008:31) and Cooke (2015:37) highlights that non-climatic stressors such as poor market access, poor government and organised agriculture support (policy, extension services, limited farmers associative mechanisms), lacking or underdeveloped agriculture inputs (irrigation, crop varieties, small farm sizes) poor cropping techniques, environmental degradation and lack of insurance mechanisms hamper the overall level of adaptability of subsistence farming communities in the region.

The ability to adapt and change behaviour are crucial aspects of the concept of resilience. Therefore, the lack of adaptive capacity of Southern African subsistence agriculture communities to environmental and structural stressors could also be linked to the concept of disaster resilience. According to Stringer et al (2009:749) the study and building of resilience is crucial as it aids in reducing vulnerability and builds adaptive capacity of subsistence farming communities to multiple threats. The study will therefore primarily focus on creating a more in-depth understanding of resilience, but will use subsistence agriculture communities in Southern Africa as a relevant case study tool as they constitute a community with low levels of disaster resilience.

1.3 RESEARCH DESIGN AND METHODOLOGY

As elaborated on in section 1.2, the thesis aimed to identify the potential contribution of CAST and its specific elements such as non-linearity, emergent behaviour and feedback loops in understanding disaster resilience. To achieve the research purpose as specific research design and methodology had to be applied. This section will highlight some of the key methodological step that applied to achieve the researches overall purpose. As a point of departure the research objectives formulated to guide the study are discussed. This is followed by an in-depth discussion on the research question formulated for the study and how the researcher envisioned these questions to link together to give answers pertaining to the overall research goal.

1.3.1 Research Objectives

The research objectives formulated for the thesis are as follows:

RO 1: Determine the theoretical tenets of resilience and Complex Adaptive Systems Theory.

RO 2: Explore the theoretical linkages between Complex Adaptive Systems Theory and the concept of Resilience.

RO 3: Explain how information feedback within farmers associative mechanisms play a role in fostering disaster resilient behaviour.

RO 4: Determine the basic theoretical principles associated with systems emergence.

RO 5: Explain how systems emergence contributes to understanding and building disaster resilience in agricultural communities.

RO 6: Determine the basic theoretical principles associated with systems principle of non-linearity.

RO 7: Explain the implications of the concept non-linearity on our understanding of disaster resilience and the building thereof.

1.3.2 Research questions

This section describes the research questions and how they were formulated. The overall research question for the study was formulated as follows:

Can a Complex Adaptive Systems paradigm provide an alternate understanding of how to build disaster resilience?

This question was broken down into sub-questions that prescribes how the research was focused, in order to achieve the overall research objective. They are:

RQ 1: What are the theoretical tenets of resilience and Complex Adaptive Systems Theory?

RQ 2: What are the theoretical linkages between Complex Adaptive Systems Theory and the concept of Resilience?

The thesis had to firstly establish if there is a theoretical linkage between the concept of resilience and the theory (CAST) that would guide the subsequent analysis process. RQ1 and RQ2 were formulated to work in unison to illuminate possible areas of synergy between the two areas. RQ1 aimed to identify and separate the key tenants of the individual areas of inquiry (Resilience and

CAST). Once RQ1 had been achieved, RQ 2 endeavoured to identify similarities between the different areas and the possible application of CAST elements in understanding disaster resilience.

To test whether the theoretical conclusions reached and system based tools identified by RQ 1 and RQ 2 were applicable to understanding resilience in reality it was necessary to elaborate on and test some of systems based tools for understanding resilience. The system tools identified could be sorted into ***cross-cutting issues*** and ***priority investigation issues***. It was found that a subject like context based responses would not need to be investigated in a separate article as different social context would effect feedback loops, emergence and lead to non-linearity. As such, context based responses would feature in all these specific articles in some form. Priority investigation issues would have to be addressed in separate articles, as these elements have extensive theoretical literature connected to them. The understanding of which would provide a clearer insight into how systems function and could stimulate system wide resilience. Priority investigation issues would focus on the elements of information feedback loops, emergence and non-linearity. These priority investigation issues would also be applied to the context of subsistence agriculture communities in three Southern African countries. The following broad(BQ) and specific (RQ) research question were formulated per priority investigation issues:

BQ: Does CAST concepts advance current resilience thinking?

RQ 3: How does information feedback within farmers' associative mechanisms play a role in fostering disaster resilient behaviour (see article 2)

This research question served as an important point of departure for the study once the theoretical grounding was established (**RQ 1 and 2; Article 1**). The reason for this was that within complex adaptive systems theory it is argued that adaptation and change (and by extension resilience behaviour) within systems are controlled by the presence of information feedback loops. Information feedback loops allow for interaction to take place between internal and external system elements, and from these interactions, complex emergent system behaviours such as disaster resilience can arise. Therefore, RQ 3 was formulated with the view of identifying central role information feedback in driving systems to more resilient behaviour.

Information feedback loops and interaction play a central role in the emergence of system wide behaviours including disaster resilience. The identification of emergent behaviour stimulated the question about what emergence entails on a theoretical and practical level. Therefore, RQ 4 and RQ 5 were formulated to create a more in-depth understanding of the functioning of emergence and emergent system behaviour.

RQ 4: What are the basic theoretical principles associated with systems emergence?

RQ 5: How does systems emergence contribute to understanding and building disaster resilience in agricultural communities?

RQ 4 was crucial as a means to identify the theoretical concepts associated with emergence. Identifying the key concepts related to emergence would allow the researcher to have a theoretical insight into the workings of emergence. This would also provide a theoretical parameter that would guide the practical analysis of how emergence could aid in building disaster. This practical application was to be guided by answering RQ5.

RQ 5 was formulated with the view of determining the specific benefits of using the systems concept of emergence for the understanding of disaster resilience. The question gave guidance to the practical application of the concepts identified in RQ4. The results from RQ5 gave an indication of how micro-level interactions could escalate into macro level behaviours such as disaster resilience. This resilience could be beneficial to the system as a whole. However, a cursory literature review towards answering RQ5 established that emergent behaviour is inherently non-linear in its outcome. This means that even though resilience could emerge due to micro-level interactions, how one would get to the macro level resilience behaviour would differ from community to community as contextual factors would greatly influence micro level interactions that subsume the emergence of resilient behaviour.

This finding was significant in that traditionally the building of resilience is treated as a very linear process, with “one size fits all” models to building disaster resilience being the norm in disaster risk science. The notion of non-linearity and its applicability was therefore crucial to explore, if there is to be a move to a systems paradigm of disaster resilience. RQ 6 and RQ 7 were formulated to give guidance on non-linearity’s possible contribution to understanding disaster resilience

RQ 6: What are the basic theoretical principles associated with systems principle of non-linearity?

RQ 7: What are the implications of the concept non-linearity on our understanding of disaster resilience and the building thereof?

RQ 6 and RQ 7 were formulated with the intention to work in unison. As was stipulated when exploring the concept of emergence, the theory stated that macro level behaviour such as resilience can emerge because of micro level interactions, but that the process of how the behaviour might emerge would be different depending on the context. To test this implication RQ 6 had to be formulated to give a solid theoretical understanding of what non-linearity refers and what the implication of these theoretical tenants are to the understanding of resilience. This would be followed up by RQ 7, which would aim to practically apply the theory of non-linearity to the case of agricultural communities. From this application patterns of non-linear behaviour would be identified

and the implication of these patterns for our traditional understanding and building of resilience would be explored.

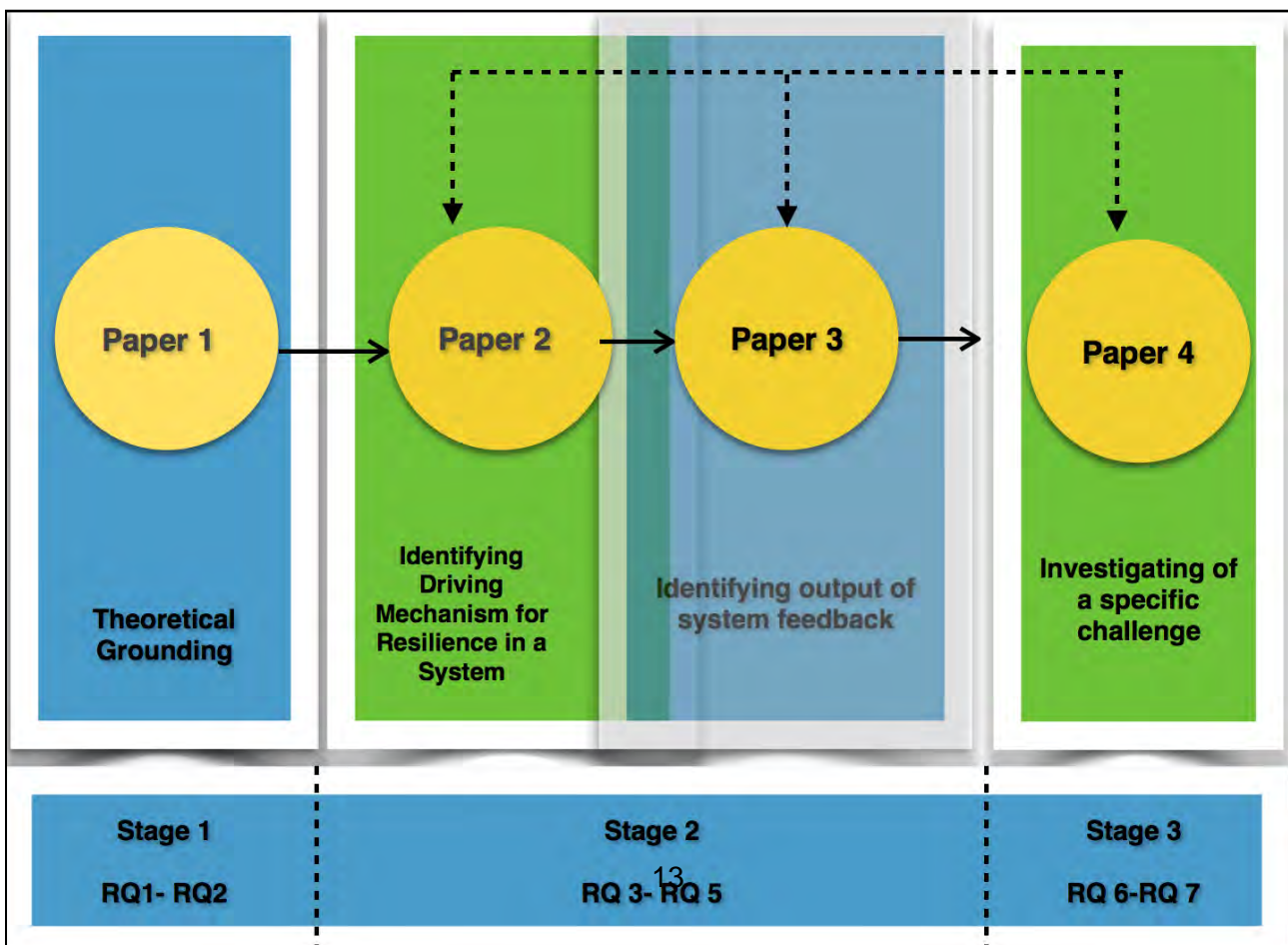
1.3.3 Research Process

The research questions described in the preceding section were developed in a process that unfolded over a period of 2 years. Therefore, this section does not necessarily reflect the original research plan, due to dynamic changes that occurred as the research process evolved. Figure 2 shows the three stages that comprised the research process.

Figure 2: Stages of the research process

1.3.3.1 Stage 1

Paper 1 was developed during this stage. This paper provided the foundation for the research as it aimed establish a theoretical link between the concept of disaster resilience and the theory of CAST. Stage 1 established that on a theoretical level the underlying principles of disaster resilience and CAS are very similar, warranting the use of CAST as a theoretical analysis tool for further study of resilience. Specifically, elements of non-linearity, aggregation, emergent behaviour, feedback loops, adaptation and context-based responses were found would assist researchers focusing on the issues of disaster resilience to gain a holistic view of the dynamic interaction between resilience generating factors and local, sub-national and national and sectorial context in which they function. The results motivated the more in-depth investigation of feedback loops, emergent behaviour and non-linearity. Context based responses, aggregation and adaptation would be treated as cross cutting issues across the papers produced in stage 2 and 3.



1.3.3.2 Stage 2

Figure 2 shows that paper 1 directly led to the development of paper 2. During the development of paper 1 it became clear that that information feedback is the key driver to adaptive behaviour that is a prerequisite to moving to more resilient societies. This finding therefore warranted the formulation of paper 2. The development of paper 2, reviewed that due to information feedback between micro level elements could leave to macro-level behaviour through the process of emergence. This finding influenced the formulation of paper 3. Within paper 3 it was established that although macro level resilience could emerge due to micro level interactions, the emergent behaviour would be non-linear due to unique contextual factors of communities.

1.3.3.3 Stage 3

Stage 3 presented an investigation of a specific challenge. In this instance paper 4 addresses the issues that contemporary understanding and addressing of disaster resilience often approach the process in a very linear way. In this instance it is argued that linear approaches to building resilience does not talk to the reality that very little of the world or even regions within a country is the same. Paper reports the results of testing the influence on non-linearity in different agricultural context and illustrates that considering the CAST concept of non-linearity would allow for a move to more context specific resilience building interventions instead of “one size fits all approaches”.

1.3.4. Philosophical assumption and methodology of thesis

There are three dominant research paradigms namely positivism, interpretivism and transformativism that help to frame the purpose and outcomes of a research intervention (Paterson and Williams, 2005:38). Positivism and interpretivism (also referred to as anti-positivism) represent polar opposite paradigms in that positivism argues for a research intervention to be mostly quantitative, based on the world of numbers and statistics as separated from human feelings/values and beliefs (Snape and Spencer, 2013). Interpretivism focuses mostly on the realm of trying to understand the social world by deciphering human emotions, beliefs and values by means of qualitative inquiry (Ponterotto, 2005). Additional to these two paradigms is the paradigm of transformativism. This paradigm departs from the point of view that scientific inquiry should contribute to addressing structural injustices, inequalities and asymmetries within society (Mertens, 2007).

Although all these paradigms have relevant application for the proposed research study, none of them constitute an outright match to assist with addressing the research question and objectives. Instead, to accommodate the overarching positive qualities of all three these paradigms, a transdisciplinary paradigm was selected to guide the research study. On a theoretical level, transdisciplinary paradigms incorporate methods, concepts and tools from other research disciplines to bring about a holistic understanding and problem solving ability within different

research environments (Alroe and Kristensen, 2001:17; Nowotney et al, 2003:186). This characteristic of transdisciplinary research is ideally suited to understand a complex issue such as disaster resilience in agriculture. Specifically, it allowed the researcher to employ both qualitative and quantitative research concepts, theoretical frameworks and tools, to help to understand the dynamic interactions of variables that can contribute to generating resilience within societies.

Nowotney et al (2003:191), Scott (2003:78) and Gibbons (2000:159-160) highlights that a trans-disciplinary approach to research is ideally suited to research context where new methodologies, theories and concepts are being designed. This characteristic is extremely relevant to the context of this study as it intends to explore the application of complex adaptive system theory to the understanding of disaster resilience, something that has not yet been attempted. The novelty, of the study therefore forces the researcher to apply a trans-disciplinary research paradigm comprising of multiple research approaches and tools in a single study.

The selection of a transdisciplinary research paradigm also allowed for an applicable research ontology, epistemology and axiology. In a research context, ontology refers to a broader philosophical paradigm that guides the study based on the researchers "beliefs about the nature of the social world and what can be known about it" (Snape and Spencer, 2013:13; Winter, 2001:587; Scholz et al., 2006: 233). The ontology of a transdisciplinary study postulates that although differences exist between studies focused on the natural and human systems, it becomes almost a logical fallacy in treating these two systems as separate. Instead, meaning and understanding of reality can only be generated in a holistic manner, searching for possible linkages between knowledge about nature and society that would provide a deeper understanding of human systems in their entirety (Snape and Spencer, 2013:13). This orientation suited the proposed study as understanding factors that contribute to generating disaster resilience in agricultural settings would require the study to take into account factors from the natural and social environments of the communities (Alroe and Kristensen, 2001:4). Finally, selecting this approach allowed for the selection of a holistic research paradigm, such as Complex Adaptive Systems Theory, which allowed for the incorporation and consideration of variables from the natural and human environment.

According to Farley et al. (2009:61) and Scholz et al. (2006:233), "epistemology is concerned with ways of knowing and learning about the social world and focuses on questions such as: how can we know about reality and what is the basis of our knowledge?". A primary concern of epistemology is the relationship between the researcher and the researched (Snape and Spencer, 2013:13). In the case of this study, a secondary data analysis was conducted, so there is no direct relationship with the "researched". However, the research data base from which the proposed study was generated was collected with the aim of being as inclusive as possible to ensure agreement between the researcher and the researched on key issues (Snape and Spencer, 2013:13). The questionnaire was developed by the primary research partner (African Centre for Disaster Studies), but before it was implemented in the field, the questionnaire went through

several peer review processes, and a pilot study, with FAO and in-country partners in Malawi, Mozambique and Madagascar to assure the relevance and accuracy of the questions being asked. This co-production of knowledge was extended to the research participants, as they were not only asked to answer quantitative question, but were encouraged to elaborate on the qualitative issues to provide deeper insights into aspects of the research. Once the draft report was generated, the collaborative nature of the research was continued with in-country partners who provided peer review and input towards the final project report. The collaborative approach applied to the study is indicative of the underlying axiology of the research project.

According to Jahani and El-Gohary (2012:798), if the term axiology is to be broken down to its Greek roots, two components can be identified, 'axios' and 'logos', meaning 'value' and 'theory' respectively. On a practical level, axiology relates to the underlying values at the core of the development of theory or knowledge within scientific research. Within traditional research paradigms such as positivism and interpretivism, strict adherence to disciplinary knowledge systems and research traditions form the core of why and how research is conducted. Traditionally there is very limited transdisciplinary integration of knowledge to explore a research problem. This value limitation is problematic when addressing a problem in a complex field such as disaster risk management, which inherently deals with multi-dimensional problems, such as building societal resilience to disaster risk, which is in turn the focus of the research study. Therefore, the axiology of the study drew on information and models that were not solely based in the field of disaster risk management, but made use of a diverse disciplinary and non-disciplinary models from knowledge fields such as systems theory, agriculture, sustainable development and human ecology to analyse contextual factors that are crucial in generating societal disaster resilience.

The discussion on research paradigms, ontology, epistemology and axiology has sketched the philosophical inclinations that gave guidance to the thesis. The next section focuses on the research context and methods applied within the study.

1.3.4.1 Research Context and Method

The study was based on an extended research project conducted as part of a research team on behalf of the Food and Agricultural Organization of the United Nations in three Southern African states namely Madagascar, Malawi and Mozambique (see figure 2). A combined total of 1110 respondents formed part of the study, of which Mozambique represented 40.3% (N=447) of participants, Madagascar 30.4% (N=337) and Malawi 29.4% (N=326). The main driver behind the study was the realisation that Southern Africa's ever-changing risk profile poses a very real threat to exploiting the existing societal vulnerabilities, which could lead to catastrophic disasters in the region. Notably within the region small scale, subsistence agriculture plays a crucial role in generating livelihoods and food security for households and society as a whole. Although this sector is seen as a primary driver for social-economic development and food security, it still remains one of the most vulnerable to the impact of hazards. As such one of the proposed outcomes of the original study was to identify factors that could build resilience in the context of

livelihood systems, which when threatened by shocks, severe events and hazards, have the potential to help the system to recover from and adapt to adverse outcomes. Specifically, the study tried to track the relative contribution of the following agricultural inputs to building resilience in all three countries:

- Small-scale irrigation systems;
- Farmers' associative mechanisms;
- Appropriate crop varieties;
- Cropping Techniques; and
- Timing of production.

The study provided a wealth of data that was not fully analysed or presented in the final report to FAO. This unexplored data set provided interesting insight into the macro level agricultural resilience in the region, and also provide an opportunity to identify contextual drivers of resilience within each country and sub-region. Due to the fact that much of the data from the project was not analysed , the thesis employed a secondary data analysis methodology on the existing data set. The section to follow will highlight the rationale for the selection of secondary data analysis methodology and why it was relevant to achieving the outcomes of the study.

1.3.4.2 Relevance of secondary data analysis in the study context

Methodologically, secondary data analysis can be defined in various ways. According to Rew et al. (2000:223), secondary analysis relates to using existing data sets, and formulating new lines of enquiry that might not have been the focus of the original study. Ritchie et al. (2003:89), Coyer and Gallo (2005:60) and Windle (2010:332) agree that secondary data analysis can be identified by the revisiting of existing data sets and applying new research objectives to illuminate different perspectives. However, each of these sources also highlights additional aspects that are key to understanding what secondary analysis is, and why it would be useful for the proposed study. For instance, according to Ritchie et al. (2003:89), secondary data analysis is a method that not only allows the researcher to conduct research with a new set of research objectives, it also allows for historical comparative studies due to the existence of multiple data sets, and for the application of new theoretical perspectives on the same data sets. Coyer and Galo (2005:60) elaborate briefly that secondary research is an ideal tool for studies with large sets of statistical data as it allows the researcher the opportunity to apply different statistical techniques and methods to the data to generate multiple perspectives. Windle (2010:332) adds another crucial perspective on the use of secondary data analysis as an appropriate methodology in stating that:

“It allows for the analysis of an existing dataset to address a different research question or to conduct research with data that was not collected for research purposes”.

The quality highlighted by Windle (2010) provides an appropriate link to the relevance of the use of secondary data analysis as an appropriate method of inquiry for the study. The data set collected for the FAO project was collected primarily to gain baseline information on five resilience-generating factors in agricultural communities in Malawi, Mozambique and Madagascar. The data collection did not make provision for the application of theoretical models such as Complex Adaptive Systems Theory, as an academic audience was not the intended recipient of the final report, but disaster practitioners within the target countries. Additionally, the data were collected with a certain set of prescribed research objectives (as per the direction of FAO) that would help to establish basic indicators of resilience in farming communities. This was subsequently done, but the wealth and depth of the data collected allowed for the possibility of more in-depth analysis of resilience and for isolating those emergent systems behaviours that contribute to building resilience. A secondary analysis of the data set is therefore not only possible, but also crucial if the thesis is to give insights into the dynamic nature of resilience in agricultural settings.

From the discussion above it is clear that there was a clear theoretical grounding and benefit to applying secondary data analysis as a means of extrapolating new research focuses from existing data sets, as is the case with this thesis. The proposed application of the secondary data analysis research is touched on next.

1.3.4.3 Application of secondary data analysis in the study

According to Windle (2010:332-333), secondary data analysis can be applied to study either as an appended study or meta-analysis. A meta-analysis would refer to a study that compares data sets from different studies to identify positive or negative correlations between the different sets of data (Scandura and Williams, 2000:1251). This is opposed to an appended study, which opts to use the same data set collected for an original study, but with new research objectives to either open up new avenues of exploration, or to allow for a more in-depth analysis of existing findings (Windle, 2010:332-333). This study was framed within the provisions of an appended study. The main reasons for this is that the initial study provided only a basic impression of how small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, cropping techniques and timing of production, contribute to disaster resilience in agricultural communities. The dynamic interplay between these factors in different scales and contexts was touched on only briefly and warranted further study. Consequently, the study formulated new research questions and objectives to better illustrate some of the dynamic interaction between factors in order to generate disaster resilience

The process that was followed in conducting the appended, secondary data analysis is summarised in the table 1 below:

Table 1: Research Process: Secondary analysis in the context of the Thesis

Methodological Process	Study Application
<i>Determine data context</i>	The general rule within secondary data analysis is that data sets with similar focuses and operational definitions should be compared to ensure relevance and accuracy of findings. Being an appended study, alignment with the original focus and context is assured as the same variables focusing on determining disaster resilience and same contexts (Malawi, Mozambique and Madagascar) formed the focus of study.
<i>Determine research population applicability</i>	According to Rew <i>et al.</i> (2000:225-226) the researcher has to “ <i>ensure that there is a resemblance between the subjects from whom data were originally collected and the population to whom the new set of research questions applies</i> ”. This did not affect the study, as the same populations used in the original data collection was used again. This is because the purpose of the study was to gain a more in-depth understanding of the data gained from the participants in the original data collection process.
Formulation of research questions	As the research context and research population do not differ from the original study, the process of generating appropriate research questions is vested in a critical review of the total research report produced for FAO on resilience in agricultural communities. This critical review has already been completed and appropriate research questions and objectives have been produced.
<i>Select appropriate theoretical framework</i>	An appropriate theoretical framework, in the form of Complex Adaptive Systems Theory was applied in the study to explore the dynamic interplay of resilience-generating factors. The application of the theory is consistent throughout the four research articles.

<p>Selecting research tools to address research questions</p>	<p>The study used the quantitative data set collected within the FAO study. The data set contained over 60 variables associated with disaster resilience collected across three countries. This provided the study with a wide scope to conduct in-depth studies on resilience-generating behaviour between different factors and in different contexts. The data set allowed the researcher to answer the formulated research questions.</p> <p>Additionally, the study used qualitative reports formulated by regional partners in Mozambique, Malawi and Madagascar to inform and elaborate on the quantitative data collected.</p>
<p>Conduct literature reviews to address the subject or new research questions</p>	<p>The final process in the methodology included conducting individual literature reviews for all the articles that formed part of the thesis. This enabled the researcher to focus on the theory related to each question separately, while also assuring alignment with the overall theoretical framework of the study.</p>

1.3.4.4 Research methods an empirical data

For the purpose of clarity it is also necessary to outline the research and empirical data collection methods applied to the appended study (see summary in Table 2 below).

Table 2: Research methods an empirical data within the thesis

PAPER	RESEARCH METHOD AND SAMPELING	EMPIRICAL DATA	GEOGRAPHICAL AREA AND LEVEL
<i>Paper 1</i>	Document analysis	80 (academic articles; book chapters; technical reports)	Global
<i>Paper 2</i>	Document analysis and Secondary Data Analysis Purposeful sampling	70 (academic articles; book chapters; technical reports) 593 respondents	Madagascar; Malawi; Mozambique
<i>Paper 3</i>	Document analysis and Secondary Data Analysis Purposeful sampling	37 (academic articles; book chapters; technical reports) 891 respondents	Madagascar; Malawi; Mozambique

Paper 4	Document analysis and Secondary Data Analysis Purposeful sampling	47 academic articles; book chapters; technical reports) 891 respondents	Madagascar; Malawi; Mozambique
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As discussed in section 1.3.4. a transdisciplinary paradigm was followed to guide the selection of research design and tools within the study. The selection of a transdisciplinary paradigm allowed each individual research article to have its own unique research design and tools. This however meant that the overall study did not have a single overarching research design and tools. Therefore a brief discussion can only be given on the research design and empirical data collection methods applied within each article (see summary in Table 2 below).

Article 1, being the theoretical base of the study, made use of a qualitative research design comprising of an in-depth document analysis. The document analysis made use of a wide array of document including, academic articles, book chapters and technical reports on the issues of disaster resilience and CAST. Paper 2, 3 and 4 made use of mixed method approaches. As a base Paper 2,3 and 4 all have a qualitative component in the form of a document review. In the case of Paper 2 (“Information feedback functions within farmers associative mechanisms and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa”) an additional qualitative component is added with focus group interview responses from case study countries. Paper 2,3,4 also contain significant quantitative components. Paper 2, 3, and 4 all contain correlation statistics as the primary format for statistical analysis. Correlation statistics were selected as the most appropriate statistical tool as it could indicate a relationship between agricultural inputs and resilience indicators. Paper 2 also added descriptive statistics to indicate in percentage, the level of agreement of participants with certain statements. Purposeful samples were utilised in all the papers. Importantly, only purposeful samples with valid responses (i.e respondents providing responses to the questioning being asked) were considered for analysis. This explains the difference in the amount of respondents per paper (P 2=N593; P 3= 891; P= 891).

1.3.5 Limitations of Study

A key limitation of the study is that it made use of a pre-existing data set to guide the data analysis process. Using a pre-existing data set had the implication that the data variables collected were already set and could not be added to by the researcher. This meant that the research could only use the variables of irrigation systems, farmers’ associative mechanisms; crop varieties, cropping techniques and timing of production to guide the formulation of correlation and descriptive statistics. This could create the impression that that the author had not considered other factors that could impact on the resilience of subsistence agriculture communities in the case study countries. This however, is not the case and is a limitation imposed on the study by the extent of the data collected in the original study conducted by FAO.

1.4 DIVISION OF CHAPTERS

Chapter 1: Introduction

Chapter 2: Disaster Resilience and Complex Adaptive Systems Theory - Finding common grounds for risk¹

Chapter 3: Information feedback functions within farmers associative mechanism and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa²

Chapter 4: Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture³

Chapter 5: Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa⁴

Chapter 6: Conclusions and Recommendations

The chapter to follow will serve as the departure point for the theoretical argument to be made by the thesis. Crucially, it will primarily focus on establishing the theoretical tenants of both disaster resilience and Complex Adaptive Systems Theory (CAST) as a means to find possible areas of synergy between the two concepts. The possible application and contribution of CAST concepts to the understanding of disaster resilience are also elaborated on.

¹ Coetzee, C., Van Niekerk, D and Raju, E. 2016. Disaster Resilience and Complex Adaptive Systems Theory -reduction. *Disaster Prevention and Management*. 25(2): 196 - 211. doi:10.1108/DPM-07-2015-0153

² Coetzee, C., Van Niekerk, D and Raju, E. 2016. Information feedback functions within farmers associative mechanism and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa. Submitted to *International Journal of Disaster Risk Science* (April, 2016)

³ Coetzee, C., Van Niekerk, D and Raju, E. 2016. Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture. *International Journal of Disaster Risk Reduction*. 16:115-122. doi: 10.1016/j.ijdr.2016.02.001

⁴ Coetzee, C., Van Niekerk, D and Raju, E. 2016. Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa. Submitted to *Natural Hazards* (March, 2016)

Chapter 2: Disaster Resilience and Complex Adaptive Systems Theory - Finding common grounds for risk reduction

It all starts here TM



Disaster resilience and complex adaptive systems theory

Finding common grounds for risk reduction

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Abstract

Purpose – The purpose of this paper is to explore the emergence of resilience into the contemporary discourse of disaster risk. As a counter position to the current status quo in defining and addressing resilience, this paper introduces the theoretical lens of complex adaptive systems theory (CAS). Some of the key characteristics related to CAS are discussed and linkages are made to possible benefit that they might have in enhancing the understanding of disaster resilience.

Design/methodology/approach – An indepth review of literature pertaining to disaster resilience and CAS was conducted to find common grounds for theoretical synergies.

Findings – The inherent similarities between the concept of resilience and CAS provides ample practical and theoretical contributions to the field of disaster risk studies.

Originality/value – The paper provides a different perspective to the contemporary discourse on disaster resilience. A better understanding of disaster resilience and its underlying dynamics as illuminated by the application of CAS could in future provide an effective tool to manage disaster risks and building of resilience.

Keywords Disaster risk, Adaptation, Resilience, Complex adaptive systems theory

Paper type Research paper

1. Introduction

Disasters have been part of human existence since the beginning of time, however the impact of these events have become more pronounced in recent decades leading to increase in loss of lives, livelihoods, infrastructure, biodiversity and linked socio-ecological systems. The dramatic impact of hazards and disasters on human systems have caused society to create new scientific fields, policies and programmes to deal with their consequences. One such scientific field that has risen to prominence since the early 1990s is the field of disaster risk management (Van der Waldt, 2013). The field has used concepts such as vulnerability, and risk to explain why human systems are susceptible to disasters whilst also formulating possible explanation and tools to determine how to reduce disaster risk. A prominent contemporary issue of debate and practice in reducing disaster risk is the notion of resilience (Miller *et al.*, 2010). Originally introduced from the field of ecology, the operational definition of resilience adopted in the paper within a disaster context is the defined as “ability of a community to respond and recover from disaster impacts through adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a disaster” (Timmerman, 1981; Pelling, 2003; Cutter *et al.*, 2008).



In spite of the contemporary nature of resilience in the disaster risk reduction discourse very little agreement exists between academics and practitioners as to preferential methods to build disaster resilience in disaster and hazard affected communities (Maru, 2010; Gaillard, 2010; Zobel, 2011; Alexander, 2013). A possible avenue for exploration presented in this paper is the use of complex adaptive systems (CAS) theory. The application of systems thinking (including CAS) in the understanding of disaster resilience is not part of a completely new discourse (Cutter *et al.*, 2008; Frerks *et al.*, 2011). However, the use CAS as a theoretical perspective to study disaster resilience is still in its infancy. The inherent similarities between the concept of resilience and CAS could provide ample practical and theoretical contributions to the field of disaster risk studies and therefore warrants further investigation. A better understanding of disaster resilience and its underlying dynamics (as illuminated by the application of CAS and hazard) could in future provide an effective tool to manage disaster risks and build resilience.

The paper explores the emergence of resilience into the contemporary discourse of disaster risk (DRR). As a counter position to the current status quo in defining and addressing resilience, this paper introduces the theoretical lens of CAS theory. Some of the key characteristics related to CAS are discussed and linkages are made to possible benefit that they might have in enhancing the understanding of disaster resilience.

2. Emergence and application of resilience in DRR

With the recurrent and increasing human and capital costs of disasters, came the realisation that there must be more efficient ways of managing and preventing disasters than merely responding to impacts (United Nations, 1989; Oliver Smith, 2009). Pre-disaster planning seemed like a practical and necessary component to compliment traditional thinking (Lewis *et al.*, 1976). Consequently, since the 1960s, a plethora of disaster management theories, tools and policies such as the disaster management cycle (Baird *et al.*, 1975), the pressure and release model (PAR) (Wisner *et al.*, 2004) and international policy measures such as the United Nations (1994), the International Decade for Natural Disaster Reduction (1990-2000), International Strategy for Disaster Reduction (2001-2010), the Hyogo Framework for Action (2005-2015) and recently the most recent Sendai Framework for DRR (Action 2015-2030), all of which aims to contribute to the curbing of disaster losses, were developed. Key to all the ideas and protocols was the emergence of definitions and practices that espouse a pro-active orientation to disasters and risk, these included: disaster risk reduction (where the orientation was always about disaster response and civil protection), vulnerability (of communities and the systems in which they function), societal capacity and resilience (Miller *et al.*, 2010; Cimellaro *et al.*, 2010).

The concept of resilience in its present form as it has taken prominence between 1990-2015 remains one of the most contested in the field of disaster risk studies (Manyena, 2006; Gaillard, 2010; McEntire, 2005). For instance, there is consensus that risk is a function of people's vulnerability (social, economic, political, physical and environmental) interacting with hazards (hence the notation of risk = vulnerability×hazard) (Oliver Smith, 2009; Lopez-Calva and Ortiz-Juarez, 2009; Mechler, 2004). There is also a large degree of agreement that people's vulnerability to natural hazards and a lack of capacity to address identified vulnerabilities makes a society more susceptible to the impact of a disaster and often amplifies the eventual damage (Oliver Smith, 2009; Wisner *et al.*, 2004; Lopez-Calva and Ortiz-Juarez, 2009). This level of agreement does not exist when academics and practitioners argue the merits of the concept of resilience (Manyena, 2006; Gaillard, 2010; Klein *et al.*, 2003; Zobel, 2011; Zhou *et al.*, 2010; Hufschmidt, 2011).

According to Mayunga (2007) and Manyena (2006, p. 434) one of the greatest issues around the concept of resilience is that there is little theoretical understanding of the concept. Academics and practitioners alike are often at a loss as to how to operationalise, quantify or determine which factors, variables or indicators, make a community resilient. This creates substantial problems. Without a solid theoretical base, “resilience” almost becomes a redundant term that offers very little to improve the effectiveness of existing disaster risk reduction interventions or policy formulation (Mayunga, 2007). Therefore as a point of departure in understanding the complexities in using a term and its application in CAS, one should focus on describing the origins and original use of the term resilience.

2.1 Stability and resilience

The term resilience in the DRR domain, gained prominence in the contemporary post-2005 discourse, resulting from the devastating impact of the Indian Ocean tsunami (2004) followed by the World Conference on Disaster Reduction held in Hyogo, Japan (2005) (Shaw, 2006; Levy and Gopalakrishnan, 2005; Djalante, 2012). During the conference there was recognition that there is a need to not only build back communities once disasters occur, but also to improve their overall level of resilience with the view to eliminating the threat of future disaster or at least mitigating their impacts (Cimellaro *et al.*, 2010, p. 3640; Manyena, 2006; United Nations International Strategy for Disaster Risk Reduction, 2005; Gaillard, 2010; Zobel, 2011; Cutter *et al.*, 2008; Tadele and Manyena, 2009; Zhou *et al.*, 2010). To appreciate the contemporary understanding and application of resilience in disaster risk management, it is crucial to explore the influence of the field of ecology on the theoretical development of resilience.

The term resilience (as used in the field of disaster risk management) resembles that of the definition of resilience as conceptualised within the fields of ecology, during the 1970s (Kuhlicke, 2013; Rose, 2007; Gaillard, 2010; Klein *et al.*, 2003; Cutter *et al.*, 2008; Zhou *et al.*, 2010; Hufschmidt, 2011). Specifically, Holling (1973) postulated that resilience can be defined as:

[...] the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameter and still persist.

Holling’s definition refers to the ability of a system to absorb changes to its basic or complex building blocks yet still manage to function following a disturbance (Tidball *et al.*, 2010; Maru, 2010; Klein *et al.*, 2003; Rose, 2007; Hufschmidt, 2011). In his discussion on resilience, Holling (1973) also introduced the related concept of stability. Stability refers to the ability of a system to return to equilibrium after a temporary disturbance (Holling, 1973; Alexander, 2013; Klein *et al.*, 2003; Cutter *et al.*, 2008). Interestingly, many contemporary definition of disaster resilience have integrated the concepts of resilience and stability as proposed by Holling thereby confusing the two concepts as parts of the same holistic definition of resilience (Rose, 2007; Paton, 2006; McEntire, 2005). Rose (2007) and Gaillard (2010), elaborate that a resilient system is often not stable, in that is constantly changing and adapting to external or internal pressures, thereby rendering it with an improved (safer) equilibrium state. Therefore stability is not needed for a system to be deemed resilient but adaptability is (Norris *et al.*, 2008; Zhou *et al.*, 2010; Paton, 2006; Klein *et al.*, 2003).

According to Timmerman (1981, p. 21) the value of the original definition by Holling was exactly in that it separated the issue of stability (reaching an equilibrium state) from the issue of resilience, which serves as a function of “probability of extinction”. This separation would help to make it easier to identify only those state variables[1]

and driving variables[2] that would most likely fail and contribute to the extinction of a system (Pisano, 2012; Walker *et al.*, 2012). Timmerman (1981) elaborates on this by stating that there are vulnerabilities (“wounding” as he calls it) that a system could have built into it that would in no way inhibit its ability to persist. This system would address these vulnerabilities through extra efforts or by using excess capacities available to it (Timmerman, 1981, p. 21). The same cannot be said when a system’s resilience characteristic is overwhelmed. When resilience fails, the system cannot compensate from its existing capacities and the system ceases to function (Timmerman, 1981, p. 21). Many subsequent definitions of resilience coming from the field of ecology have shared the basic principles postulated by Holling, and have for the most part focused on the concept of absorbing pressure without losing ability to function (or becoming extinct) (Timmerman, 1981, p. 21; Mayunga, 2007, p. 3).

The ecological definition of resilience shows a close relation to contemporary definitions of disaster resilience (as the engineering definitions focus specifically on structural integrity) Timmerman (1981, p. 21). Various disaster risk management scholars (Mayunga, 2007; Gaillard, 2010; Klein *et al.*, 2003; Rose, 2007; Alexander, 2013; Zhou *et al.*, 2010) agree that the term was most likely first used by Timmerman (1981) in his research on the complex interaction between society and climate. In this seminal work Timmerman, greatly influenced by the work of Holling (1973), defined resilience as: “The measure of the system’s or part of a system’s capacity to absorb and recover from an occurrence of a hazardous event” (Timmerman, 1981, p. 21).

If the definition is analysed it becomes apparent about where some of the confusion comes from when defining resilience. Specifically the definition seems to have integrated resilience functions of a system (its capacity to absorb pressure and avoid probable extinction) and the aspect of stability (ability of a system to return to equilibrium after a temporary disturbance) that allows a system to recover from a hazardous event. This integration causes confusion because it does not allow a differentiation between those components that are crucial to the continued existence of a system (resilience as per the ecological definition) and those components that, although not crucial for the continued existence of the system, still need to recover in order to restore stability (equilibrium).

The lack of differentiation between components crucial for continued resilience of human systems affected by disasters and those components that would contribute to restoring the stability and status quo of affected systems has had serious policy and practical implications. Specifically when communities are assessed for capacities (economic, social, political) they possess to reduce disaster risk, all capacities are automatically presumed to contribute to generating resilience, which is not always the case. Additionally, when a plethora of “resilience factors” are identified, it is difficult to prioritise which should be protected, which should be improved, and which are redundant.

On a theoretical level the combination of resilience and stability lead to a reactive notion of disaster resilience (Klein *et al.*, 2003). Specifically resilience was conceived just as a means to recover from the impacts of a disaster and return to the status quo or previous level of functioning. Maru (2010), supports this by saying: “Most applications of the resilience concept on individual or social systems either explicitly or implicitly assume that a steady state (an equilibrium) is crucial to hold onto or bounce back to after perturbation”.

This notion of resilience (i.e. resisting impact and returning to a steady state), however is problematic in that returning to the status quo means that the societal systems will remain vulnerable to future disaster impacts as it has not adapted to the new conditions and imperatives to change forced on it by the disaster (Klein *et al.*, 2003;

Manyena, 2006). The realisation that it is not enough for human systems to be resistant (ability to bounce back) after disasters, but that adaptation is crucial to resilience, has started to open a new understanding of the holistic nature of resilience (Hufschmidt, 2011; Gaillard, 2010; Rose, 2007). Some of this new understanding is illustrated through the work of Manyena *et al.* (2011) where they state that resilience should rather be viewed as a process of “bouncing forward” or using disaster as a platform from which local societies and the livelihoods on which they depend can be enhanced and be made more adaptable following the inevitable change brought about by disaster. Additional developments in our conceptual understanding of resilience can be seen in the evolution of resilience terminology as depicted in Table I.

Mayunga (2007, pp. 3-5) and Hufschmidt (2011) both agree that new conceptualisations of resilience are starting to place more intimate connections between resilience of communities and capacities available to them, to not only cope with, but adapt to disaster impacts (or adapt to perceived future disaster impacts). According to Hufschmidt (2011) a diverse set of adaptive capacities is key in providing humans systems with the flexibility needed to adapt to disasters and risk, and reduce its inherent vulnerabilities. Incorporating adaption in our conception of resilience also has the potential to change orientation towards resilience. Resilience is often viewed as an outcome that needs to be achieved for a community to be rendered “safe” from disaster-related impacts. However, if one views resilience as an outcome instead of a continuous process, the system can be regarded as stable. As was alluded to earlier, stable systems no longer have the ability to adapt and learn from disaster and risk situations and this would eventually lead to the total collapse of the system (Manyena, 2006).

The above argument links with systems theory notions of open vs closed systems. Closed systems, such as outcome-focused resilience, already contain the premium level of resilience that the system will attain as well as all the capacities that support it (Von Bertalanffy, 1950). This type of resilience will eventually fail in the light of new environmental and social pressures associated with changing disaster risk profiles, as the system has lost the ability to learn and to adapt. On the other hand, treating resilience as

Author (year)	Definition
United Nations International Strategy for Disaster Risk Reduction (2002)	“The capacity of a system, community or society to resist or change in order that it may obtain an acceptable level of functioning and structure”
Pelling (2003)	“The ability of an actor to cope with or adapt to hazard stress”
Cutter <i>et al.</i> (2008)	“Resilience is the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat”
Zhou <i>et al.</i> (2010)	“Dynamic resilience can be enhanced by adjusting, adapting to hazards, and learning from the disasters according to the theory of the adaptive cycle”
Manyena <i>et al.</i> (2011)	“Disaster resilience could be viewed as the intrinsic capacity of a system, community or society predisposed to a shock or stress to ‘bounce forward’ and adapt in order to survive by changing its non-essential attributes and rebuilding itself”

Table I.
Development
of resilience
terminology

open systems (process orientated resilience) will allow for social systems that achieve disaster resilience through maintaining themselves in a continuous inflow and outflow of information (learning from past events) and building up and breaking up of components (adding new capacities/losing absolute capacities) (Von Bertalanffy, 1973; Boardman and Saucer, 2008; Kast and Rosenzweig, 1972; Whitchurch and Constantine, 1993).

Apart from theoretical and philosophical differences in defining and explaining resilience, there are also practical difficulties in measuring when a community is resilient or what components or capacities they need to develop/build in order to become “more resilient” (Renschler *et al.*, 2010).

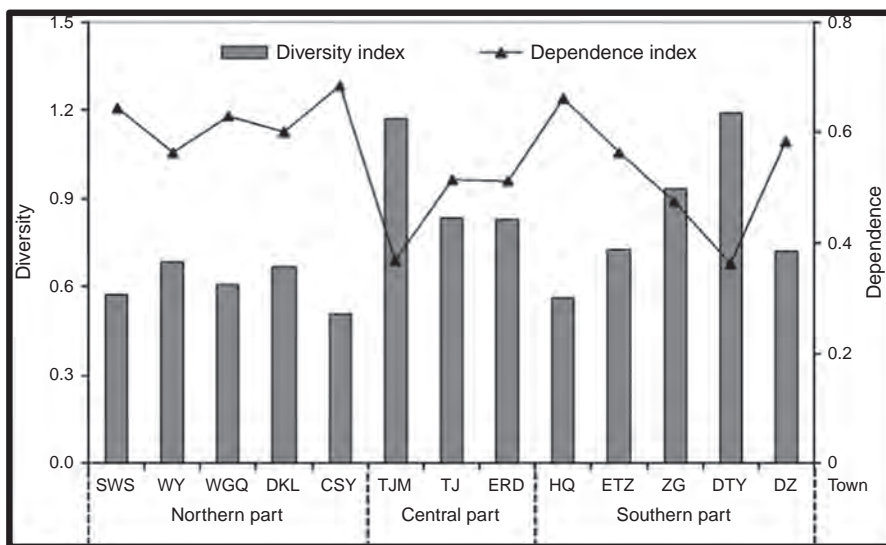
2.2 Resilience: is it the same for everybody?

Renschler *et al.* (2010) and Alexander (2013) states that resilience is a particularly difficult concept to quantify. There are many reasons for this but foremost is the reality that it is not only that differing communities are faced by a multitude of different hazards (which would have had an influence on their existing capacities and coping strategies) but also the prevailing socio-cultural -economic and political intricacies would greatly affect the level of resilience in a given society (Mayunga, 2007, p. 3; Zobel, 2011). No one community has the same set of socio-cultural or economic dynamics, therefore it follows logically that their relative resilience will differ (Zhou *et al.*, 2010). Alexander (2013, p. 2713) highlights context-specific nature of resilience by stating: “One person’s resilience may be another’s vulnerability, and one would not want the concept to be used as a means of reinforcing unethical practices or hegemonies”. This view has been supported by Cutter *et al.* (2008) as “[...] due to the multidimensional nature of resilience in different communities a broad model for measuring resilience should be designed and empirically tested at community levels”.

The importance of understanding context-specific resilience is also highlighted by Zhou *et al.* (2010) in a case study of relative resilience of farmers in the Xinghe county in Northern China. In Zhou’s study, three sets of agricultural communities operating in differing geographical contexts (highlands, plains and mountains) within the same county, were compared to determine their resilience to drought. The analysis was scaled down to a town/village level. The study found that not only did resilience differ between the larger geographic areas (i.e. the mountain and plain areas had significantly higher levels of resilience compared to the highland region) but also showed significant difference on town/town basis within similar areas as illustrated in Figure 1. Specifically Zhou *et al.* (2010) highlighted the fact that communities that scored higher in their ability to diversify their income, were more resilient to the effects of a prolonged drought and was less dependent on agricultural activities for income than those communities with less diversified income options. The ability to diversify income was, however, influenced by a plethora of issues such a physical location, climate topography, choice of irrigation method, agricultural type, condition of infrastructure, economic systems (markets), land use structure, time, learning capacity and cultural practices. All of these factors, or combinations thereof, could greatly change the adaptive resilience in the larger regions and sub-regions.

Therefore, there are theoretical and practical discourses about the reality that resilience differs from community to community and that it might be impossible, if not undesirable, to design a “one size fits all” model or framework to determine resilience. Mayunga (2007) and Zobel (2011) explain that reducing the measurement of resilience to a set of pre-determined parameters that is developed without taking heed of the specific contextual factors that could contribute/lessen resilience, does not allow us to

Figure 1.
Fluctuating levels
of resilience in
Xinghe county,
Northern China



Source: Zhou *et al.* (2010)

gain a holistic picture of resilience at community level. According to Zobel (2011) taking into account a holistic set of factors that impact of contextual levels of resilience can dramatically improve the ability of decision makers to support relevant resilience building projects as there would be a better understanding of the interaction between different resilience generating components and the resilience scenario's they create.

To accommodate an analysis of the ever-changing dynamics that underlay resilience, it is necessary to apply analytical models that have been designed to facilitate the analysis of complex human-environmental systems (Cutter *et al.*, 2008). For this purpose, theoretical models associated with systems thinking, and more specifically complex system theory might provide a means to better assess and understand constantly changing resilience profiles. Taking a holistic analysis approach through systems theory enhances our understanding of disaster risk and societal vulnerability, and also assists in improving community coping capacities and livelihood strategies (Manyena, 2006).

3. CAS theory

In deciphering complexities, scientists often consider an entity or concept as a system (Boulding, 1956; Ashby, 1960; Buckley, 1968; Becker, 2009; Skyttner, 2005; Richardson, 2005). Specifically, systems science approaches work from a point of view of understanding humans and their environment as part of interacting systems (Skyttner, 2005; Von Bertalanffy, 1972; Whitchurch and Constantine, 1993). It also aims to understand the subsequent behaviours or patterns that emerge because of these interactions between the components over time (Skyttner, 2005; Meadows and Wright, 2008; Boulding, 1956). Systems theory therefore accepts that community resilience should be treated as a system, that can only be fully understood by considering the interaction of the parts that form overall resilience (Skyttner, 2005; Kast and Rosenzweig, 1972; Von Bertalanffy, 1972). A specific variation of systems theory referred to as CAS theory presents an interesting tool for studying dynamic concepts such as resilience (Holland, 1992; Hartvigsen *et al.*, 1998).

CAS is a variation of traditional systems theory that has emerged in natural science fields of ecology and biology aimed at explaining non-linear adaptation on micro and macro scales in the natural environment (Hartvigsen *et al.*, 1998; Holden, 2005; Ahmed *et al.*, 2005; Levin, 1998). Holland (1992, p. 17) states that CAS was created as means of trying to comprehend inherently non-linear systems such as economies, brain biology and immune systems that are impossible to accurately simulate using linear diagnostic tools such as computers. Railsback (2001) adds that at the core of CAS analysis is an attempt to show how simple interactions between individual elements at a micro level lead to very complex behaviours at a macro level. Interestingly for all its potential in explaining complexity in systems behaviour, the social sciences have been very slow in adopting CAS as a possible means of analysing human behaviour and larger social systems (Innes and Booher, 1999; Holden, 2005). This in spite of the fact as iterated by Lansing (2003, p. 183), that CAS concepts such as systems emergence (“the idea that larger patterns with new properties can emerge from local interactions”) could contribute significantly to our understanding of how micro-level decision-making impacts positively or negatively on a larger social dynamics. Hartvigsen *et al.* (1998) also highlights the potential of CAS in social research in stating that CAS provides us with a means of analysing and understanding social dynamics not through the lens of society as a heterogeneous set of individuals but as an aggregate of interacting diverse set of individuals. The benefit of analysing society in this way is that it would give us more accurate impressions of population-level and community-level behaviour (Railsback, 2001; Hartvigsen *et al.*, 1998). Due to the slow uptake by the social sciences most of the definitions defining CAS have been within the natural sciences, but the basic principles can be extrapolated to social settings in general and the understanding of disaster resilience specifically (see section 3.1). Some key views (as summarised in Table II) on what a CAS is includes the following.

Author (year)	Definition
Levin (1998, p. 432)	“The study of complex adaptive systems is a study of how complicated structures and patterns of interaction can arise from disorder through simple but powerful rules that guide change”
Innes and Booher (1999, p. 417)	“Organisms are considered CAS when they can adapt and change in response to information it gathers from its environment. It develops new activities and evolves as it ‘learns’ about that environment”
Plsek (2001, p. 312)	“A complex adaptive system (CAS) is a collection of individual agents that have the freedom to act in ways that are not always predictable and whose actions are interconnected such that one agent’s actions changes the context for other agents”
Railsback (2001, p. 48)	“Complex Adaptive Systems (CAS) focuses on how the properties of aggregations of individuals can be determined by the characteristics and behavior of the individuals”
Ahmed <i>et al.</i> (2005, p. 1)	“A complex adaptive system consists of inhomogeneous, interacting adaptive agents. Adaptive means capable of learning”
Rammel <i>et al.</i> (2007, p. 10)	In general, CAS is based on “complex behavior that emerges as a result of interactions among system components (or agents) and among system components (or agents) and the environment. Through interacting with and learning from its environment, a complex adaptive system modifies its behavior to adapt to changes in its environment”

Table II.
Defining and
characterising
complex adaptive
systems

The definition as postulated by Rammel *et al.* (2007) most accurately conceptualises the key tenants of a CAS as: CAS aims to understand complex emergent behaviour at a macro level by looking at interactions between inhomogeneous components at a micro level; All CAS are characterised by their ability to learn from their environment; and, this learning aims to bring about adaptation or change to the system that helps it survive or absorb shocks to the system. Consequently, CAS can be said to be inherently characterised by panarchy, or the ability to be dynamically influenced or adapt to changes that emerge within or from outside the system (Gunderson and Holling, 2002; Folke *et al.*, 2004).

These aspects highlight the importance of studying disaster resilience through the theoretical lens of CAS theory. Disaster resilience is not fully understood or even measurable due to the fact that the contextually based capacities leads differing resilience profile of communities often within the same regions (Plsek, 2001). Holland (2006, p. 18), Rammel *et al.* (2007, p. 10) and Innes and Booher (1999, p. 416) all emphasise that CAS is an excellent tool for analysing systems that are constantly changing (“functioning at the edge of chaos”) and constitutes what can be describe as “moving targets” or anarchy (Cutter *et al.*, 2008). By addressing disaster resilience as a CAS it would place the emphasis on understanding individual capacities and how they interact to generate resilience Hartvigsen *et al.* (1998). This might provide insight into those capacities that most likely contribute to positive emergent behaviour and improved disaster resilience within a specific context (Holden, 2005; Rammel *et al.*, 2007; Zhou *et al.*, 2010). Importantly, by basing the analysis of resilience and the formulation of subsequent models for understanding resilience on CAS, means that there is an inherent understanding that resilience is not the end-point for a society to achieve, but rather a journey that will lead to constant adaptive change (Norris *et al.*, 2008; Rose, 2007). This philosophical orientation significantly increases our chances of gaining a holistic impression of societal resilience (Holland, 1992). It has also been established that a disaster resilient system is inherently an open system that is able to learn from previous disaster impacts and make creative adaption (from information feedback loops) possible (Ahmed *et al.*, 2005; Holden, 2005; Lansing, 2003). Additionally CAS will also allow the tracking of so-called second order and third order effects brought about in a society because of improved disaster resilience (Innes and Booher, 1999). CAS comprises of various concepts that could greatly contribute to our understanding of the dynamics associated with disaster resilience. A set of key concepts and their possible contribution understanding disaster resilience are presented below.

3.1 CAS concepts: possible contribution in explaining disaster resilience

CAS contains a multitude of characteristics and elements that could assist in attaining a more nuanced understanding of disaster resilience. Although the discussion is by no means an extensive listing of possible synergies between the CAS and disaster resilience, some of the key characteristics and their possible application to understanding disaster resilience.

3.1.1 Non-linearity. The basic premise of non-linearity in CAS is that the size of inputs into a system might not be proportional to expected outputs (Boal and Schultz, 2007; Railsback, 2001). Specifically, small seemingly insignificant variables or inputs in a system might fundamentally change the operation of a system whilst major inputs or variables might have no impact in changing the system (Schneider and Somers, 2006; Plsek, 2001). This notion is in line with the work of Lorenz (1963) and Chaos Theory. By viewing disaster resilience through the lens of non-linearity it might be possible to determine or track impact of individual variables on the overall generation of disaster resilience in a society.

3.1.2 Aggregation. According to Levin (1998, p. 432), aggregation is the process whereby individuals in complex systems arrange themselves into sub-groups or hierarchal organisation that have similar interests, needs and practices they have. Once sub-groups are formed they do not remain isolated. Instead, multiple interactions are established between different sub-groups that allows for dynamic development and adaptation to changing environments (Railsback, 2001; Boal and Schultz, 2007). The concept of aggregation provides interesting avenues of exploration within the field of disaster resilience, as it would help to focus some attention on the role, correlation and total contribution of social coping mechanisms to the overall resilience of a society.

3.1.3 Emergent behaviour. According to Innes and Booher (1999, p. 417) emergent behaviour is one of key characteristics of CAS. Emergence refers to how system-level properties, characteristics and patterns emerge from interaction between individual elements at a micro level, even though the individual elements bare no similarity the final wider system characteristics (Railsback, 2001; Schneider and Somers, 2006; Hartvigsen *et al.*, 1998). The concept of emergence could be useful in the exploration of disaster resilience as it will allow for the investigation into how an aggregation of smaller variables could lead to improving resilience profiles of disaster effected communities.

3.1.4 Feedback loops and adaptation. According to Walker *et al.* (2012) and Holden (2005) feedback loops play a crucial role in the development of CAS by either enhancing, stimulating, detracting or inhibiting elements within the existing system. Through these processes feedback loops allow for learning and adaptation within a dynamic environment thereby preventing the extinction of a system (Begun *et al.*, 2003; Rammel *et al.*, 2007; Innes and Booher, 1999). The study of feedback loops allow for greater insight into how communities learn from past events to improve their overall level of disaster resilience. It could also provide insight into the second and third order knock on effects of building disaster resilience within a specific community Innes and Booher (1999).

3.1.5 Context-based responses. A crucial aspect of CAS is its emphasis on the importance of context on the functioning of a system (Boal and Schultz, 2007). According to Holden (2005) and Holland (1992) any complex system is inseparable from the context and history that it finds itself in. The influence of context on CAS is so extensive that it contributes to making each CAS unique (Begun *et al.*, 2003; Hartvigsen *et al.*, 1998). However, the context of a CAS is not static and can also be altered due to the dynamic interaction between interconnected elements (Holden, 2005). For instance, dramatic events at a local level (i.e. disaster in a community) does not only change of the context of the community itself, but could also cause changes at national and regional level (e.g. changes in disaster risk management policies), which in turn would impact once again on the context of the community (Zhou *et al.*, 2010; Schneider and Somers, 2006). The emphasis on understanding of the context provides an opportunity of not only studying the aggregation of unique element's that make a community resilient on a case to case basis but also allows form the exploration of the interconnectedness of elements and how changes at lower levels of a system can change the wider context of resilience.

The failure to address resilience as an open system characterised by complexity has led to unclear understanding of what resilience is, and how it can assist in a better comprehension of communities that are vulnerable to disasters. The preceding discussion has shown that societal resilience to disasters and risk is inherently a CAS comprising of a variety of capacities and non-linear interactions that could only be fully comprehended by considering the interaction of the parts that form overall resilience. By using CAS concepts such as non-linearity, aggregation, emergent behaviour,

feedback loops and adaptation and context-based responses it would be possible for disaster researchers to analyse the dynamic changes in societal resilience profiles, whilst also allowing for the tracking of micro-level interactions and the complex changes they create for macro-level disaster resilience in society. Finally CAS will also allow researchers to better understand the adaption and learning mechanisms that could contribute adaptive disaster resilience.

4. Conclusion

Generating societal resilience to disaster impacts has become a prominent issue of discussion in disaster management and humanitarian circles since the early 1990s. For much of the time period (1990-2015) there have been great differences in opinion on how to define, quantify, operationalise or determine which factors, variables or indicators make a community resilient. Much of the confusion around the concept of resilience and how it should be applied, as illustrated in the paper, lies with two issues: a confusion of what resilience pertains to as per the ecological definition (which was the primary influence on the definition of resilience in a disaster context); and the subsequent philosophical orientation to how resilience should be increased (resilience is often viewed as an outcome to produce an equilibrium, and not a continuous process of adaptation). These theoretical complications have caused disaster researchers risk scientists and practitioners to often take a narrow view on how disaster resilience can be quantified and explained. Specifically it is often thought that resilience could be generated through simply applying generalised models that aim to build linear capacities in all societies. This thinking is problematic because without taking into account a society's complex context-specific variables (social, economic, political, physical, ecological) there will be very limited success in building adaptive resilience within at-risk communities.

The paper proposes that, as possible way to change the current theoretical and philosophical orientation to building disaster resilience it might be useful to look at the problem through the lens of CAS. CAS would allow disaster scientist and practitioners to treat the issue of resilience as an open-systems process that is constantly changing due to the inflow and outflow of information (learning from past events) and building and breaking up of components (adding new resilience capacities/removing absolute capacities) that constitute the resilience profile of a community. It has also been shown that on a theoretical level the underlying principles of disaster resilience and CAS are very similar, warranting the use of CAS as a theoretical analysis tool for further study of resilience. Specifically, elements of non-linearity, aggregation, emergent behaviour, feedback loops, adaptation and context-based responses would assist researchers focusing on the issues of disaster resilience to gain a holistic view of the dynamic interaction between resilience generating factors and local, sub-national and national and sectorial context in which they function. Adopting a CAS approach to deciphering the complexity of resilience could have practical application in reducing disaster risk and creating contextual relevant resilience building policies and programmes.

Notes

1. "Internal variables that represent the minimum amount of information that needs to be retained at any time in order to determine future behavior of a system".
2. "External variables emerging from the ecosystem, social or economic system that positively or negatively impact on the underlying dynamics within a system" (Rammel *et al.*, 2007).

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**Chapter 3: Information feedback functions
within farmers associative mechanism and their
role in fostering disaster resilient behaviour:
Selected cases from Southern Africa**

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Information feedback functions within farmers' associative mechanism and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa

1. Introduction

Disaster losses continue to have substantial impacts on the lives, livelihoods and environment upon which people depend. In efforts to reduce these losses, disaster risk management practitioners, academia and the international community have joined forces in formulating policies and models to reduce disaster risk. These efforts have however enjoyed limited success in reducing losses and building resilient communities. Efforts to produce disaster resilient societies have proved to be one of the most elusive outcomes of contemporary risk reduction endeavours, as many of the traditional policies and models to build resilience are based upon a linear and oversimplified understanding of resilience. Contemporary understandings of resilience are starting to recognise that disaster resilience and the building thereof is a much more complicated process than previously anticipated. Some of the complication lies in the fact that resilient systems are the epitome of anticipation, change and adaptation, making resilience not a static goal to achieve, but instead a moving target that changes constantly as the variables that make up the social system are changed during periods of stress.

The dynamic change and adaptation that is characteristic of resilience behaviour means that disaster resilience and the building thereof can be situated within the domain of complex adaptive systems behaviour. This paper will explore the possible contribution of Complex Adaptive Systems Theory (CAS) in gaining a more holistic understanding of how resilience can be fostered in at risk communities. In particular, attention will be focused upon the role of information feedback and interaction within CAS. The reason for this focus is that anticipation, adaptation and change (and by extension resilience behaviour) within systems are controlled by the presence of information feedback loops. Information feedback loops allow for interaction to take place between internal and external system elements, and from these interactions, complex emergent system behaviours such as disaster resilience can arise.

The study aims to test the hypothesis outlined above in the context of agricultural communities in Southern Africa. To this end the paper will explore the role of farmers' associative mechanisms in stimulating information feedback and interaction amongst group members. It is argued that the information feedback and interactions between group members could have a positive effect in building resilience, as they allow members to adopt positive coping strategies or to make use of communally pooled resources (loans, seeds, labour) and eschew negative disaster coping

strategies. Overall it is found that information feedback loops and interactions could stimulate anticipation and learning opportunities, which enable farmers to change, re-organise and adapt to disaster impacts as a means to creating dynamic adaptation to disaster risk. This dynamic adaptation fostered through the interaction and feedback of farmers' associative mechanisms could be said to make a contribution to improving the overall levels of disaster resilience in farming communities.

2. Resilience

Disasters continue to have a dramatic impact upon society in terms of lives, livelihoods and environmental losses (Aldunce *et al.*, 2014:253). The continued struggle to reduce disaster risk is best captured in the introduction of the Sendai Framework for Disaster Risk Reduction:

“Over the same 10-year time frame (*the period of implementation for the Hyogo Framework, 2005-2015*), however, disasters have continued to exact a heavy toll, and as a result the well-being and safety of persons, communities and countries as a whole have been affected. Over 700 thousand people lost their lives, over 1.4 million were injured and approximately 23 million were made homeless as a result of disasters. Overall, more than 1.5 billion people were affected by disasters in various ways. Women, children and people in vulnerable situations were disproportionately affected. The total economic loss was more than \$1.3 trillion. In addition, between 2008 and 2012, 144 million people were displaced by disasters“ (UN, 2015:4).

In lieu of such staggering losses, new paradigms and concepts are being introduced by disaster theorists, practitioners and policy makers. Arguably, the most prominent of these concepts is the concept of resilience (Manyena, 2006; Gaillard, 2010; McEntire, 2005; Cimellaro *et al.*, 2010:3640; Cutter *et al.*, 2008; Tadele and Manyena, 2009). Although the concepts have been part of the disaster risk management lexicon since as early as the declaration of the International Decade for Natural Disaster Reduction in 1989, the concept has only recently been recognised as a main outcome of risk reduction efforts, as per the Hyogo Framework for Action (2005-2015) and the Sendai Framework for Disaster Risk Reduction 2015-2030 (Van der Walddt, 2013; Cutter *et al.*, 2008:599; Cordona, 2004:3). Accordingly, much of the theoretical and practical discourse around the application of resilience in risk reduction efforts is still very much in its infancy, with some academics and practitioners still conceptualising what resilience entails and how it should be “measured” (Manyena, 2006; Gaillard, 2010; Klein *et al.*, 2003; Zobel, 2011; Weichselgartner and Kelman, 2015:251; Prosser and Peters, 2010:8; Kelman, 2008:197). With such a proliferation of information on the concept, resilience becomes important to operationalise what resilience would mean in the context of this paper. In this regard two conceptualisations of resilience have a major bearing on how resilience is understood here.

The first influence can be traced back to the exploration of the term resilience by Holing in the field of ecology in the 1970s (Burton, 2012; Kuhlicke, 2013; Rose, 2007). Although resilience in this context was not intended to explain resilience to disasters, it did lay the foundation of what would later become resilience to disaster shocks as postulated by Timmerman in 1981 (Alexander, 2013). Holing (1973) contended that resilience can be defined as: “*the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters and still persist*”. Thus Holing’s definition alludes to the fact that resilient systems are systems that can undergo fundamental changes to all their critical drivers due to perturbation, yet do not go extinct (Lewis, 2013(b):300). Instead such systems are constantly adapting to their environment. What stands out from this definition is the emphasis it places upon the need for systems to be able to change instead of the function of variables (i.e. state, driving or parameter variable) that make up the system (Allen *et al.*, 2005:958). This emphasis on constant change constitutes a secondary influence on how resilience is defined in this paper.

For many years following the works of Holing (1973) and Timmerman (1981) disaster resilience was viewed as the ability of a community to resist disaster impact and, as efficiently as possible, return to a normal level of functioning or “bouncing back” as it is colloquially referred to. However, critiques of the notion of “bouncing back” were especially wide spread throughout the academic community. The argument is made that the “notion of bouncing back” is problematic because it essentially propagates a return to a vulnerability context that put a community at risk in the first place (Klein *et al.*, 2003; Paton, 2006:7; Aldunce *et al.*, 2014:262; Cretney and Bond, 2014:18; Prosser and Peters, 2010:8; Kelman *et al.*, 2015:22;). Secondly, the ability of a system to resist something is fundamentally not the same as a system being resilient. Although both concepts aim to protect a system, elements that resist perturbation are created as static interventions meant to address a known risk. If the context or the environment that underlies a specific risk changes, the intervention formulated with the intention to provide resistance is often overwhelmed as it was not designed to change with context (e.g. levies that failed during Hurricane Katrina in New Orleans) (Aldunce *et al.*, 2014:262; Handmer and Dovers, 1996:501; McEntire, 2005:209). Resilient systems however, as indicated by the definition by Holing (described above), are characterised by their ability to adapt and change, even when all the variables that make up the system are changed during periods of stress (Paton, 2006:8; Kendra and Wachtendorf, 2003:41; Mileti, 1999:209). The realisation that it is not enough for human systems to be resistant (ability to bounce back) after disasters, but that anticipation, change and adaptation is crucial to resilience, has started to open a new understanding of the complex nature of resilience (Hufschmidt, 2011; Manyena *et al.*, 2011; Lewis, 2013:60; Weichselgartner and Kelman, 2015:251). In this regard Kelman *et al.*, (2015:22), Prosser and Peters (2010:8) and Paton (2006:7) postulate that it is crucial that resilience is viewed as a process of “bouncing forward” where societies learn from disaster impacts, anticipate and constantly adapt or change their coping strategies, thereby contributing to improved societal resilience. From the above influence, resilience can be operationalised as follows within the context of the paper:

The ability of a system and its underlying variables to constantly change, re-organise, adapt to and learn from disaster impacts as a means to creating dynamic adaptation to disaster risk.

The dynamic change and adaptiveness that is characteristic of resilience behaviour, means that disaster resilience and the building thereof can be situated within the domain of Complex Adaptive Systems behaviour (Keshavarz *et al.*, 2010:1468; Allen *et al.*, 2005:958; Rammel, *et al.*, 2007:10). Paina and Peters (2012:366) and Anderson (1999:216) reinforce this point by stating that CAS are considered complex, not only because such systems contain a multitude of interacting parts, but more importantly, because the results of these interactions include self-organising behaviour, adaptation and learning. All of these are crucial to creating new systems configuration such as system resilience (McCarthy *et al.*, 2006:442). These CAS, whether biological, ecological, human or economic can be typified by their ability to dynamically change and adapt to internal and external system pressures and create system resilience (Wycisk *et al.*, 2008:110; Aritua *et al.*, 2009:76; Muller *et al.*, 2008:24). By recognising the CAS nature of disaster resilience, a necessity arises for new theoretical and management approaches within the field of disaster risk science (Pahl-Wostl, 2007:53; Aritua *et al.*, 2009:76; Foster, 2005:873; Schwandt and Goldstein, 2008:86). One such approach is presented through the application of Complex Adaptive Systems Theory and its associated tools and concepts. Rhul (1997:944) and Theise and d’Inverno (2003:17) explain that CAS Theory has been adopted in various physical and social scientific fields and this has brought forth new and innovative approaches to research and policy development. It should be noted that although Complex Adaptive Systems Theory has a multitude of associated concepts that can be used to explore the issues of disaster resilience in great depth (Coetzee *et al.*, 2016, Coetzee *et al.*, 2016(b)), the focus of this paper will be upon the influence of information feedback loops that subsume all adaptive processes within complex systems. The study of information feedback loops, it will be argued, provides disaster researchers with an opportunity to gain deeper insights into micro (internal to the system) and macro levels (external to the system) that subsume adaptation, change and ultimately resilience (Bonabeu, 1998:438; Keshavarz *et al.*, 2010:1469).

3. Information feedback loops as key driver to resilient behaviour

All complex adaptive systems (including social resilience profiles) are inherently open systems that dynamically adapt and change between different states, due to the in and out flow of matter, energy or information (Limberg *et al.*, 2002:410; Cheng *et al.*, 2009:1; Holden, 2005:654; Jost, 2003:1). A central driver of change within open systems is the presence of information feedback loops. According to Anderson (1999:217) and Brun *et al.*, (2009:56-57) these feedback loops comprise of both negative and positive feedback loops that work in unison to prevent systems from becoming too chaotic or stagnating by remaining in a state of equilibrium for too long. Thus feedback loops are key to keeping systems within the optimal zone for adaptation or what is known as the “edge of chaos” for system scientists (Schneider and Somers, 2006:356; Boal and Schultz,

2007:412). The reasoning behind this argument is that systems that function at the “edge of chaos” are characterised by optimal amounts of negative and positive information feedback loops that allow for interaction between different systems levels (internal and external) and components, which in turn facilitate adaptation and resilience building (Holden, 2005:656; McCarthy *et al.*, 2006:451). Muller (2008:23), Innes and Booher (2007) and Levin and Lubchenco, (2008:30) add to this argument by stating that adaptation and change (and by extension resilience behaviour) within systems are controlled by the presence of information feedback loops. The information feedback loops allow for interaction to take place between internal and external system elements, and from these interactions, complex emergent system behaviours such as disaster resilience arise (Curseu, 2006:249; Liu *et al.*, 2007:1513; Foster, 2005:874). Meso and Jain (2006:27), Goldenberg *et al.*, (2001:212-213) and Pahl-Wostl (2007:53) elaborate that often individual elements within a system are either too simplistic in nature or too specialised to influence a system’s behaviour in its totality. To optimise or create more holistic system-wide behaviours, these individual elements have to interact with other elements (internal/external, complex/simple) to bring about more complex behaviours such as anticipation, adaption, change, transformation and system resilience (Rammel *et al.*, 2007:11; Liu *et al.*, 2007:1514; Theise and d’Inverno, 2003:17; Bonabeu, 1998:441). Once complex behaviours have emerged on a macro systems level through the interaction at micro levels, they provide new information feedbacks that can in turn influence individual elements at the micro systems level (Wysick *et al.*, 2008:113; Rammel *et al.*, 2007:12; Curseu, 2006:251).

Within the context of building disaster resilience in agricultural communities, it is the contention of this paper to prove that membership to farmers’ associative mechanisms plays a key role in stimulating information feedback in agricultural settings, which in turn could lead to households adopting positive disaster coping strategies. However, before this assertion can be tested, it is necessary to examine the role of farmers’ associative mechanisms in stimulating information feedback in agricultural settings.

4. Farmers’ associative mechanisms: Stimulating adaptation through information exchange and feedback

Since the agricultural revolution (around 10,000 B.C) farming societies have formed collective groups to manage a wide array of agricultural activities including water management, labour sharing and marketing (Pretty and Ward, 2001:209; Chirwa, 2005:5). According to Stewart (2004:13), Sabates-Wheeler (2002:1745) and Bandiera and Rasul (2003:5) farmers’ associative mechanisms are established as a means for economically and politically (lack of power) deficient farming communities to pool their individual capacities and resources to achieve collectively beneficial outcomes. Consequently farmers associative mechanisms take on a variety of shapes, including (but not limited to) either broad formation such as formal associations, or family based societies or associations formed for specific purposes such as water users associations (WUA), producers associations (e.g. sugar producers associations) or credit groups (Yercan, 2003:206; Qiao *et al.*, 2009:823; Stewart, 2004:13-14; Lyon, 2007:100). Stringfellow *et al.*, (1997:1)

emphasise the central role of farmers' associative mechanisms in improving the prospects of individual farmers by stating that the formation of farming associative mechanisms provide a means for farmers to collectively bargain for greater access to agricultural services and improved market participation. Carney (1996:2) argues that a prominent reason why farmers' associative mechanisms provide benefits to their members is that they allow member to negotiate and operate at many different levels including local, district, national and international levels (in the case of larger farmers' unions).

Knowler and Bradshaw (2007:36) and Isham (2002:2) elaborate that the usefulness of farmers' associative mechanisms are vested in the fact that they create social capital for agricultural communities. Social capital in this case is the notion that the social bonds between groups of people serve as an asset to achieve group goals (financial or development) or provide a safety-net during stress or disturbance (Bingen *et al.*, 2003:408; Stewart, 2004:3-4). Bandiera and Rasul (2003:18) highlight that membership to farmers' associative mechanisms (and co-opting the social capital created through them) holds both financial, productive and social benefits for subsistence agricultural communities. From a cursory literature review it is apparent that there are two broad benefit categories associated with the involvement in farmers' associative mechanisms. The first of these is a direct agriculture benefits category and the second category relates to social benefits derived from membership to the farmers' association. Some of the agricultural and social benefits derived from membership to farmers' associative mechanisms are listed in Table 1 below:

Table 1: Benefits derived from membership to a farmers' associative mechanism

Benefit	Authors
Direct Agricultural Benefits	
Increases in production outputs	Sabates-Wheeler, 2002:1737; Yercan, 2003:206; Qiao <i>et al.</i> , 2009:823
Improved income	Yercan, 2003:206; Lyon, 2007:104; Carney, 1996:2; Stewart, 2004:2
Improved access to planting and harvesting equipment	Sabates-Wheeler, 2002:1740; Carney, 1996:2; Stewart, 2004:2
Improved cropping techniques and practices	Yercan, 2003:206; Adesina <i>et al.</i> , 2000:259 ;Boahene <i>et al.</i> , 1999:172; Isham, 2002:23; Bandiera and Rasul, 2003:4; Pomp and Burger, 1995:430
Access to labour	Sabates-Wheeler, 2002:1740; Boahene <i>et al.</i> , 1999:182; Stewart, 2004:2
Improved natural resources management	Qiao <i>et al.</i> , 2009:823; Khalkheili and Zamani, 2009:859; Bebbington <i>et al.</i> , 1994:11-12

Increased likelihood of adopting new farming technologies	Adesina <i>et al.</i> , 2000:259; Chirwa, 2005:2; Boahene <i>et al.</i> , 1999:172; Carney, 1996:2; Isham, 2002:23; Bandiera and Rasul, 2003:4; Pomp and Burger, 1995:430
Improved economic opportunities and market access	Lyon, 2003:323; Lyon, 2007:109; Coulter <i>et al.</i> , 1999:2
Increased bargaining power with governments and traders	Lyon, 2003:323; Lyon, 2007:103; Carney, 1996:2-3; Bebbington <i>et al.</i> , 1994:11-12; Stewart, 2004:2
Improved access to credit and loans	Stringfellow <i>et al.</i> , 1997:4; Lyon, 2007:109; Stewart, 2004:19
Social Benefits	
Poverty reduction	Pretty and Ward, 2001:221; Qiao <i>et al.</i> , 2009:823; Lyon, 2003:324-32; Boahene <i>et al.</i> , 1999:182; Stewart, 2004:5
Increased access to education (building of schools, school enrolments)	Lyon, 2007:103; Lyon, 2003:327
Improved community self-sufficiency and ownership of develop projects	Khalkheili and Zamani , 2009:860; Pretty and Ward, 2001:210; Lyon, 2003:323
Infrastructure improvements	Yercan, 2003:206; Qiao <i>et al.</i> , 2009:823
Enhanced political power (needed for negotiation with government stakeholders)	Bingen <i>et al.</i> , 2003:407; Lyon, 2003:323; Carney, 1996:2; Bebbington <i>et al.</i> , 1994:11-12; Knowler and Bradshaw, 2007:44
Conflict reduction and building trust between community members	Stringfellow <i>et al.</i> , 1997:4; Pretty and Ward, 2001:210
Reducing urban migration	Lyon, 2003:324-32; Lyon, 2007:104

Apart from the broad social and agricultural benefits derived through the social capital created by membership to a farmers' associative mechanism, social capital could also benefit the building of disaster resilience. Sligo *et al.*, (2005:549) observe that when people are exposed to a major risk (such as natural hazards), they will often gravitate toward collective groupings that allow them to gather information and resources to mitigate or adapt to a risk. In this instance, social capital (social networks, social contacts, social cohesion, social interaction and solidarity) provided by a social structure such as farmers' associative mechanisms, serves as a crucial adaptive capacity

that could contribute to improving community resilience (Sherrieb *et al.*, 2010:233; Mathbor, 2007:360). Adger (2003:389) and Murphy (2007:299) add that the social capital provided by social structures such as farmers' association mechanisms in pastoral economies are a key determinant in these communities' ability to cope with risk. Mathbor (2007:364) and Murphy (2007:302) elaborate that communities with social capital are often (but not always, due to the possible influence of contextual factors) found to be "better prepared and more effective in responding to natural disaster

A crucial observation about social capital associated with farmers' associative mechanisms is that it emerges from, and enhances, the information flow between group members and external entities (e.g. government, markets, needs) that improves the likelihood of adopting innovative behaviour, relating to agricultural activities and disaster resilience building (Isham, 2002:2; Chirwa, 2005:5; Boahene *et al.*, 1999:168; Bebbington *et al.*, 1994:12). Carney (1996:2), Pomp and Burger (1996:425) and Khalkheili and Zamani (2009:860) reiterate this view by detailing that farmers' associative mechanisms promote horizontal and vertical learning amongst group members and external entities through the exchange of innovation information. As noted by Adger (2003:394) the synergetic interactions stimulated by social capital between internal system groups and external groupings (state, markets and civil society) are key to reducing disaster risk and building resilience. Thus it can be argued that without the information or communications channels provided by farmers' associative mechanisms, the emergence of innovative or adaptive behaviour (such as disaster resilience) becomes problematic for farming communities (Knowler and Bradshaw, 2007:36; Adesina *et al.*, 2000:259).

Information feedback as directed by farmers' associative mechanisms could play a crucial, if not definitive role in formulating social capital that is necessary for innovative and adaptive behaviours. However, much of the current research on the role of farmers' associative mechanisms, information feedback and innovation relates purely to agricultural aspects. This paper attempts to determine whether information feedback and the social capital that arises from it could also hold benefits for the emergence of innovative disaster resilient behaviour. To achieve this, the role of farmers' associative mechanisms and their role in the adoption of disaster coping behaviours (which serve as a proxy indicator for disaster resilient behaviour) in three countries (Madagascar, Malawi and Mozambique) in Southern Africa was investigated. For the purpose of the study a mixed qualitative and quantitative data gathering approach was followed.

5. Methodology

According to De Vos *et al.* (2013:443), in an embedded mixed method design "one data set provides a supportive, secondary role in a study, based primarily upon the other data type". The need to follow a mixed design was noted because it was felt that a quantitative design alone would not be able to accurately indicate the interaction between farmers' association group members, and its contribution to adopting better coping and recovery strategies. As such, the study

comprised one data collection method associated with each research design (two for the whole study). The primary tool for data collection was a quantitative survey which was administered to a combined total of 1110 respondents (representing the household level) in three case study countries (Mozambique - N=447, Madagascar - N=337 and Malawi - N=326). All the respondents identified through the broad study were from communities partaking in agricultural and food security activities supported by the FAO and partners from 2009-2014, under Disaster Preparedness EU Humanitarian Aid and Civil Protection (DIPECHO) funding (Kruger, 2015). From this initial 1110 respondents a purposeful sample was taken to isolate those respondents that confirmed that they are actively part of a farmers' associative mechanism. Out of the initial 1110 participants, 593 respondents across all case study countries indicated involvement in farmers' associative mechanisms (see Table 2).

Table 2: Delineation of study participants

Are you a member of a farmers' association?		
	Frequency	Valid Percent
Yes	593	53,4%
No	517	46,6%
Total	1110	100%

It is recognised that in the context of the study the resilience behaviours (specifically the inclination to certain disaster coping behaviours) of members of farmers' associative mechanisms could be influenced by a wide array of variables (i.e. increased income, increased production). Due to the fact that the purpose of the study is to determine whether the feedback and interaction within the farmers' association contributes to stimulating more resilient behaviour, a specific analysis had to be conducted. Consequently, the original factor analysis focusing upon farmers' associative mechanisms was broken up into its individual parts. The variables identified through this process included:

- Good cooperation between farmers' association members;
- Farmers association members helping other members to recover from natural disasters/hazards (through donations, advice etc.);
- Increase in production since joining the farmers' association; and
- Increase in income since joining the farmers' association.

From this analysis the variable pertaining to farmers' association members helping other members to recover from natural disasters/hazards (through donations, advice etc.), was selected as the key variable that is indicative of how interaction and feedback within farmers' associative mechanisms

are key in stimulating resilient behaviour. To this end, a basic frequency analysis was conducted on the responses of respondents to the question: *“Please indicate the level to which you agree or disagree with the following statement: Members in the farmers associations will often help other members recover from natural disasters/hazards (e.g. donations, advice)?”* The results from this analysis are presented in Table 3 below. To complement the quantitative findings relating to the question above, results from the quantitative questionnaire are also added in the analysis. The qualitative data was collected through focus groups and face-to-face interviews, in order to gain a deeper understanding of, and elaborate upon, the findings from the quantitative data. Ten (10) focus group interviews were held per participating country. Thus thirty (30) focus groups were held for the study overall. During these interviews the participants were asked: *“Do members of the farmers’ association help (donations, advice, support, safety nets) each other when there are members who have incurred losses due to disasters? If so, how? If not, why not?”* Additionally, a statistical correlation analysis was conducted to determine what the preferred and non-preferred coping strategies are that emerge in instances where members of the farmers’ associations help other members recover from natural disasters/hazards (through donations, advice) of farmers’ association members. This analysis was carried out in order to determine whether the information feedback and help provided by members of farmers’ associations fosters an inclination towards positive or negative coping behaviours. The inclination of members (either positive or negative) would serve as a proxy indicator to existing levels of resilience within the farmers’ associative group (see Table 4).

6. Analysis

The data analysis is presented in two stages. The primary analysis focuses upon establishing whether farmers’ associative mechanisms, and the information exchange within the association, play a key role in members’ ability to recover from natural hazards and disasters. This analysis is augmented by exploring whether the interactions and information feedback associated with being a member of a farmers’ association could be a significant contributor to stimulating resilient coping behaviour.

6.1 The role of farmers’ associations in stimulating information feedback for disaster recovery

A basic frequency analysis was conducted on a variable relating to whether members in the farmers’ associations help other members recover from natural disasters/hazards (e.g., donations, advice). This variable was selected as it directly tests if there is interaction or information feedback between members in the form of advice, donations or resource sharing that will help those affected by disaster to cope, learn, recover and adapt following disasters. The results from the data analysis indicate that the overwhelming majority of respondents **81% (N=476)** either agree or strongly agree that the interactions and information feedback that are part of the activities of the farmers’ associative mechanisms make vital contributions to farmers’ ability to recover from and cope with disaster impacts.

Table 3: Farmers’ associations and their role in disaster recovery efforts

Please indicate the level to which you agree or disagree with the following statement: Members in the farmers’ associations will often help other members recover from natural disasters/ hazards (e.g., donations, advice).		
Strongly disagree	9	1%
Disagree	48	8%
Neither disagree nor agree	60	10%
Agree	276	47%
Strongly agree	200	34%
Total	593	100%

The quantitative results on the key role of farmers’ associations in stimulating interaction and information feedback for disaster recovery are reinforced by the summarised replies from focus group interviews:

“According to the peasants, being member of a farmers’ association made it possible for the existence of mutual aid, exchange of ideas as, generally speaking, there are mutual assistance, synergy and cohesiveness between members of farmers’ associations.” - Focus Groups Madagascar

“Members in a group learn, support, advise each other in terms of need (whether about agricultural activities or coping with hazards). Through their cooperation other people outside the group are interested to join the group” - Focus Groups Malawi

“All associations/committees help members of the community in case of emergencies or special needs, and they can do that through donations, suggestions, help in rebuilding a destroyed house, accompanying sick people to the hospital, etc. Farmers’ committees also provide early warning and evacuation functions to those living in the most exposed areas during cyclone events” - Focus Groups Mozambique

The responses provided highlight the pivotal role interaction and information feedback within farmers’ associations play in enhancing an array of disaster risk management activities including relief, response, early warning and preparedness for association members. It can be argued that the ability to perform these disaster functions more effectively could also contribute to improving

the overall level of resilience of members, as all the activities mentioned contribute to a community's ability to constantly change, re-organise, adapt to and learn from disaster impacts by creating dynamic adaptation to disaster risk.

6.2 Farmers' associations members and preferred and non-preferred disaster coping strategies

From the preceding analysis it was clear that participants strongly felt that the information feedback inherent to farmers' associations aided the farmers' ability to recover from disasters. The ability to recover from disaster impacts can however only be seen as one aspect of resilient behaviour. It was therefore necessary to investigate the coping behaviours of farmers that receive information feedback (through donations, advice) from the farmers' association. The analysis of coping behaviour could give a clearer indication of the total level of resilience in participating farming communities. The analysis is presented in Table 4 below.

Table 4: Members of a farmers' association helping each other to recover from disaster and preferred/non-preferred coping strategies

Farmers' Associative Members (N= 593)	Preferred Disaster Coping Strategy	Correlation Coefficient
	Selling of household goods Sig. (2-tailed)	.210** ,000
	Moving away from household's plots for off-farm work for income Sig. (2-tailed)	0,068 ,100
	Member of household go to work in other people's fields in exchange for food Sig. (2-tailed)	0,059 ,149
	Non-Preferred Strategies	
	Hunting and gathering Sig. (2-tailed)	-.173** ,000
	Reducing the number of meals per day Sig. (2-tailed)	-.110** ,008

	Reducing the size of food portions	-.255**
	Sig. (2-tailed)	,000
	Eating seed stock	-.128**
	Sig. (2-tailed)	,002

Mostly small statistical correlations are evident between the members of farmers' associations helping each other to recover from disaster (through advice and donations) and non-preferred coping strategies. However, exceptions can be noted with smaller statistical correlation, but in some instances strong relationships ^{**1} between members of a farmers' association helping each other to recover from disaster and adopting or avoiding certain coping behaviours is evident. The data contained in Table 4 indicates that farmers, once they have received advice or donations to aid their disaster recovery efforts, only have a clear preference for selling of household goods (**.210****) as a coping strategy, whilst moving away from household plots for off-farm work for income (**.068**) and members of households going to work in other people's fields in exchange for food (**.059**) show only minor correlations. The availability of household goods could be indicative of a buffer coping capacity created by greater financial endowments brought about by the membership to a farmers' associative mechanism (see Table 1). Consequently, respondents can first sell off household goods instead of immediately reverting to survival tactics such as reducing food portion sizes or hunting and gathering. The buffer coping capacity provided by the availability of household goods could give farmers' association members time to adapt and learn from disasters, thereby contributing to their level of resilience.

Arguably, more significant for the study is what coping strategies are not considered viable. In this instance, farmers that have received help from other members to recover from disaster do not consider hunting and gathering (**-.173****), reducing the number of meals (**-.110****), reducing the size of food portions (**-.255****) and eating of seed stock (**-.128****). Although all of these correlations are small, they also display strong relationships. This could be indicative of the fact that members of the farmers' association would first consider approaching other members of the association to help cope with a disaster/hazard, rather than resort to negative coping strategies that are indicative

¹ Within correlation statistics ** indicate that there is a strong relationship between two factors. This correlation although small, is statistically significant, and should be reported.

survival tactics. This claim is supported by qualitative responses gathered from the focus groups. The following responses are specifically summarised from the focus group discussions:

“Mutual aid is given to members of the association in the event of disasters like inundations. A community fund is created to support members when it is required. The fund provides seeds and loans to support household members to support their livelihoods” - Focus Groups Madagascar

“Members of the farmers’ association help members who have incurred losses due to disasters by sharing of seed for replanting, food sharing and club savings” - Focus Groups Malawi

“Farmers’ associations have saving mechanisms for the members, and part of the communal yield can be destined to the social fund, to provide emergency help to its members or to fund other activities such as: seeds for the following year, purchase of equipment, community ceremonies, to build infrastructure, etc.”.- Focus Groups Mozambique

Both the quantitative and qualitative responses indicate that members of farmers’ associative mechanisms tend to adopt positive coping strategies once they receive help from other group members through some type of information feedback i.e. advice. Membership to the group gives members the option of either selling surplus household goods or making use of communally pooled resources before considering adopting negative coping measures that might in the long run make them more vulnerable to the prolonged disaster impacts. Therefore adaptation and coping options provided by the information feedback innate to farmers’ associative mechanisms could have a positive impact upon the overall level of resilience of group members.

7. Discussion

The primary analysis aimed to establish whether the coping strategies that help members recover from natural disasters/hazards are a direct consequence of the interactions and information feedback between farmers’ association members. Both the quantitative and qualitative responses strongly indicated that the interactions and information feedback that are part of the activities of the farmers’ associative mechanism could make vital contributions to farmers’ ability to recover from and cope with disaster impacts. This finding is consistent with the observation of Sligo *et al.*, (2005:549) that when people are exposed to major risk (such as natural hazards) they will often gravitate toward collective groupings that allow them to gather information and resources to mitigate or adapt to a risk. Once part of the group, a simple system component (such as an individual farmer) can alter their individual coping behaviour through interaction and information feedback with other group members. According Rammel, *et al.*, (2007:11), Liu *et al.*, (2007:1514), Theise and d’Inverno (2003:17); and Bonabeu, (1998:441), the interactions and information feedback enable the use of more complex behaviours that emerge on a macro systems level such as adaption, change and system resilience by the individual farmers and farmers’ associations.

The secondary analysis aimed to determine the preferred and non-preferred coping strategies that emerge once help (advice, donations) has been received from other group members. Results

indicated that members tend to adopt positive coping strategies such as selling of household goods or selling individuals' ability to labour, instead of considering negative coping strategies such as reducing meals per day or portion sizes. In this instance the tendency to eschew negative coping behaviours could be indicative of the ability of farmers' associative mechanisms to allow farming communities to pool their individual capacities and resources to achieve collectively beneficial outcomes, such as farmers within the group being able to avoid the need to adopt negative coping strategies. This finding is consistent with the theory presented by experts in Section 4 that farmers' associative mechanisms create social capital for agricultural communities that in turn provide a safety net during stress or disturbance (Knowler and Bradshaw, 2007:36; Isham, 2002:2; Bingen *et al.*, 2003:408; Stewart, 2004:3-4). Thus the social capital provided by being a group member gives members the option of either selling surplus household goods or making use of communally pooled resources before considering adopting negative coping measures, that might in the long run make them more vulnerable to the prolonged disaster impacts.

What is clear from both sets of analysis is that help provided by farmers' associative mechanisms to their members could play a significant role in improving disaster recovery, coping and resilience behaviours of participating farming communities. The help commonly comes in the shape of advice or donations which can be described as types of information feedback within the system. Consistent with the theory presented, information feedback in the shape of advice or donations, allows for interaction between individual members (internal feedback) or the larger farmers' association (external). This in turn facilitates the emergence of more complex behaviours such as improved disaster recovery (see Table 3) or avoidance of negative disaster coping behaviours (see Table 4). The presence of feedback loops within farmers' associative mechanisms therefore allows for the interaction between different systems levels and components, which in turn could facilitate adaptation and eventually disaster resilience building in agricultural communities.

8. Conclusion

Building disaster resilience remains a key imperative of contemporary disaster policy and theory. Although resilience has been defined and discussed from many theoretical perspectives in the past, it was the contention of this paper that at its core, disaster resilience is vested in human systems' ability to constantly change, re-organise, adapt to and learn from disaster impacts, as a means to creating dynamic adaptation to disaster risk. This focus upon adaptability and consistent change places resilience within the realms of Complex Adaptive System Theory. CAS are characterised by interaction between multiple system components, and the results of these interactions include self-organising behaviour, adaptation and learning. A central driver of change within open systems is the presence of information feedback loops. The information feedback loops allow for interaction to take place between internal and external system elements, and from these interactions, complex emergent system behaviours such as disaster resilience arise.

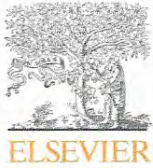
It was the contention of this paper to prove that membership to farmers' associative mechanisms in Southern Africa could play a key role in stimulating information feedback in agricultural settings, which in turn leads to households adopting positive disaster coping strategies which is indicative of improved levels of disaster resilience. To this end it was first established that members of farmers' associative mechanisms tend to avoid negative coping behaviours, and instead opt for positive coping strategies or making use of communal resources. The social capital provided by being a group member gave members the option of either selling surplus household goods or making use of communally pooled resources (labour, seed banks, loans) before considering adopting negative coping measures, that might in the long run make them more vulnerable to the prolonged disaster impacts. Quantitative and qualitative responses by the majority of participants (81%) pointed to the fact that the choice of positive coping behaviour or using of pooled resources was largely driven by the interaction and feedback provided by farmers' associative mechanisms. The participants felt that the information exchange between group members makes a significant contribution to members' ability to recover from disaster impacts. These interactions could stimulate learning opportunities which enable farmers to change, re-organise and adapt to disaster impacts as a means to creating dynamic adaptation to disaster risk. This dynamic adaptation fostered through the interaction and feedback of farmers' associative mechanisms can be said to make a contribution to improving the overall levels of disaster resilience in farming communities.

Finally, on a much broader theoretical level, the finding presented above also points to the significance of considering the role of information feedback and interaction between system components in our endeavours to gain a more holistic understanding of disaster resilience. The introduction of information feedback and interaction into our approach to understanding resilience could be significant, as components that are aimed at building disaster resilience are often introduced in isolation. This is frequently done without a notion of resilience components that could interact with and enhance the ability of individual elements to evolve into more complex, system-wide behaviours such as disaster resilience. It can be argued that the more in-depth study of information feedback loops could provide disaster researchers with an opportunity to gain deeper insights into micro (internal to the system) and macro levels (external to the system) that subsume anticipation, adaption, change and ultimately, resilience.

Chapter 4: Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture

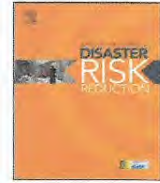
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Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture

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ABSTRACT

Prominent international policy documents such as the Sendai Framework for Disaster Risk Reduction 2015–2030 and contemporary academic discourses on disasters reiterate the importance of understanding and prioritising building societal resilience. However, despite its prominent position in current and future disaster risk management, much confusion still exists on what exactly resilience entails and how it can be enhanced. This paper attempts to provide a perspective on this problem from the point of view of Complex Adaptive Systems Theory, with specific focus on the notion of emergence within adaptive systems. The paper explores the presence of emergent behaviour that could generate disaster resilience by reviewing statistical correlations between four agricultural interventions (small-scale irrigation system, farmers' associative mechanisms, appropriate crop varieties, and cropping techniques) and prominent indicators of disaster resilience (coping strategies and hazard adaptation/avoidance behaviour) in subsistence agricultural activities in Mozambique, Malawi and Madagascar. The results from the analysis illustrate that emergent behaviour in the form of various coping strategies and hazard avoidance behaviour is indeed observable in agricultural communities that use all or a combination of agricultural interventions such as small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, and cropping techniques. These resilience abilities are newly formed macro-level behaviours that emerge due to the interactions of agricultural interventions at a micro-level.

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1. Introduction

The concept of resilience is becoming an increasingly important paradigm for managing risk faced by disaster affected societies. Prominent international policy documents such as the Sendai Framework for Disaster Risk Reduction 2015–2030 and contemporary academic discourses on disasters reiterate the importance of understanding and prioritising building societal resilience. However, despite its prominent position in current and future disaster risk management, confusion still exists on what exactly resilience entails and how it can be enhanced. This paper attempts to provide a perspective on this problem from the point of view of Complex Adaptive Systems Theory, with specific focus on the notion of emergence within adaptive systems. Emergence, which is defined as the concept that complex behaviours at macro-level can emerge from interaction between micro-level

components, which modify, transform and create new components on a macro-level, that do not necessarily bear any resemblance to the micro-level components from which they arise, provide an interesting avenue in the exploration of how disaster resilience can be developed. Specifically, the origins and theoretical principles associated with emergence (i.e. micro-macro effect, radical novelty, interacting parts, dynamic change, decentralised control, and robustness and flexibility) are discussed and likely applications thereof in the context of understanding disaster resilience are elaborated on.

The paper aims to explore the presence of emergent behaviour that generates disaster resilience by reviewing statistical correlations between four agricultural interventions (i.e. small-scale irrigation system, farmers' associative mechanisms, appropriate crop varieties, and alternative cropping techniques) and prominent indicators of disaster resilience (coping strategies and hazard adaptation/avoidance behaviour) in subsistence agricultural activities in Mozambique, Malawi and Madagascar. Through this analysis it becomes possible to understand the complexity associated with building disaster resilience in specific agricultural contexts.

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2. Understanding disaster resilience through the lens of complex adaptive systems theory

The debate around disaster resilience has gained prominence due to the realisation that traditional approaches towards managing disasters, such as the disaster management cycle (see Fig. 1), have largely failed in building adaptive capacity that is crucial for societal change and perseverance in the face of increasing disaster impacts [31]. This is largely due to the strong focus on disaster response often perpetuated by models such as the disaster management cycle [23]. Instead, the traditional way of managing disasters was through the application of a cycle of activities that began with disasters and ended with disaster (see Fig. 1). The inevitable return to a state of disaster espoused by such cycles created the impression that disaster and subsequent loss of lives, livelihoods, infrastructure, biodiversity and linked socio-ecological systems are inevitable outcomes [15,23].

An alternative to the traditional cyclical thinking about disasters is the concept of resilience, which was introduced to the contemporary discourse of disaster management in the early 1990s [1]. Resilience is said to refer to the ability of a community to respond and recover from disaster impacts through adaptive processes that facilitate the ability of the social system to re-organise, change, and learn from disasters [5,24,35]. This definition of resilience opens up many possibilities for the way disasters are managed and understood. Specifically, it contributes to the idea that, as with any other social system, building community resilience to disasters is inherently a non-linear, open system process where new information can continuously flow in and out of, thereby changing the system dynamics—or in this instance, the composition of community resilience profiles (this is opposed to the linear, closed-system process of managing disasters as proposed by the disaster management cycle) [34]. Importantly, the open system process of building community resilience implied by the above-mentioned definition can be better understood through the application of theoretical tools specifically designed to provide clarity to the dynamic complexity and interactions of open systems [16,19,33,36]. One such tool that can be used is Complex Adaptive Systems Theory (CAST). The application of CAST in exploring disaster resilience is a dramatic departure away from the traditional approach of addressing disaster risk issues. To a large degree, traditional disaster management tools, theories and frameworks (disaster management cycle and the Hyogo Framework) are based on a mechanistic scientific paradigm that espouses linear cause and effect relationships. In practice, the traditional paradigm over simplifies our understanding of complex social behaviours such as societal resilience by reducing efforts to build and promote resilience to a few simple steps. Such an approach misses the reality that linked socio-ecological issues such as disasters and disaster resilience are inherently complex, and should be addressed as such. CAST, as a variation of General Systems Theory, focuses specifically on how interactions at micro-levels of a system lead to complex adaptive behaviours at macro-levels [9,11,18,20,25]. Additionally, Holland [13], Rammel et al. [26] and Innes and Booher [14] determined that CAST is extremely appropriate in analysing systems that are constantly changing in accordance with their environment. The ability to analyse constantly changing systems is particularly relevant for disaster resilience, as a society's resilience profile is not static but is constantly adding or losing capacities, or being affected (or not) by disasters and risks. Thus the introduction of CAST and other systems-thinking theories and tools into our endeavours to understand disaster resilience could serve as a paradigm shift towards more in-depth and holistic understanding of the concept.

According to Lansing [17] and Smith and Wandel [31], CAST employs a wide array of concepts such as self-organisation,

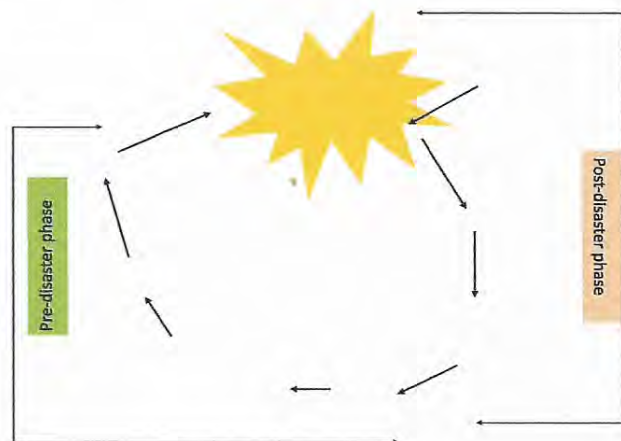


Fig. 1. Disaster management cycle.

emergence, attractors, feedback loops, aggregation, symmetry, and edge of chaos to assist in gaining a deeper understanding of how a systems functions and adapt to shocks. Of these concepts, emergence provides a particularly interesting avenue of investigation for disaster risk scientists in their quest to gain a deeper understanding of disaster resilience. Lansing [17] explains that emergence is a process where larger patterns with new properties can emerge from local interactions between system components. Understanding such interaction could clarify how micro-level decision-making and interactions impact positively or negatively on larger social patterns, structures and properties such as community resilience [8]. According to Goldstein [8] it is important to note that although emergence could provide a better understanding of a system, it cannot provide all the answers as to how a system functions. To gain a deeper insight into the concept of emergence it is necessary to elaborate on its development and key tenants.

2.1. Emergence: historical development and modern applications

The study of emergence has a long history of explaining the holistic nature of systems [6,8,14]. The earliest conceptualisation of emergent behaviour has been credited to one of the fathers of science and philosophy, Aristotle, when he stated: "the whole is something over and above its parts, and not just the sum of them all" [4]. The rapid development of scientific theories and methods in the 19th and early 20th centuries, especially those focusing on the fields of chemistry and evolutionary biology, re-emphasised the need to explain how new levels of organisation and behaviour emerge within systems without it displaying the nature and characteristics of the individual parts [6,25,29]. According to Goldstein [8], the study of how complex and dynamic systems organise themselves and adapt to change has extended into the modern era and provides a range of scientific fields with a tool to explore the as yet unknown impact of emergent system behaviour. The ability to understand the extent to which emergent behaviour influences systems could lead to a better understanding of complex paradigms and concepts within a variety of scientific fields. The field of disaster risk science is one such field that could greatly benefit from the study of emergent behaviour. A specific benefit is in the exploration of disaster resilience as it will allow for the investigation into how an aggregation and interaction of smaller micro-level variables and capacities in disaster risk prone communities could build macro-level disaster resilience. Crucially, emergence places an emphasis on understanding the contribution of complex system interaction in building resilience, where

Table 1
Characteristics of emergence within complex adaptive systems.

Author	Definition/characteristics
Lissack [21]	"Emergence is an overall system behaviour that comes out of the interaction of many participants-behaviour that cannot be predicted or even envisioned from a knowledge of what each component of a system does in isolation."
Goldstein [8]	"Emergent phenomena are conceptualized as occurring on the macro-level, in contrast to the micro-level components and processes out of which they arise."
Corning [4]	"Emergent effects would be associated specifically with contexts in which constituent parts with different properties are modified, re-shaped or transformed by participation in the whole."
De Wolf and Holvoet [6]	"A system exhibits emergence when there are coherent emergent at the macro-level that dynamically arise from the interactions between the parts at the micro-level. Such emergent are novel with regards to the individual parts of the system."
Lichtenstein and Plowman [20]	"Emergence occurs when lower level system participants interact, exchange information, and act without coordination from a central decider, resulting in unintended changes at higher levels within and beyond the focal organization."

traditional approaches tend to focus on the capacities in isolation. However, before considering a practical application, it is necessary to focus on the characteristics of emergent behaviour of which Table 1 contains a summary.

From the above-mentioned characteristics it becomes apparent that the emergent behaviour has its genesis primarily at a micro-level. However, its greatest influence can be seen at a macro-level where the micro-level interactions between components are transformed to entirely new components of behaviour. This creation of new macro-level behaviour is however subsumed by certain processes, which are micro-macro effect, radical novelty, interacting parts, dynamic change, decentralised control, and robustness and flexibility. These are elaborated on in more detail below.

2.1.1. Emergence and its possible implications for understanding disaster resilience

The concept of emergence has a long history of being used to describe aspects of how complex and dynamic human and ecological systems adapt their properties, behaviour, structure and patterns to prevent the extinction of a said system [6,19]. It is necessary to define what is meant by the term "emergence" so to explore the possible implications that emergent principles could have in explaining disaster resilience.

Two clear properties associated with emergence can be ascertained from the definitions above. The first of these properties relates to how macro-level behaviour in a system emerge from interactions between different micro-level components within a system. This first component of emergence could allow for the attainment of a deeper understanding of resilience to track the interaction between micro-level capacities within households and understand if this interaction leads to community-wide resilience at a macro-level.

Secondly, the interaction of micro-level components causes the modification, transformation and creation of new components on a macro-level that do not necessarily bear any resemblance to the micro-level components from which they arise. Put differently, emergence is inextricably linked to the creation of radical novelty in systems. This allows a system to¹ avoid equilibrium and constantly adapt to stress [6,8]. The aspect of radical novelty will allow researchers to select an array of capacities within a community and evaluate whether they generate behaviour that might be completely new compared to the original purpose of said capacity. Additionally, it could also allow for the measurement of the level of adaptability which a certain capacity contributes to a system.

The concept of emergence also has innate characteristics that

¹ Within Complex Adaptive System a state of equilibrium is undesirable, as it is believed that systems that display equilibrium are essentially closed systems. Closed systems cannot take on new information, learn or adapt to changes in an environment. This lack of adaptability means that such systems will stagnate and eventually die or become redundant.

could help researchers to indicate when it is observable in a system, and if it does indeed contribute to generating resilience. Some of the characteristics include the micro-macro effect, radical novelty, interacting parts, dynamic change, decentralised control, and robustness and flexibility. Two of these characteristics have already been discussed in the preceding paragraphs (i.e. radical novelty and micro-macro effect) and will not receive further attention, instead, the other characteristics that make up the concept of emergence will be briefly alluded to.

2.1.1.1. Interacting parts. According to Cilliers [3] and Sawyer [34], the interaction between various components in a system is needed for a system to generate emergent behaviour. Without interaction the micro-macro effect is impossible [4]. It can be argued that it is not enough to only identify all the capacities that are perceived to generate resilience; instead there should be an additional step in quantifying and qualifying the level of interaction between various components.

2.1.1.2. Dynamic. Goldstein [8] states that emergent phenomena evolve over time in a dynamic process. The dynamic evolution leads to radical novelty within a system; be it in the form of new capacities, components or behaviours [6,20]. The dynamic characteristic associated with emergence highlights it as a continuous process and not a final state of being within a system. This means that capacities within communities may be tested for their ability to contribute to the continuous change within a society as this would help to identify those capacities that are most likely to lead to dynamic changes in overall resilience profiles.

2.1.1.3. Decentralised control. De Wolf and Holvoet [6] assert that decentralised control refers to the fact that the macro-level behaviour of a system cannot be controlled or directed by a single component at the micro-level. Decentralised control is needed for a system to generate radical novelty in that there are no components in place at micro-level that serve as a control in terms of setting rules, parameters and limits for how the system could develop at a macro-level [3]. Interestingly, once an emergent behaviour evolves at macro-level it would be possible for this new emergent behaviour to influence the micro-level in what De Wolf and Holvoet [6] describe as "downward causation".

2.1.1.4. Robustness and flexibility. According to De Wolf and Holvoet [6], emergent phenomena are extremely robust and flexible as they remain mostly intact even if there is a failure or replacement occurs of individual entities that make up the phenomena. An example of this ability of an agricultural community to still show disaster resilience in the form of macro-level coping strategies and hazard avoidance behaviour, even if there is a change in a micro-level component, like the transition from informal family/friend-based farming networks to more formalised farmers'

associative mechanisms. This flexibility and robustness allows emergence to exhibit a dynamic quality and allows for adaptation to shock and disturbances [31]. Therefore, identifying emergence can assist in determining capacities and components within a system that could contribute to generating robustness and flexibility within systems.

It can be seen that by applying CAST and its related concept of emergence, there is a solid theoretical grounding for further research and application in creating a better understanding of how macro-level disaster resilience is generated through micro-level interaction within a wide array of communities. One such community that needs urgent attention in identifying emergent behaviour is subsistence farmers in Southern Africa. Southern Africa's ever-changing risk profile poses a very real threat to the exploitation of existing societal vulnerabilities, which could lead to disasters in the region. Notably within the region, small-scale subsistence agriculture plays a crucial role in sustaining livelihoods and food security for households and society as a whole. Although this sector is seen as a primary driver for social-economic development and food security, it remains one of the most vulnerable to the impact of disasters. As such it is crucial to gain a clearer understanding of how resilience currently emerges within such communities by focusing on the contribution of four strategic agricultural interventions identified by the Food and Agricultural Organization of the United Nations (FAO) in the three African states of Malawi, Mozambique and Madagascar.

3. Methodology

The case study research is based on a research project conducted on behalf of FAO in Madagascar, Malawi and Mozambique (see Fig. 2). The outcome of the study was to identify factors that could build resilience in the context of livelihood systems, which when threatened by severe events and hazards, have the potential to assist the system to recover from, and adapt to, adverse outcomes. Specifically, the study attempted to track the relative contribution of the following interventions in building resilience in all three countries:



Fig. 2. Case study countries.

- ² small-scale irrigation systems use;
- membership of a farmers' association;
- ³ crop varieties; and
- ⁴ alternative cropping techniques.

To gain greater insight into the contribution of the above-mentioned interventions to overall resilience, questionnaires aimed at household level were used. A total of 1110 respondents formed part of the study. Mozambique represented 40.3% ($N=447$), Madagascar 30.4% ($N=337$), and Malawi 29.4% ($N=326$) of the total respondents. Respondents were purposefully sampled from communities partaking in agricultural and food security activities supported by FAO and its partners from 2009 to 2014 under Disaster Preparedness EU Humanitarian Aid and Civil Protection (DIPECHO) funding.

A quantitative survey was administered to selected participants to test the relative contribution of natural, social, human, economic, and financial capacities in generating disaster resilience at household level. These capacities were integrated with the four main intervention areas mentioned above. Once the data was gathered, statistical analysis was conducted using descriptive statistics, exploratory factor analysis, Pearson correlation coefficient, and effect size. Correlation statistics were used to firstly determine micro-level interactions (this was done by correlating interaction between the four interventions), and secondly, to correlate the combined effect of these interventions to contributing to macro-level resilience behaviour by focusing on preferred/non-preferred coping strategies and hazard coping/adaptation behaviour. Correlation coefficients were selected as the preferred method of analysis as they provide a standardised measure of the strength of relationships between two variables [7].

Secondary data analysis was applied to the data set. According to Windle [37] and Sørensen et al. [32], secondary data analysis can be applied to a study, either as an appended study or meta-analysis. A meta-analysis refers to a study that compares data sets from different studies to identify positive or negative correlations between the different sets of data [10,28,30]. This is opposed to an appended study, which opts to use the same data set collected for the original study, but with new research objectives to either open up new avenues of exploration, or to allow for a more in-depth analysis of existing findings [2,37]. This study was framed within the provisions of an appended study. The main reason for this is that the initial study provided only a basic impression of how small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, cropping techniques and timing of production, possibly contributed to disaster resilience in agricultural communities. The dynamic interplay between these factors in different scales and contexts warranted further study.

Validity in the study was ensured by two possess. Firstly, the research tools were workshoped with the research teams from the three participating countries. The research personnel were trained on the utilisation of the research tools, technology and techniques. Subsequent to the workshop a pilot study was carried out in Chikhwana district in Malawi to see if there were any unforeseeable problems with the application of the questionnaire, and to test the research technology in a live environment. During the pilot study the quantitative questionnaire was constantly adapted in line with the learning of the pilot team in the field.

² Including the use of treadle pumps, fuel pumps, canals, buckets, wells, and gravitational water interventions.

³ Use of short-cycle crop varieties (reduced growing time) or traditional crop varieties.

⁴ Mulching, row planting, manure and fertiliser, intercropping, pit planting, moisture retention, minimum tillage, agroforestry, crop rotation, and no-tillage.

Table 2
Correlations between agricultural intervention per country.

Country	Intervention	Irrigation intervention (correlation)	Farmers' associative mechanism (correlation)	Crop varieties (correlation)	Cropping techniques (correlation)	
Malawi	Spearman rank order method	Irrigation intervention	1.000	.586**	.559**	.177**
		Farmers' associative mechanism	.586**	1.000	.568**	.294**
		Crop varieties	.559**	.568**	1.000	.273**
		Cropping techniques	.177**	.294**	.273**	1.000
Mozambique	Spearman rank order method	Irrigation intervention	1.000	.523*	.549**	0.045
		Farmers' associative mechanism	.523*	1.000	.564**	0.045
		Crop varieties	.549**	.564**	1.000	.284**
		Cropping techniques	0.045	0.045	.284**	1.000
Madagascar	Spearman rank order method	Irrigation intervention	1.000	.396**	.210**	.253**
		Farmers' associative mechanism	.396**	1.000	.464**	.245**
		Crop varieties	.210**	.464**	1.000	0.041
		Cropping techniques	.253**	.245**	0.041	1.000

After the workshop and pilot study the final questionnaire was compiled. Secondly, structural validity was ensured through an exploratory factor analysis on the sections pertaining to the four key technical areas of the questionnaire to identify the structure and factors of each construct.

The secondary data analysis focused on determining how micro-level interaction between the four interventions of the study could contribute to building resilience in terms of preferred coping strategies and hazard avoidance behaviour. The results of this analysis are presented below.

4. Interaction between four agricultural factors and its contribution to emergent resilience

Within the specific case study, the four interventions to building resilience were correlated with each other on a country-to-country basis to establish statistically significant interactions by examining whether there is a relationship between the four interventions, and the strength of the relationship. These interventions function on the micro-level as individual households were asked if they apply an intervention in their day-to-day agricultural activities. Table 2 illustrates the statistical correlations between the four interventions per country.

Moderate to large statistical correlations⁵ are evident between most of the interventions in the country context. However, exceptions can be noted with smaller statistical correlation (but in some instances strong relationships) between the use of cropping techniques, and all the other factors are evident in all three country contexts. Although variations exist within the correlations' statistics, it establishes that there is a small–medium relationship between the interventions, and thus a possible interaction between the various factors. For example, in all three of the country contexts it was found that if farmers used irrigation agriculture, they were likely to belong to farmers' associations, adopt a mixture of crop varieties (including traditional and short-cycle crop varieties), and implement innovative cropping techniques to

increase production and food security. This pattern seems to repeat itself even if the perspective from which the data is read changes (e.g. from farmers' associative mechanisms or crop varieties).

The correlation statistics also provided clarity on the strength of the relationships. For the most part, the relationships between interventions in the different countries were also found to be very strong (as indicated by **). Even in an instance such as Madagascar, where a smaller statistical correlation (.396**, .210**, .253**) exists between the interventions, the correlation is significant. In the instance of Madagascar, fewer farmers (than in the case of the other two countries) adopted irrigation, farmers' associative mechanisms, crop varieties and cropping techniques; however, when they did adopt one type of intervention, they were very likely to integrate it with all the other interventions. The opposite scenario was observed in the Mozambican context. Although there was a moderate statistical relationship between the use of irrigation and farmers' association (.523*), the relationship was not strong, possibly indicating that even if irrigation is used by farmers it could be done in isolation and could not be strongly linked to the activities of farmers' associative mechanisms.

Some of the statistical anomalies described above can be linked to non-linearity within open systems and should be explored in subsequent research. However, within the context of tracking emergent behaviour for building disaster resilience, the statistics also indicate how the micro-interactions clarified above could lead to macro-level resilience indicators. These macro-level resilience indicators, including coping capacities, hazard adaptation and avoidance are highlighted in Tables 4 and 5 below.

4.1. Emergent effect created through interaction: macro-level resilience

Two major macro-level indicators of resilience were identified. These relate to the ability to cope with the impact of disasters and to avoid risk periods. These two indicators are selected because both are crucial components in generating disaster resilience through allowing a social system to absorb impacts, respond to, and cope with a disaster event. Both these indicators also contribute to re-organisation, change and learning behaviours that are associated with resilience [5].

⁵ Statistical correlation – statistical correlations between factors can be indicated as either having a small effect: $d=.1$, (b), medium effect: $d=.3$, or (c) large effect: $d=.5$ on a related factor.

Table 3
Mean and standard deviation: factor combined intervention use.

Factor	N	Minimum	Maximum	Mean	Standard deviation
Combined intervention use	891	1.00	1.00	1.0000	0.00000
N	891				

The results of the secondary statistical analysis of both coping strategies and hazard avoidance/adaptation are conveyed in the following section. This statistical analysis is based on the hypothesis that the use of all, or the combination of interventions at micro-level, would lead to emergent behaviour at a macro-level, specifically behaviour associated with disaster resilience. To test the hypothesis, data sifting first took place and this produced 891 instances of valid data out of 1110 participants. Valid data refers to participants who indicated that they use all or a combination (1, 2 or 3) of the interventions to assist in their agricultural activities. These valid responses were then combined into a new factor titled “Combined intervention use” (the mean and standard deviation of this factor is detailed in Table 3 below), which was used to facilitate correlations with the resilience indicators of coping capacity and hazard avoidance/adaptation using the⁶ Spearman Rank Order method of analysis.

4.1.1. Coping strategies

Correlations revealed (see Table 4) several indications towards resilient behaviour emerging in communities that use all or a combination of interventions. Specifically, medium correlations are shown with what can be regarded as positive coping behaviours, such as the selling of household goods (.333**), moving away from household’s plots for off-farm work for income (.332**), and working in other people’s fields in exchange for food (.350**). These strategies are regarded as “positive coping strategies” because they indicate the existence of a pre-existing buffer capacity within a household that prevents it from showing a preference for strategies that are primarily focused on survival and reducing of basic⁷ physiological needs as per Maslow’s Basic Human Needs Hierarchy (1943). Therefore, households that exhibit positive coping behaviours would prefer to sell their excess household goods and their labour, agricultural skills and knowledge (that function on the safety level of human needs) before considering survival tactics associated with the physiological level to cope in times of disaster stress. This assertion is supported when the correlations on negative coping strategies are taken into account. These correlations indicate that respondents are not inclined to consider⁸ hunting and gathering (−.190**), reducing the number of meals (−.103**), or no strategies (−.125**). Interestingly, respondents also indicated that they would not consider support from family members (−.192**) as a possible coping strategy. This

⁶ The significance level of the Spearman correlation is calculated assuming that under the null hypothesis is distributed as a *t* with *N*−2 degrees of freedom. A one- or two-tailed significance level is printed depending on the user-selected option.

⁷ Physiological needs are described by Maslow as the pre-potent need of all needs. For example, if a person is lacking food, safety, love, and esteem-hunger for food will be stronger in driving human behaviour than anything else. The same can be said for all physiological needs when compared to other human needs (Maslow [22]:5).

⁸ Hunting and gathering is considered here as a negative coping strategy as the skill set required for agriculture and domestication of cattle divided from the skills required for hunting and gathering in Southern Africa about 10 000 years ago [12,27]. Consequently modern farming societies might not possess the specialised skills and knowledge of hunter gatherer societies to maintain themselves for a sustained period by turning to hunting and gathering to cope with disaster impacts.

could be indicative of respondents considering their financial (household goods) and physical assets (labour, agricultural skill and knowledge) to be of such a magnitude that they could adequately cope with disaster periods without having to approach extended family for additional assistance.

Added to the coping capacities exhibited, it was also determined that by using combinations of intervention strategies allows for innovative hazard avoidance and adaptation for priority hazards of droughts, floods and tropical cyclones during high-risk periods (usually between January and March annually).

4.1.2. Hazard avoidance/adaptation

Correlations display (see Table 5) an adaptive capacity amongst farmers that allow them to maintain or safeguard their agricultural and income-generating strategies in high-risk periods. Specifically, farmers are shown to select either adaptation to, or avoidance of, a hazard as a means to protect their livelihood. Adaptive behaviour is shown to be prevalent in coping with droughts (.363**, .379**, .189**) and floods (.268**, .245**, .139**). Participants indicated with certainty that applying a combination of interventions allows them to produce agricultural outputs despite droughts and floods. Hazard avoidance behaviour is seen from participant responses in that participants who use a combination of interventions tend to avoid engaging in agricultural activities that could be affected by cyclones (−.170**, −.202**, −.272**) between January and March. This avoidance behaviour could be attributed to conscious efforts to protect existing irrigation infrastructure, crop varieties and cropping techniques from cyclone damage, and information sharing on possible cyclone intensity by farmers’ associations as a means of early warning. The ability to adapt to hazards and hazard avoidance both are crucial indicators of an existing level of disaster resilience.

Both of the resilience indicators discussed can be said to be aligned with the two basic theoretical properties of emergence. Firstly, macro-level (societal) resilience indicators (coping strategies and hazard adaptation/avoidance strategies) have emerged because of the interaction of micro-level components (four agricultural interventions). Secondly, what is clear from the correlation statistics is that what began as agricultural activities, also contributed to building disaster resilience in the agricultural communities. These primarily agricultural activities have thus transformed and created new behaviour that does not bear any resemblance to the micro-level components from which it arose. Theoretically the newly-formed resilience components could provide several benefits to the entire system, including system robustness, flexibility and dynamic change in disaster contexts.

The findings described above illustrate that it is indeed possible to identify the development of complex resilience behaviour by examining emergent system behaviour. Correlations (see Table 2) have shown that there is a correlation between the various agricultural interventions that could be indicative of interaction between these interventions. This micro-level interaction is a basic building block needed for emergent behaviour. There is also confirmation that once the agricultural interventions functioning at the micro-level are used in combination and correlated with disaster coping strategies and hazard avoidance and adaptation behaviour, macro-level resilience behaviour emerges (as illustrated in Tables 4 and 5). This could point to the presence of the process of micro–macro interaction and radical novelty as discussed in theory (see Section 2.1.1.1). Additionally, it is shown that not one of the individual agricultural interventions at the micro-level controls the process of change that leads to the emergence of resilience at the macro-level. Instead it is a combination of all or some of the interventions in unison tallows for change to occur within the system. This is indicative of decentralised control behaviour associated with the generating of radical novel behaviour, such as

Table 4

Preferred and non-preferred coping strategies within agricultural communities in the case study countries' correlation with the number of intervention strategies used by a respondent.

Combined intervention use factor	Positive coping behaviour	Selling of household goods	Moving away from household's plots for off-farm work for income	Member of household working in other people's fields in exchange for food	
	Correlation	.333**	.322**	.350**	
Combined intervention use factor	Negative coping behaviour	Support from family members	Hunting and gathering	None	Reducing the number of meals
	Correlation	-.192**	-.190**	-.125**	-.103**
	N	891	891	891	891

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Table 5

Preferred and non-preferred adaptation/avoidance hazard strategies within agricultural communities in case study countries' correlation with the number of intervention strategies used by respondents.

Factor	Hazard	January	February	March	Hazard coping type
Combined intervention use	Droughts	.363**	.379**	.189**	Adaptation
Combined intervention use	Floods	.268**	.245**	.139**	Adaptation
Combined intervention use	Cyclone	-.170**	-.202**	-.272**	Avoidance
	N	891	891	891	

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

resilience. Robustness and flexibility associated with emergent behaviour within systems is also shown to be present upon a review of the positive coping strategies and hazard avoidance and adaptation strategies adopted by farmers using all or a combination of the four interventions. The robustness and flexibility provided by disaster resilience at the macro-level could in turn have a positive effect on the sustainable use of the four agricultural interventions at the micro-level. This aligns with the notion of "downward causation" associated with the concept of decentralised control. The only theoretical aspect of emergence that proves difficult to report on within the scope of this study is the concept of dynamic adaptation. This is not because it is not present within the study, but because dynamism is a factor that is linked to development over a period of time. This study could therefore serve as a source of base data, which could be re-evaluated over time in order to track dynamic changes in the disaster resilience profiles of the communities involved.

5. Conclusion

The concept of emergence has a long history of being utilised to describe aspects of how complex and dynamic human and ecological systems adapt their properties, behaviour, structure and patterns to prevent the extinction of a said system. The article has illustrated the benefits of applying the systems concept of emergence to attain a greater understanding of disaster resilience. At a theoretical level, the concepts of micro-macro effect, radical novelty, interacting parts, dynamic change, and decentralised control will assist in setting parameters for the observation of resilience behaviour in a disaster-affected community. This in turn provides disaster risk scientists with the ability to understand the resilience paradigm in a more holistic manner and offers greater insight into how to measure existing resilience profiles in communities. It also

assists in building on such profiles to ensure that a community has the ability to adapt, avoid, recover and learn from disaster impacts.

Using the two main principles associated with emergence (i.e. micro-level interactions leading to macro-level behaviour and the emergence of radically new behaviour as a guide), an analysis was conducted on whether emergent behaviour is observable in agricultural communities in Malawi, Mozambique and Madagascar. The results from this analysis illustrated that emergent behaviour (i.e. coping strategies, and hazard avoidance behaviour) is indeed observable in agricultural communities that use all or a combination of agricultural interventions such as small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, and cropping techniques. These resilience abilities are newly formed macro-level behaviours that emerge due to the interactions of agricultural interventions at a micro-level. This illustrates that the practical application of emergence in measuring disaster resilience indicators could provide valuable results in improving our understanding of how resilience emerges in agricultural settings.

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Chapter 5: Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa

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Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa

1. Introduction

Disasters continue to have significant impacts upon human existence. The impact of disaster events has become more pronounced in recent decades, leading to an increase in the loss of lives, livelihoods, infrastructure, biodiversity and linked socio-ecological systems. To combat the impact of these events, a multitude of disaster risk reduction theories and policies have been developed. Yet many of these theories and policies still reflect the basic premise of Mechanistic Theory that has been the dominant paradigm for scientific reasoning since the Renaissance. These theories and policies propose that disaster risk can be reduced to a set of hazards, vulnerabilities or policy shortcomings. Once these different elements or policy shortcomings have been identified, it would become easier to identify problem areas and suggest linear solutions towards reducing disaster risk. However, very little progress has been made towards reducing disaster losses through the application of these mechanistic theories (such as the Pressure and Release Model, the Access Model and the Sustainable Livelihoods Model) and policies (e.g. the Yokohama Framework and Plan of Action and the Hyogo Framework for Action, and also more recently the Sendai Framework for Disaster Risk Reduction). This lack of progress opens up the possibility for the application of different theories and paradigms for understanding and reducing disaster risk. One such option is the application of Complex Adaptive Systems thinking and its linked paradigm of non-linearity.

Non-linearity is the notion that inputs into a system are not always proportional to the expected outputs. Consequently, inputs into different systems would not always yield consistent results or outputs, as a variety of context specific socio-economic, political or ecological variables dramatically change the efficacy inputs. In practice this would mean that a disaster resilience building project might be successful in one area, as it speaks to the context specific needs of the area, but attempts to use the same project parameters and methodologies would lead to project failure in the other areas, as they do not take non-linearity into account. This paper will attempt to test the presence of non-linear behavior in agricultural communities in Southern Africa. This process is facilitated through the identification of non-linear behaviour in the application of four agricultural interventions and their effect upon disaster coping strategies adopted in different districts of Madagascar, Malawi and Mozambique. The analysis highlights that certain non-linearity exists relating to coping behaviour, in particular that the size and the number of interventions used for resilience generation in these communities are not necessarily proportional to the expected outcome. Thus, communities that use more agricultural interventions are not necessarily less vulnerable or more resilient than communities that use less interventions. To the contrary, the analysis establishes that in some

contexts communities using less interventions display a greater tendency to positive coping behaviour than those using more interventions. These findings could provide a paradigm shift away from the linear approach of generating generic theories and policies for reducing disaster risk, towards more holistic and contextually adaptable theories and policies.

Before the specific results can be discussed in more detail, a theoretical background is given on traditional mechanistic scientific thought and the impact thereof on the theoretical and practical tenants of disaster risk science. The Mechanistic Approach is briefly critiqued from a Complex Adaptive Systems Approach (and its associated concept of non-linearity) as a means of highlighting a possible alternative approach to how disaster risk reduction and disaster resilience should be understood and operationalised.

2. Mechanistic thought and its influence on scientific reasoning and problem solving

Creating an understanding of how the environment and human society function within western society has been dominated by the Mechanistic Approach to scientific inquiry (Rihanna and Geyer 2001; Vallacher 2002). According to Scoones (1999) the roots of the Mechanistic Approach can be traced as far back as ancient Greece and medieval Christian Europe. However, the heyday of mechanistic thought emerged during the Renaissance (14th–17th centuries) and Enlightenment periods (16th-18th centuries) of world history with the works of Da Vinci, Copernicus Galilei, Descartes, Hobbes and Newton playing a major role in establishing mechanistic thought as the dominant approach to scientific inquiry and problem solving (Rihani and Geyer 2001:237; Wulun 2007:394-395; Alexander, 2013). The Mechanistic Approach as developed by these great scholars espouses three major orientations to scientific inquiry, i.e. reductionism, determinism and linear reasoning/problem solving (Wulun 2007). The combination of these orientations states that all complex human, psychological or environmental phenomena can be understood by reducing them to their base components (reductionism). Once phenomena have been reduced to their basic components, it become possible to identify or understand the “natural laws” or components that determine larger behaviour within a system (determinism). Determinism therefore helps to establish a linear relationship between micro and macro level components of a system. Thus the hypothesis that flows from this reasoning is that by altering aspects of component “A”, it will bring about a directly proportional change in component “B” (thus linear reasoning) (Hawking 1988; Rihanna and Geyer 2001; Vallacher, 2002). A typical example of this type of reasoning can be represented by Isaac Newton’s Third Law of Motion:

“To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts”.

If we translate the mechanistic approach to the level of systems analysis it makes the argument that “*a whole is the sum of its parts*” (Vallacher 2002; Wulun 2007). Therefore the Mechanistic Approach often approaches problem solving from a closed-system perspective (Rihani and Geyer 2001). Its basic tenets are that both the components that create a problem within a system and those that could solve the problem are already contained within the system boundaries (Scoones 1999). This assertion is supported by Vallacher, (2002) who states that a linear system and its accompanying behaviour is a direct reflection of the number of elements contained within the system, and the interaction between these elements to bring about equilibrium. Thus in a linear approach (by identifying a problematic component within an environmental, human or societal system) there is sufficient departure to finding a possible solution. Identifying undesirable component/status will help one move towards restoring equilibrium and harmony within a system. However, these traditional ways of reasoning were being challenged at the beginning of the 20th Century with the emergence of systems/holistic thinking.

3. Systems thinking as a paradigm shift in science

Mechanistic, linear reasoning has helped humankind to gain deeper insights into the fields of physics, biology and economics, and it reached an impasse in explaining dynamic ever-changing phenomena, especially those at the interface between society and the environment like disaster risk and the reduction thereof (Costanza et al. 1993; Wulun 2007; Levin 1998; Lichtenstein et al. 2006). The need to find solutions to dynamic and ever-changing problems within all branches of scientific inquiry lead to the formation of the Systems Movement. This movement can trace its roots back to thinking that emerged on how human, environmental and electronic systems function (following World War I and II) (Anderson 1999; Morel and Ramanujan 1999). During this period, physicists such as Schrödinger and Dirac, introduced the notion that some phenomena are probabilistic in nature (as opposed to deterministic), and therefore subject to chance variation (Rihani and Geyer 2001, Anderson 1999). The implication of this notion was the fact that all systems are not easy to understand (as per the Mechanistic Approach) because constant change leads to complexity within systems and complex systems are harder to break down to their constituent parts, as these are not constant but ever-changing (Vallacher 2002; Alexander, 2013). The basic idea that certain phenomena are probabilistic in nature stimulated the growth in fields of inquiry pertaining to Holism, General Systems Theory and Complex Adaptive System Theory (Von Bertalanffy 1972; Wulun 2007). Complex Adaptive System Theory hailed a major shift in scientific thinking away from reducing a system to a sum of its parts to the notion that “*a whole is more than sum of its parts*” - or that systems do not just comprise various components, but are also comprised of dynamic interaction of components, temporal and contextual influences, and feedback loops that help the systems build up or break down certain components to foster adaptation (Boulding 1956; Ashby 1960; Buckley 1968; Becker 2009; Skyttner 2005; Richardson 2005).

This holistic, systems thinking alluded to above has also prompted a change in how real world problems are approached and solved. Thus, where the orientation has always been towards linear problem solving, the Systems Approach introduced non-linear reasoning where there is a recognition that the size of inputs into a system might not be proportional to expected outputs (Boal and Schultz 2007; Railsback 2001; Wulun 2007; Vallacher 2002). Therefore perceived insignificant variables or inputs in a system might fundamentally change the operation of a system, whilst major inputs or variables might have no impact in changing the system (Schneider and Somers 2006; Plsek 2001). The end goal or problem solving has also changed with the introduction of the system perspective. Where linear reasoning aimed to achieve a certain idealised end state, characterised by stability, systems based solutions aim for solutions to complex problems that are continuously adapting to and coping with changing environments, contexts and time constraints. This approach propagates that viable solutions to complex problems can only be achieved by functioning at what is known as the “edge of chaos”, allowing for flexibility and constant change without destroying the system and allowing for resilient and adaptable system behaviour to emerge (Scoones 1999).

Systems thinking has brought about a dramatic change in the last hundred years to thinking and problem solving, especially in natural science and biology, although it is noticeable that the social sciences have been slow to adopt this theoretical framework to explain social phenomena (Scoones 1999; Rihani 2002; Matthews et al. 1999) due to the complexities of social systems (Alexander, 2013). There has, however, been an increasing realisation within the last twenty years that society, and the functioning thereof, cannot be separated from environmental, economic and temporal contexts that are constantly interacting with it and changing it (Adger 2006). Wulun (2007), Matthews et al. (1999) and Costanza et al.(1993) add that to move towards a holistic understanding of social problems and solutions thereof, there can no longer be a reduction of social issues as separate to the context in which they function, as such a separation works counter to the reality that society, environment and economy are inseparable from each other. A field of social inquiry that still struggles to some degree with incorporating systems thinking and the concept of nonlinearity is disaster risk management and disaster risk reduction.

4. Mechanistic thinking in disaster risk management and Disaster Risk Reduction Theory and practice

The dramatic impact of hazards and disasters on human systems has necessitated the creation of the new fields of enquiry of disaster risk management and disaster risk reduction. Both these fields rose to prominence subsequent to the early 1990s, when the first International Decade for Natural Disaster Reduction was declared by the United Nations General Assembly through Resolution 42/169 (Van der Waldt 2013; Cutter et al.2008; Cordona 2004). Since this time, models, tools and policies were developed aimed to facilitate an understanding of how disaster risk should be managed and reduced, such as: the Pressure and Release Model (PAR) (Wisner et al, 2004; Kelman,

2011), the Household Access Model (Wisner et al. 2004) and international policy measures such as the Yokohama Strategy (1994), the International Strategy for Disaster Reduction (2001-2010), the Hyogo Framework for Action (2005-2015) and the Sendai Framework for Disaster Risk Reduction (2015-2030) (Birkman 2006; Miller et al. 2010; Cimellaro *et al.* 2010; Blaikie et al. 1994, UN, 1994; UNISDR, 2005; UNISDR, 2015). A contemporary aim of these documents and tools is to build disaster resilience in disaster affected communities. Originally introduced from the field of ecology, resilience remains a contested term with some scholars viewing it as the ability of a community to “bounce back” to their normal state of functioning following a disaster and others viewing it as a more nuanced process comprising of adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a disaster or what is referred to by some policy makers, academics and practitioners as “bouncing back better” or “bouncing forward” (Timmerman 1981; Pelling 2003; Cutter et al. 2008; Manyena et al. 2011). Although all of the policy documents and models have been designed to reduce disaster losses and build the disaster resilience of society, evidence in creating societal resilience to disaster and reducing loss in lives, livelihoods and ecological systems has been very limited over the past 25 years (since the declaration of the International Decade for Natural Disaster Reduction in 1990) (Cardona, 2004; Alexander, 2013). Both the Hyogo Framework for Action and the Sendai Framework for DRR reiterate the limitations of current policies and theoretical tools by stating:

“Disaster loss is on the rise with grave consequences for the survival, dignity and livelihood of individuals, particularly the poor, and hard-won development gains. In the past two decades, on average more than 200 million people have been affected every year by disasters” (UN, 2005).

and

“Over the same 10-year time frame (*the period of implementation for the Hyogo Framework, 2005-2015*), however, disasters have continued to exact a heavy toll, and as a result the well-being and safety of persons, communities and countries as a whole have been affected. Over 700 thousand people lost their lives, over 1.4 million were injured and approximately 23 million were made homeless as a result of disasters. Overall, more than 1.5 billion people were affected by disasters in various ways. Women, children and people in vulnerable situations were disproportionately affected. The total economic loss was more than \$1.3 trillion. In addition, between 2008 and 2012, 144 million people were displaced by disasters” (UN, 2015).

So although minor progress has been achieved in reducing some risk, the overall trend in terms of lives, livelihoods and economic losses due to disasters, is mostly negative. A possible reason for this could lie in the mechanistic thinking and the lack of consideration of systems concepts such as non-linearity in the formulation of models and policies that are supposed to reduce disaster risk. Examples of this are typified by the practical implementation of the Pressure and Release Model (PAR) (see Figure 1) and the recently formulated Sendai Framework for DRR (See Table 1). These will be briefly discussed and critiqued from a systems perspective.

4.1 A systems critique of DRR models and policy

The PAR Model was designed to explain how a society's vulnerability progressed from deeply embedded root causes to more observable dynamic pressures and specific unsafe conditions and how these interact with hazards to cause disasters (Blaikie et al, 1994; Fjord and Manderson, 2009; Adger 2006; Birkman 2006). Importantly, the PAR model might not have been developed to be a simple linear discussion on the construction of vulnerability, but a broad framework explaining the construction of disaster risk and eventually how it can be reduced. However, over time the practical implementation of the model has often taken on a linear interpretation (Birkman 2006; Kelman, 2011; Cordona 2004; Oliver-Smith 2009). Consequently, in the implementation of the PAR Model the argument is made that if disaster risks are to be reduced, it is necessary to identify root causes of social vulnerability, and by doing this, one will have a departure point for addressing dynamic pressures and eventually specific unsafe conditions (Kelman, 2011). The outcome of this process is a less vulnerable community (this being the ideal end state for a society) (Cordona 2004; Turner 2003). The practical implementation of PAR Model therefore displays the process and reasoning associated with mechanistic thinking: i.e. a problem reduced to its components, applying determinism to identify the linear relationship between components, and offering a linear solution to address the problem and reaching a desired end state.

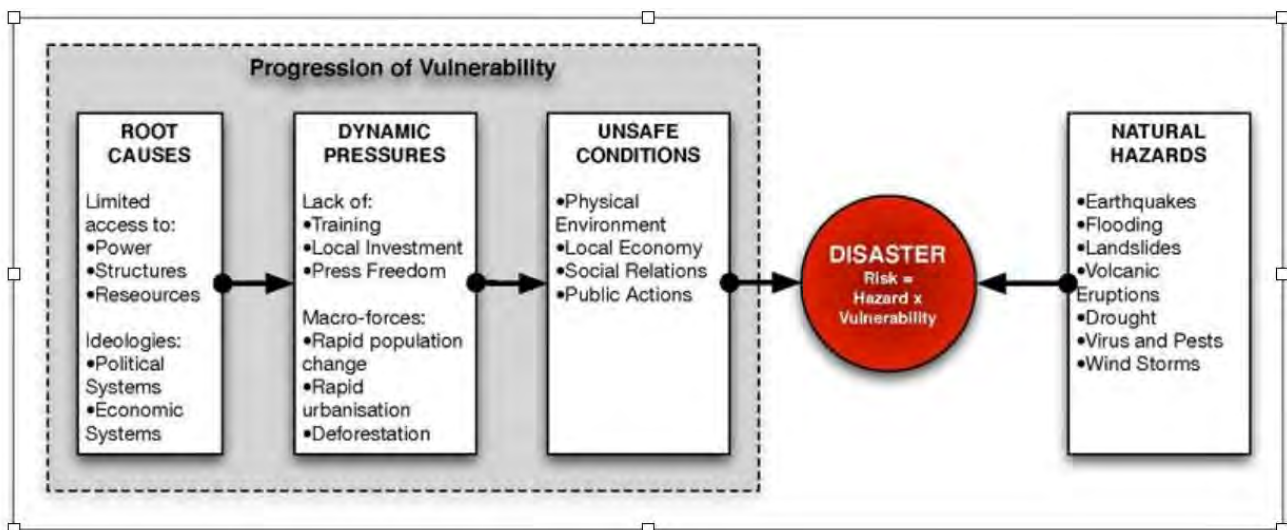


Fig1: Pressure And Release Model (Blaikie et al., 1994; Wisner et al., 2004)

From a systems perspective, the practical implementation of PAR Model becomes problematic because it fails to take into account the important issue of non-linearity and the dynamic interaction associated with it. Thus the assumption made by the PAR Model is that perceived root causes lead to unsafe conditions in all contexts (Heijmans 2001; Adger 2006). This is problematic from a systems perspective because the principle of non-linearity states that the size of inputs into a system might not be proportional to expected outputs. Thus, in this instance, a perceived root cause may actually have a minimal effect or contribution of an eventual unsafe condition in some contexts, whilst in others it (a root cause) may have a major contribution (Birkman 2006; Kelman 2011; Cordona 2004). In other instances, a root cause might lead to a certain level of vulnerability to disas-

ters, but without the presence of root causes and dynamic interaction it fosters with other components, the system descends into chaos, making a society even more vulnerable (Heijmans 2001; Turner et al. 2003; Adger 2006). Geyer and Rihani (2010) highlight an example of the last mentioned principle within the context of modern Iraq, where the root cause of the problems in the country was identified as the political and power structure established by Saddam Hussein to oppress his countrymen. However, after his removal from power in 2003, the country has been in a constant state of chaos with millions of people being more vulnerable now than under the previous oppressive regime. Although this example comes from the realm of politics and development, the lesson still rings true within disaster science. It is not enough to reduce a problem like societal vulnerability to only root causes, dynamic pressure and unsafe conditions, without taking into account the dynamic interaction between the various components, their environment (context), temporal dimensions and the information exchange that subsumes adaptation within a system (Cutter et al. 2008; Cordona 2004). A failure to take into account the holistic nature of a problem fosters solutions that either promote stability or chaos, both of which are undesirable if the aim is to build more disaster resilient societies (Matthews et al. 1999 Turner et al. 2004).

The problematic situation of finding linear solutions to disaster risk, as established in theory, has extended into global policy. A review of the Hyogo Framework for Action and the policy that has superseded it, the Sendai Framework for DRR 2015-2030, shows the presence of linear thinking in the outcomes formulated by both these documents to reduce disaster risk (see Table 1). Both documents specifically identify a multitude of complex problems that contribute to the dramatic increase in disaster losses related to lives, livelihoods and infrastructure over the past 25 years. However, to move towards a stage where policy recommendation can be made to guide the risk reduction efforts of international and national governance structures, both policies reduce the problem of disaster risk to five (HFA) and four priorities (Sendai Framework) for action (reductionism). The assumption in both the documents is that there is a definite linear relationship between the lack of implementation of the priority areas, and the increase in disaster losses in all contexts (determinism). Thus the logical argument made by both policies is that if progress is to be made in reducing or eliminating disaster losses, the primary focus should be upon implementing the five or four step global plan (linear reasoning). Put differently, once these priority areas have been implemented, at risk communities will be rendered safer from disaster risk (or a possible state of equilibrium would have been achieved).

Table1: International Disaster Risk Management Policies and Linear Outcomes

Framework	Priority Action Areas	Policy Targets
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<p>Hyogo Framework for Action (2005-2015)</p>	<ol style="list-style-type: none"> 1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation 2. Identify, assess and monitor disaster risks and enhance early warning 3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels 4. Reduce the underlying risk factors 5. Strengthen disaster preparedness for effective response at all levels 	<p>No specific policy targets outlined. The achievement of the five (5) priorities for actions serve as the main targets to be achieved</p>
<p>Sendai Framework for Disaster Risk Reduction (2015-2030)</p>	<ol style="list-style-type: none"> 1. Understanding disaster risk; 2. Strengthening disaster risk governance to manage disaster risk; 3. Investing in disaster risk reduction for resilience; 4. Enhancing disaster preparedness for effective response, and to “Build Back Better” in recovery, rehabilitation and reconstruction. 	<ul style="list-style-type: none"> • Substantially reduce global disaster mortality by 2030 aiming to lower per 100 000 global mortality between 2020-2030 compared to 2005-2015 • Substantially reduce the number of affected people globally by 2030 aiming to lower the average global figure per 100 000 between 2020-2030 compared to 2005-2015 • Reduce direct disaster economic loss in relation to global gross domestic product by 2030 • Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 • Substantially increase the number of countries with national and local disaster reduction strategies by 2020 • Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030 • Substantially increase the availability of and access to multi hazard warning systems and disaster risk information and assessments to the people by 2030

Although both policies have at their core the noble goal of reducing disaster risk, the implementation and achievement of goals have been and will remain problematic. A key reason for this is highlighted by Oxley (2015:7) and Wisner (2015) in their critical review of the HFA and Sendai Framework. The review by Oxley highlights that one of the crucial gaps in the implementation of the HFA (2005-2015) was “a lack of appropriateness in contexts of complexity, uncertainty, informality, fragility, insecurity (including conflict)”. This highlights the inability of the HFA to take into account the Systems Theory concepts of non-linear thinking and the effects which different contexts and fac-

tors could have on achieving risk reduction goals. The lack of systems thinking has also been passed on to the Sendai Framework with a key critique of the framework being that it does not make “provision for system wide perspectives and holistic approaches”, or again that it lacks appropriateness in contexts as explained by Oxley (2015). Additionally, from a systems perspective, both policies fail to take into account the dynamic nature of disaster events by putting out desired targets to be achieved, especially in the context of the Sendai Framework. This is problematic because it creates the impression that once these “arbitrary” targets have been achieved, communities will be safe. Thus through the linear reasoning and problem solving contained in these policies, risk reduction becomes an ideal outcome of risk reduction interventions and not a constant process. This makes it difficult for these global policies to be implemented and adapted within different contexts, especially if known contexts start to change.

The critique of the Mechanistic Approach to disaster risk reduction and resilience building serves as a rationale for the focus upon selected agricultural communities in Madagascar, Malawi and Mozambique. The agricultural communities in these countries formed part of a larger Food and Agriculture Organisation (FAO) study, that aimed to determine an ideal model for building disaster resilience in agricultural communities by focusing upon the relative contribution of four agricultural interventions, namely use of small-scale irrigation systems, membership to a farmers’ association, use of crop varieties and cropping techniques. The basic premise of the original study being that the more of the various agricultural interventions are identified within the community, the more resilient they are. This premise is very much in line with contemporary disaster management thinking. However, a secondary analysis of the data from the perspective of a Complex Adaptive System Theory concept of non-linearity challenges the assumption that more capacity equals higher levels of resilience and forces us to reconsider the applicability of generic models of building disaster resilience. The methodology underlying this analysis is outlined in the following section.

5. Methodology

A quantitative survey was administered to a combined total of 1110 respondents (representing the household level), that formed part of the study. Mozambique represented 40.3% (N=447), Madagascar 30.4% (N=337) and Malawi 29.4% (N=326) of participants. These respondents were purposefully sampled from communities partaking in agricultural and food security activities supported by the FAO and partners from 2009-2014 under Disaster Preparedness EU Humanitarian Aid and Civil Protection (DIPECHO) funding (Kruger 2015). The original analysis of the information created a plethora of data categories which either did not form part of the final project report or were only analysed in a very superficial way. This has provided an opportunity to conduct a secondary analysis of data to test different theoretical constructs through the application of more in-depth statistical analysis. As such the study endeavoured to identify the presence of non-linear behaviour relating to preferred/non-preferred disaster coping strategies that emerge, in comparison to the number of agricultural interventions used to build disaster resilience in the case study countries. The pres-

ence of non-linear behaviour would provide a means to illustrate that the mechanistic assumption that more capacity (or more interventions used) equals higher levels of resilience and better coping strategies is problematic for the theoretical and practical understanding of contextually specific risk profiles.

To facilitate analysis, the district (sub-national government) demarcation of the three case study countries formed part of the original study. The sub-division into their respective districts for analysis was necessary so as to effectively capture the unique disaster coping profile of sub-national spaces and avoid distortions that might occur because of the aggregation of coping measures at a national level. Consequently, this separation also made it easier to identify agricultural interventions used in each district, and also highlight possible non-linearity in coping behaviour from district to district. Once this division was made, an initial correlation analysis was carried out between two variables i.e. district of each country and the amount of interventions used (*use of small-scale irrigation systems, membership to a farmers' associations, use of crop varieties and cropping techniques*). Each respondent could indicate if they used one intervention or a combination of two, three or four interventions at any given time. The results of this initial study for each country are contained in Tables 2 (Madagascar), 4 (Malawi) and 6 (Mozambique) below.

A second correlation analysis was drawn by comparing the variables of district (per country) and preferred/non-preferred disaster coping strategies. This provided information on the tendency to adopt certain positive and negative coping strategies in times of disaster stress. A distinction is made in the study between positive coping and negative coping behavior, because certain forms of coping might actually prove harmful to resilience building efforts. In this instance positive coping strategies are considered as "positive" because they indicate the existence of a pre-existing buffer capacity within a household that prevents it from showing a preference for strategies that are primarily focused upon survival (negative coping) and reducing of basic physiological needs as per Maslow's Basic Human Needs Hierarchy (Coetzee *et al.*, 2016). The variable of preferred/non-preferred disaster coping strategies was also selected to serve as a proxy indicator of resilient behaviour. The reason being that coping behaviours serve as building blocks from which larger societal resilience behaviors such as adaptation and learning emerge (Coetzee *et al.*, 2016). Within the analysis the respondents could indicate their inclination to coping behaviour by either indicating yes, no, or uncertain. The results of this analysis are reported in Tables 3 (Madagascar), 5 (Malawi) and 7 (Mozambique) below.

Once the tables were compiled it became possible to test for non-linear behaviour in coping strategies adopted by contrasting the results with the accepted linear notation of $R = H \times V/C$. Thus it became possible to test whether the availability of more capacities (relating to the four agricultural interventions in the study) truly reduced vulnerability. This analysis highlighted certain non-linearities relating to coping behavior, specifically that the size and the number of inputs into the system are not necessarily proportional to the expected outcome, i.e. that communities that use more agri-

cultural interventions are not necessarily less vulnerable and more resilient than communities which use less interventions. To the contrary, the analysis showed in some contexts that communities using less interventions displayed a greater tendency to positive coping behaviour than those using more interventions. The findings of the analysis are discussed in more detail below.

6. Identifying non-linear relationships in agricultural communities in Madagascar, Malawi and Mozambique

The analysis exposes anomalies that do not follow a linear cause and effect relationship. It is important to take note of this, if policies or programmes to reduce disaster risk in these areas are to be effective.

6.1 Madagascar

Three study areas formed part of the study in Madagascar i.e. Vangaindrano (see Figure 2), Farafangana and Mananjary (see Figure 3). Survey data contained in Table 2 reveals that all three areas apply very diverse agricultural interventions. Vangaindrano shows the lowest adoption of agricultural interventions to build disaster resilience with mostly one (50%) or two (35%) interventions being used by participants in the area. Farafangana shows an inclination to use between two (35,1%) and three (44,3%) interventions per participant, whilst Mananjary shows a significant (80%) adoption of three interventions to build disaster resilience.

Table 2: Combined agricultural intervention use per district in Madagascar

District	1.00 (Intervention used)	2.00 (Intervention used)	3.00 (Intervention used)	4.00 (Intervention used)	Total
Vangaindrano	50% (N= 52)	35% (N= 36)	10,7% (N=11)	3.9% (N= 4)	100% (N=103)
Farafangana	16,5%(N=16)	35,1% (N=34)	44,3 % (N=43)	4, 1% (N=4)	100% (N=97)
Mananjary	6,2%(N=4)	12,3%(N=8)	80%(N=52)	1,5% (N=1)	100% (N=65)
Total	27,2% (N=72)	29,4 (N=78)	40%= (N= 106)	3,4% (N=9)	100% (N= 265)

In a linear analysis of the situation in Madagascar it would follow that the more capacities a community has, the less vulnerable they are, and the less their overall level of disaster risk¹. This would mean that by a cursory glance at Table 2, it would be assumed that the community of Mananjary would be the least vulnerable and more resilient than the communities of Vangaindrano and Farafangana, purely because the more capacities (in the form of interventions being used) are available to them, the greater chance they have to adapt to and resist possible disaster impacts

¹ According to the widely sighted Disaster Risk Notation - $R = H \times V/C$ (UNISDR, 2004).

(i.e they would be more resilient). However, this reasoning can be challenged through some non-linearities that emerge once the use of interventions are correlated with preferred/non-preferred coping strategies in each area (see Table 3).

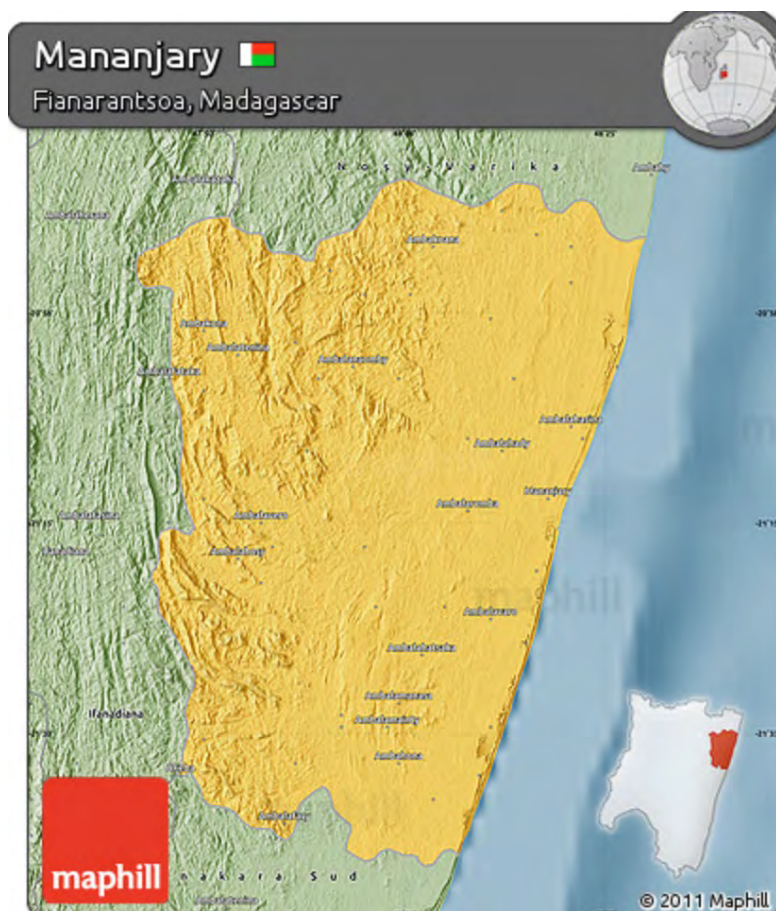


Figure 2: Mananjary, Madagascar (Maphill, 2015)

When we look at the results of the correlation it becomes apparent that Mananjary might not be as resilient as can be assumed in Table 2. Mananjary displays some negative coping behaviours i.e participants will strongly consider reducing size of food portions at meal times (88%), eating seed stock (59,7%), reducing number of meals per day (44,8%) and hunting and gathering (46,3%). Additionally, some positive coping measures are not considered to be viable strategies to cope with disasters i.e. support from family for food and income (65,7%), support from friends for food and income (65,7%) and to a lesser extent, the selling of household goods (55,2%). The results from Mananjary stand in contrast with the results from Vangaindrano and Farafangana. In both these instances, although they use less agricultural interventions to build disaster resilience than Mananjary, overall they show a tendency to avoid certain negative coping strategies.

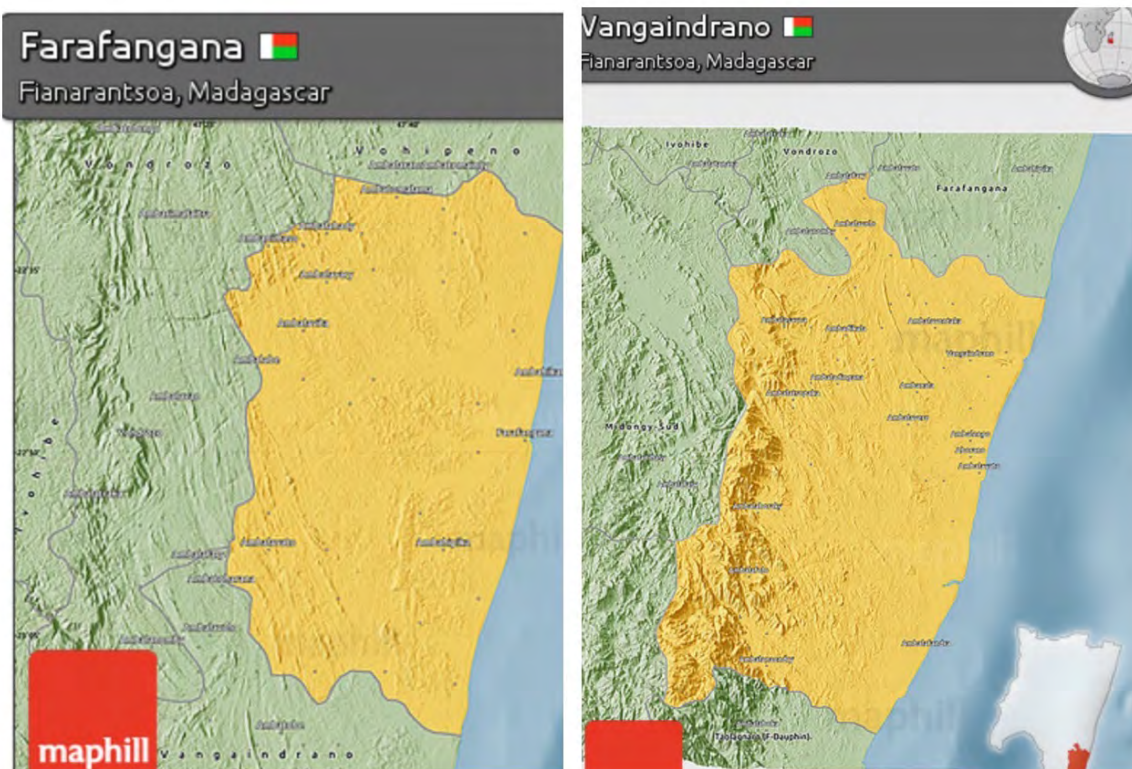


Figure 3: Farafangana and Vangaindrano, Madagascar (Maphill, 2015)

In Vangaindrano and Farafangana respectively they would not consider reducing number of meals per day (62,1%; 85%) or eating seed stock (63,9%; 61,4%), something participants in Mananjary were more willing to do. This does not imply that Vangaindrano and Farafangana do not display a penchant for negative coping strategies such as hunting and gathering (62,1%; 65,3%), and do not consider positive coping strategies such as selling of household goods (84,6%; 61,4%), support from family for food and income (85,2%; 87,1%), or support from friends for food and income (87%;85,1%), as viable options. However, it does illustrate that with less capacities (agricultural inputs) available to them, the communities in Vangaindrano and Farafangana were able to generate slightly better coping strategies and resilient behavior than those in Mananjary, using more agricultural inputs. This could be indicative of the concept of non-linearity that states that the size of the input into the system is not proportional to the expected outcome.

Table 3: Preferred/Non-preferred coping strategies per district in Madagascar

District	Selling of household goods	Hunting and gathering	Reducing number of Meals per day	Labour on other persons fields in exchange for food	Reducing size of food portions at meal times	Eating seed stock	Support from family for food and income	Support from friends for food and income	Moving away from household plot for work and income
Vangaindrano	No (84,6%)	Yes (60,4%)	No (62,1%)	No (81,7%)	Possible No = 47,9% Yes = 52,1%	No (63,9%)	No (85,2%)	No (87%)	No (86,4%)
Farafangana	No (61,4%)	Yes (65,3%)	No (85%)	No (74,3%)	Possible No= 45,5% Yes= 54,5%	No (61,4%)	No (87,1%)	No (85,1%)	No (88,1%)
Mananjary	Possible No = 55,2% Yes = 44,8%	Possible No = 53,7% Yes = 46,3%	Possible No = 55,2% Yes = 44,8%	Possible No = 52,2% Yes = 47,8%	Yes (88,1%)	Possible No = 40,3% Yes = 59,7%	No (65,7%)	No (65,7%)	No (73,1%)

Some non-linear behaviour relating to coping strategies can also be observed in the context of communities in Malawi.

6.2 Malawi

Two districts, Chikhwawa and Nsanje (see Figure 4) formed part of the case study in Malawi (see Table 4). Both these areas have a similar profile when it comes to the use of agricultural interventions to build disaster resilience. In particular, communities in both areas have been found to use three or four of the agricultural interventions to build disaster resilience. They share a similar profile in the use of agricultural interventions, therefore the traditional assumption that could be made is that they also share the same coping strategies when it comes to disasters. However, the correlations with preferred/non-preferred coping strategies reveal certain context specific variations that can be associated with non-linear behaviour (see Table 5).

Table 4: Combined agricultural intervention use per district in Malawi

District	1.00	2.00	3.00	4.00	Total
Chikhwawa	0,7% (N=1)	11,3% (N=17)	37,7% (N=57)	50,3%(N=76)	100% (N=151)
Nsanje	3,5% (N=6)	12,2% (N=21)	44,8% (N=77)	39,5% (N=68)	100%(N =172)
Total	2,2% (N=7)	11,8% (N=38)	41,5% (N=134)	44,6% (N=144)	100% (N= 323)

Various instances of non-linear behaviour in relation to coping strategies can be identified when Chikhwawa and Nsanje are compared. Prominent examples relate to statistics on selling of household goods, reducing number of meals a day and reducing size of food portions at meal times. Nearly half (46,4%) of the participants in Chikhwawa consider the selling of household goods as a viable coping strategy. Additionally, the residents of Chikhwawa also show a very strong tendency to avoid negative coping strategies such as reducing size of food portions at meal times, with 68,9% of respondents indicating that they would not do this and 65,6% adding that they would not reduce the number of meals a day. This is in contrast with Nsanje.

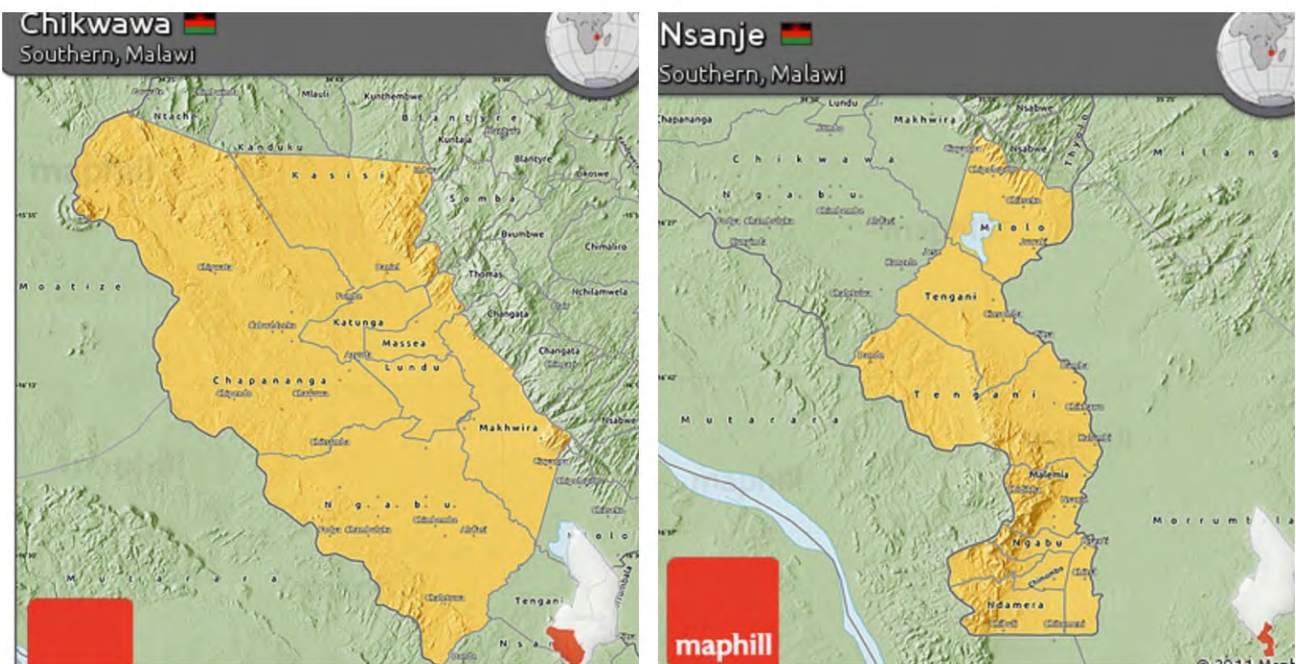


Figure 4: Chikhwawa and Nsanje, Malawi (Maphill, 2015)

In Nsanje the majority (65,7%) of participants do not consider the positive coping strategy of selling household goods as a means of coping with disasters. Moreover, there seems to be a tendency to more readily accept negative coping strategies such as reducing size of food portions at meal times, with 61,1% of participants considering this coping strategy and 47,4% considering the reduction of food portions during meal times.

Thus in the two Malawian communities, although they share exactly the same intervention use profile (three or four interventions) they differ somewhat in the coping capacities they choose to adopt. These differences could be indicative of context specific variables that limit or encourage the acceptance of certain coping behaviours. This context specific variability in the selection of coping strategies strongly relates to the basic Theory of Non-linearity discussed in Section 4.1 and also reinforces the need to understand contribution of context to individual resilience profiles.

Table 5: Preferred/ Non-preferred coping strategies per district in Malawi

District	Selling of household goods	Hunting and gathering	Reducing number of meals per day	Labour on other persons fields in exchange for food	Reducing size of food portions at meal times	Eating seed stock	Support from family for food and income	Support from friends for food and income	Moving away from household plot for work and income
Chikhwa wa	Possible No = 53,6% Yes = 46,4%	No (85,4%)	No (65,6%)	Yes (69,5%)	No (68,9%)	No (90,7%)	No (92,1%)	No (94,7%)	Maybe (41,7%= No; 58,3%= Yes)
Nsanje	No (65,7%)	No (79,4%)	Yes (61,1%)	Yes (60%)	Possible No = 52,6% Yes = 47,4%	No (62,9%)	No (94,3%)	No (93,7%)	Maybe (48,6%= No; 51,4%= Yes)

6.3 Mozambique

Participants from the Mossuril and Ilha de Mocambique districts (see Figure 5) formed part of the study in Mozambique (see Table 6). Both these areas have a very homogenous profile in relation to agricultural inputs. The majority of participants in Mossuril (52,7%) and Ilha de Mocambique (47,1%) indicated that they only use one agricultural intervention to build disaster resilience. A further 32,7% (Mossuril) and 35,3% (Ilha de Mocambique) of participants had access to at least two interventions. Compared to the other two case study countries the influence of the interventions used were less prominent (See Table 7).

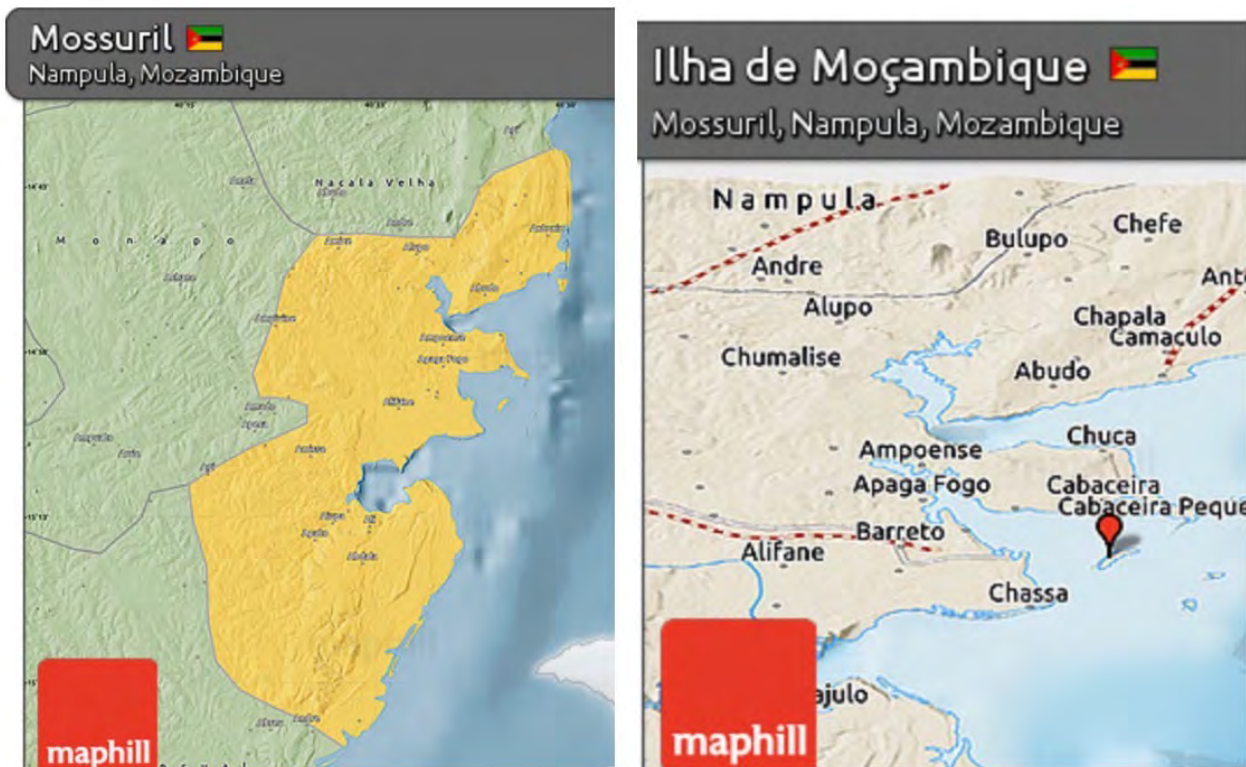


Figure 5: Mossuril and Ilha de Mocambique, Mozambique (Maphill, 2015)

The section to follow will reflect upon the presence of non-linear behaviour relating to preferred/non-preferred coping strategies per district in Mozambique.

Table 6: Combined agricultural intervention use per district in Mozambique

District	1.00	2.00	3.00	4.00	Total
Mossuril	52,7% (N=79)	32,7% (N=49)	14,0%(N=21)	0,7% (N=1)	100% (N=150)
Ilha de Mocambique	47,1% (N=72)	35,3% (N=54)	13,1% (N=20)	4,6% (N=7)	100% (N=153)
Total	49,8 % (N=151)	34% (N=103)	13,5% (N=41)	2,6% (N=8)	100% (N=303)

In the case of the two Mozambican districts, the preferred/non-preferred coping strategies per district show a very close resemblance. In most instances only a few percentage points difference can be identified per coping strategy from district to district. The only notable difference in coping strategy relates to the consideration of reducing the number of meals a day to cope with disasters. As such, 54,9% of participants in Mossuril indicated that they were not inclined to reduce the number of meals per day whilst participants in Ilha de Mocambique indicated a greater inclination (53,8%) to reduce the number of meals per day to cope with disaster.

Table 7: Preferred/ Non-preferred coping strategies per district in Mozambique

District	Selling of household goods	Hunting and gathering	Reducing number of meals per day	Labour on other persons fields in exchange for food	Reducing size of food portions d at meal times	Eating seed stock	Support from family for food and income	Support from friends for food and income	Moving away from household plot for work and income
Mossuril	No (83,1%)	No (64,8%)	Possible No = 54,9%; Yes = 45,1%	No (79,8%)	No (77%)	No (76,5%)	No (60,6%)	No (77%)	No (97,2%)
Ilha de Mocambique	No (89,3%)	No (74,4%)	Possible No= 46,2,% Yes = 53,8%	No (82,9%)	No (64,5%)	No (69,2%)	No (60,3%)	No (79,9%)	No (91,0%)

Although the data from Mozambique conveys very similar results, it remains consistent with the Theory of Non-linearity. Non-linearity means that certain inputs can create major variations in a system in some instances, as was the case in Madagascar and Malawi, and in others have only minor or no influence, as is the case in Mozambique. The results from Mozambique merely reaffirm the need to take non-linearity and context into account when assessing levels of resilience in disaster prone communities, as both these related drivers can greatly impact how resilience can be built and enhanced.

7. Discussion

The analysis reveals unique cases that highlight non-linear behaviour in coping strategies within the case study countries. Firstly, districts in Madagascar revealed a very diversified profile relating to the use of agricultural interventions with the districts of Vangaindrano (one or two interventions used), Farafangana (two or three interventions used) and Mananjary (three interventions used). If conventional Disaster Theory were to be applied to these results, it would be logically assumed that Mananjary would be the least vulnerable or more resilient, by virtue of it having more capacities available to adapt and cope with disasters. However, this conventional wisdom can be challenged by the results of the analysis. In particular, the study found that of the three districts in Madagascar, Mananjary was more inclined to engage in negative coping strategies, in spite of it having more capacities available to it than the other two regions (Vangaindrano and Farafangana). Both of these regions avoid negative coping behaviours such as reducing number of meals per day

or eating seed stock. The analysis of the districts of Chikhwawa and Nsanje in Malawi revealed that they have similar profiles relating to the use of agricultural interventions to build disaster resilience, both using three or four interventions at a time. As these districts have similar capacities available to them, a linear assumption would be that they would also share similar preferences towards coping strategies. The analysis indicated this assertion to be problematic, because although they share similar capacity profiles, the coping measures that emerge are non-linear and contextually unique. As opposed to the other two areas that formed part of the study, the districts of Mossuril and Ilha de Mocambique in Mozambique showed similar intervention uses (one or two) and mostly a similar preference in coping behaviour. However, even in this largely homogenous environment, certain non-linear behaviour emerged relating to the inclination to reduce the number of meals per day (something avoided in Mossuril, but more readily accepted in Ilha de Mocambique).

The results from the analysis reinforce the basic principle of non-linearity established in the literature review in that *"the size of an input into a system might not be proportional to expected outputs"*. So although conventional disaster thinking and policies (such as the HFA, Sendai Framework) may dictate that the more capacities a society has at their disposal, the less vulnerable they are, this is not always the case, as illustrated by the example of Mananjary, Madagascar. It could be that the focus in assessing disaster risk reduction capacity should shift from merely counting numbers of capacities (and rendering communities with the most capacities least vulnerable) and move towards measuring the effect and contribution of each capacity to fostering resilient behaviour. The case for the consideration of non-linear behaviour in disaster risk assessment processes is also supported by the case studies from Malawi and Mozambique where the districts shared similar agricultural intervention use profiles (see Tables 4 and 6) (i.e. the inputs are similar) but the preference for coping strategies remains either significantly different, in the case of Malawi, or only slightly different in the case of Mozambique (i.e. non-proportional to the expected output). From the analysis of non-linear behaviour in the various countries, it becomes clear that it is not enough to only consider the number of capacities available to reduce vulnerabilities in a community, but also to identify the actual effect and impact of the capacities on resilience behaviour such as the adoption of coping strategies in diverse communities. This allows for a more holistic diagnosis of the possible vulnerabilities and levels of resilience prevalent in a community at any given time.

8. Conclusion

The traditional mechanistic paradigm of scientific inquiry has its limitations in explaining dynamic ever-changing phenomena such as disaster risk, the reduction thereof and resilience building. This traditional paradigm is still evident in many of the current disaster risk reduction models and policies that aim to serve as the basis for building disaster resilient societies. The presence of this linear reasoning in both the existing theory and policies places a lesser importance on understanding

contextually specific capacities and the dynamic interaction between these capacities. Instead an emphasis could be placed upon the identification of generic categories and goals that are perceived to contribute most to reducing disaster risk and building disaster resilience. This, however, ignores the reality that very little of the world or even individual regions within countries are generic because of the effect of a plethora of contextual factors. This assertion is supported by the analysis of the various districts of Madagascar, Malawi and Mozambique. All of the districts displayed their own existing capacity profile (through the agricultural inputs), that in some instances were the same and in others, dramatically different. In each instance every district displayed variations in the coping strategies compared to the agricultural inputs used, making each community uniquely resilient. The presence of such non-linearities provides an adequate basis for disaster theorists and practitioners to question the applicability of linear theories and policy interventions as a means to reduce disaster risk and build disaster resilience. A paradigm shift is needed towards a more holistic understanding of how individual communities' resilience profiles are comprised and what the true contribution of individual capacities are to generating resilience. This process is crucial as the paper illustrates that more capacity does not necessarily equal greater resilience, as per conventional Disaster Risk Management Theory. A failure to take a more holistic systems approach (and the application of systems analysis tools such as a non-linearity analysis done here) into account will perpetuate the current status quo of theories and policies that achieve very little success in reducing disaster losses.

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CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The main objective of the thesis has been to determine if a Complex adaptive systems paradigm of disaster resilience could provide an alternative understanding of how disaster resilience can be understood and built. The research articles that formed part of the thesis explored this question by focussing primarily on establishing a theoretical linkages between the theories of disaster resilience and CAST. Secondly the articles aimed to establish if there are practical applications for CAST tools in analysing resilience by focussing on the case of subsistence agriculture communities in Southern Africa. This application of systems tools in a practical setting was necessary as to avoid the risk of the thesis functioning only in the realm of theoretical ambiguity.

In general thesis established that there significant scope to address issues of disaster resilience through the lens of CAST, as the theory is ideally suited to explaining concepts and phenomena that are subject to constant change and variation, such as disaster resilience. The articles also illustrated, CAST tools can be used to give insight into process that subsume resilience in societies that are at risk to disaster. These general findings will be elaborated on in the subsequent sections. Specifically, the section to follow will endeavour to give a summary of the main conclusion relating to each of the articles that formed part of the thesis. This will be followed by a discussion of the research questions and the conclusion for each emanating from the research. The chapter concludes by making recommendations from the thesis and for future research.

6.1 Conclusion per research Article

The summary conclusion of each research article will include a brief discussion on the aim, design, main findings and how research questions were address in each article.

6.1.1. Article 1: Disaster resilience and complex adaptive systems theory", Disaster Prevention and Management

The objective the article was to answer RQ 1 and RQ 2: *What are the theoretical tenets of resilience and Complex Adaptive Systems Theory? (RQ1); What are the theoretical linkages between Complex Adaptive Systems Theory and the concept of Resilience? (RQ2)*. The article aimed to establish if there is a theoretical linkage between the concept of resilience and the theory (CAST) that would guide the subsequent research process.

A total of 80 documents were analysed as part of the background research for the article. The papers reviewed included academic articles from leading academic scholars in both fields of disaster resilience and CAST; Books and Book Chapters. Technical reports and policy documents from international organisations such as the UN/ISDR were also consulted to gain an impression of the contemporary stance and approach to building disaster resilience.

Article 1 established that current definitions and methods of building disaster resilience are often inadequate as they do not take into account real world complexity. To this end it was found that a possible way to change the current theoretical and philosophical orientation to building disaster resilience it might be useful to look at the problem through the lens of CAST. CAST would allow disaster scientist and practitioners to treat the issue of resilience as an open-systems process that is constantly changing due to the inflow and outflow of information (learning from past events) and building and breaking up of components (adding new resilience capacities/removing absolute capacities) that constitute the resilience profile of a community. In addition article 1 has shown that on a theoretical level the underlying principles of disaster resilience and CAST are very similar, warranting the use of CAST as a theoretical analysis tool for further study of resilience. Specifically, elements of non-linearity, aggregation, emergent behaviour, feedback loops, adaptation and context-based responses would assist researchers focusing on the issues of disaster resilience to gain a holistic view of the dynamic interaction between resilience generating factors and local, sub-national and national and sectorial context in which they function.

Overall article 1 showed that adopting a CAST approach to deciphering the complexity associated with understanding and building societal resilience could make theoretical and practical contributions creating contextual relevant resilience building policies and programmes.

6.1.2. Article 2: Information feedback functions within farmers associative mechanism and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa

Article 1, identified that information feedback loops drive interaction between different system components allowing as system to adapt, learn and become more resilient. It was therefore clear that information feedback could play a leading role in driving entire adaptive process. Article 2 therefore had the objective of determining if feedback loops do play a pivotal role in subsuming adaptive behaviour. To guide the article the following research question was formulated and applied to the case of Southern African subsistence agriculture: How does information feedback within farmers associative mechanisms play a role in fostering disaster resilient behaviour (RQ 3)

A mixed method design was followed within the paper The primary tool for data collection was a quantitative survey which was administered to a combined total of 1110 respondents (representing the household level) in three case study countries (Mozambique - N=447, Madagascar - N=337 and Malawi - N=326). From this initial 1110 respondents a purposeful sample was taken to isolate those respondents that confirmed that they are actively part of a farmers associative mechanism.

Out of the initial 1110 participants 593 respondents across all case study countries indicated involvement in farmers associative mechanisms. Once the study sample was determined an initial correlation statistical analysis was conducted to determine what the preferred and non-preferred coping strategies of farmers associative members are. This analysis was carried out in order to determine whether members of farmers associations are inclined to positive or negative coping behaviours. The inclination of members (either positive or negative) would serve as a proxy indicator to existing level of resilience within the farmers associative group .

Due to the fact that the purpose of the study is to determine if the feedback and interaction within the farmers association contributes to stimulating more resilient behaviour, a more specific analysis had to be conducted. Consequently, the original factor analysis focusing on farmers associative mechanism was broken up into its individual parts. The variables identified through this process included: good cooperation between farmers association members; farmers association members helping other members to recover from natural disasters/hazards (through donations, advice etc); increase in production since joining the farmers association and increase in income since joining the farmers association. From this analysis the variable pertaining to farmers association members helping other members to recover from natural disasters/hazards (through donations, advice etc.), was selected as the key variable that is indicative of how interaction and feedback within farmers associative mechanism are key in stimulating resilient behaviour. To this end, a basic frequency analysis was conducted on the responses of respondents to the question “ Please indicate the level to which you agree or disagree with the following statement: Members in the farmers associations will often help other members recover from natural disasters/hazards (e.g. donations, advice)?

To compliment the quantitative findings relating results from the qualitative questionnaire are also added in the analysis. The qualitative data was collected through focus groups and face-to-face interviews, in order to gain a deeper understanding of, and elaborate on the findings from the quantitative data. Ten (10) focus group interviews were held per participating country. Thus thirty (30) focus groups were held for the study overall. During these interviews the participants were asked “Do members of the farmers association help (Donations, advice, support, safety nets) each other when there are members who have incurred losses due to disasters? If so, how? If not, why not?”

The paper established that disaster resilience should be viewed as a constant process of change, re-organisation, adaptation and learning. This focus on adaptivity and consistent change places resilience within the realms of complex adaptive system theory. Importantly, it was found that the systems concept of information feedback loops and interaction could play central role in understanding the interactions and informations exchanges that generate systemwide behaviours such as disaster resilience. This was due to the fact that that information feedback loops allow for interaction to take place between internal and external system elements, and from these interactions, complex emergent system behaviours such as disaster resilience e considered arise.

Thus information feedback and interaction can be considered to be a driving force behind emergent behaviour of a system. It is also argued that the more in-depth study of information feedback loops could provide disaster researchers with an opportunity to gain deeper insights into micro (internal to the system) and macro level (external to the system) interactions that subsume adaptive change and ultimately resilience.

Quantitative and qualitative responses from both analyses pointed out that members of farmers association could adopt positive coping strategies or make use of communally pooled resources instead of adopting negative coping strategies, that would in the long term make them more vulnerable to disasters. It was found that the tendency towards positive coping and using pooled resources was a direct result of information exchange between group members. The information feedback and interaction provided by being member of the group stimulated learning opportunities which enabled farmers to change, re-organise and adapt to disaster impacts as a means to creating dynamic adaptation to disaster risk. This dynamic adaptation fostered through the interaction and feedback of farmers associative mechanism can be said to make a contribution to improving the overall levels of disaster resilience in farming communities.

6.1.3. Article 3: Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture

Article 3 aimed to address research the following research questions: What are the basic theoretical principles associated with systems emergence? (RQ4). How does systems emergence contribute to understanding and building disaster resilience in agricultural communities? (RQ 5). To address these question the paper is presented in three parts. Firstly it establishes what emergence is by examining the characteristics of emergence. Secondly, the possible applications of emergent characteristics to understanding resilience is postulated. Thirdly, the presence of emergent behaviour is tested through an analysis of agricultural communities in Malawi, Mozambique and Madagascar. The paper finishes by providing some conclusions.

A total of 1110 respondents formed part of the data collection process conducted in the study. Mozambique represented 40.3% (N=447), Madagascar 30.4% (N= 337), and Malawi 29.4% (N=326) of the total respondents. Once the data was gathered, statistical analysis was conducted using descriptive statistics, exploratory factor analysis, Pearson correlation coefficient, and effect size. Correlation statistics were used to firstly determine micro-level interactions (this was done by correlating interaction between the four interventions), and secondly, to correlate the combined effect of these interventions to contributing to macro-level resilience behaviour by focusing on preferred/non- preferred coping strategies and hazard coping/adaptation behaviour. Correlation coefficients were selected as the preferred method of analysis as they provide a standardised measure of the strength of relationships between two variables.

Article 3 illustrated the benefits of applying the systems concept of emergence to attain a greater understanding of disaster resilience. At a theoretical level it was established that the emergence concepts of micro–macro effect, radical novelty, interacting parts, dynamic change, and decentralised control will assist in setting parameters for the observation of resilience behaviour in a disaster-affected community. This in turn provides disaster risk scientists with the ability to understand the resilience paradigm in a more holistic manner and offers greater insight into how to measure existing resilience profiles in communities. It also assists in building on such profiles to ensure that a community has the ability to adapt, avoid, recover and learn from disaster impacts.

Using the two main principles associated with emergence (i.e. micro-level interactions leading to macro-level behaviour and the emergence of radically new behaviour as a guide), the analysis testing for the presence of emergent in agricultural communities in Malawi, Mozambique and Madagascar, illustrated that emergent behaviour (i.e. coping strategies, and hazard avoidance behaviour) is indeed observable in agricultural communities that use all or a combination of agricultural interventions such as small-scale irrigation systems, farmers' associative mechanisms, appropriate crop varieties, and cropping techniques. These resilience abilities are newly formed macro-level behaviours that emerge due to the interactions of agricultural interventions at a micro-level.

The theoretical and practical analysis conducted in article 3 illustrates that considering the concept of emergence in measuring disaster resilience indicators could provide valuable inputs to our understanding to processes that subsume the emergence of resilient behaviour in agricultural settings.

6.1.4. Article 4: Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa

Findings pertaining to RQ 5 (paper 3) had direct bearing on the research focus of article 4 and its associated research questions. Specifically, there were indications in article 3 that emergent behaviour is inherently a non-linear in its outcome. This meant that even though resilience could emerge due to micro-level interactions, how one would get to the macro level resilience behaviour would differ from community to community as contextual factors would greatly influence micro level interactions that subsume the emergence of resilient behaviour. This finding was also consistent with theoretical critiques of contemporary disaster resilience policies and models. Article 4 therefore aimed to address the issues of non-linearity through the following research questions: What are the basic theoretical principles associated with systems principle of non-linearity? (RQ6). What are the implications of the concept non-linearity on our understanding of disaster resilience and the building thereof? (RQ 7).

A quantitative survey was administered to a combined total of 1110 respondents (representing the household level), that formed part of the study. Mozambique represented 40.3% (N=447),

Madagascar 30.4% (N=337) and Malawi 29.4% (N=326) of participants. These respondents were purposefully sampled from communities partaking in agricultural and food security activities supported by the FAO and partners from 2009-2014 under Disaster Preparedness EU Humanitarian Aid and Civil Protection (DIPECHO) funding. The paper endeavoured to identify the presence of non-linear behaviour relating to preferred/non-preferred disaster coping strategies that emerge, in comparison to the number of agricultural interventions used to build disaster resilience in the case study countries. The presence of non-linear behaviour would provide a means to illustrate that the mechanistic assumption that more capacity (or more interventions used) equals higher levels of resilience and better coping strategies is problematic for the theoretical and practical understanding of contextually specific risk profiles.

To facilitate analysis, the district (sub-national government) demarcation of the three case study countries formed part of the original study. The sub-division into their respective districts for analysis was necessary so as to effectively capture the unique disaster coping profile of sub-national spaces and avoid distortions that might occur because of the aggregation of coping measures at a national level. Consequently, this separation also made it easier to identify agricultural interventions used in each district, and also highlight possible non-linearity in coping behaviour from district to district. Once this division was made, an initial correlation analysis was carried out between two variables i.e. district of each country and the amount of interventions used (use of small-scale irrigation systems, membership to a farmers' associations, use of crop varieties and cropping techniques). Each respondent could indicate if they used one intervention or a combination of two, three or four interventions at any given time.

A second correlation analysis was drawn by comparing the variables of district (per country) and preferred/non-preferred disaster coping strategies. This provided information on the tendency to adopt certain positive and negative coping strategies in times of disaster stress. A distinction is made in the study between positive coping and negative coping behaviour, because certain forms of coping might actually prove harmful to resilience building efforts. In this instance positive coping strategies are considered as "positive" because they indicate the existence of a pre-existing buffer capacity within a household that prevents it from showing a preference for strategies that are primarily focused upon survival (negative coping) and reducing of basic physiological needs as per Maslow's Basic Human Needs Hierarchy (see article 3). The variable of preferred/non-preferred disaster coping strategies was also selected to serve as a proxy indicator of resilient behaviour. The reason being that coping behaviours serve as building blocks from which larger societal resilience behaviours such as adaptation and learning emerge. Within the analysis the respondents could indicate their inclination to coping behaviour by either indicating yes, no, or uncertain. Once the analyses describe above were compiled it became possible to test for non-linear behaviour in coping strategies adopted by contrasting the results with the accepted linear notation of $R = H \times V/C$. Thus it became possible to test whether the availability of more capacities (relating to the four agricultural interventions in the study) truly reduced vulnerability.

The article established that on a theoretical level that many contemporary disaster risk reduction policies and models that aim to build disaster resilience are based on mechanistic and linear focus of problem solving. The presence of this linear reasoning in both the existing theory and policies places a lesser importance on understanding contextually specific capacities and the dynamic interaction between these capacities and how this lead to disaster resilience. Instead an emphasis is placed upon the identification of generic categories and goals that are perceived to contribute most to reducing disaster risk and building disaster resilience. This, however, ignores the reality that very little of the world or even individual regions within countries are generic because of the effect of a plethora of contextual factors. The theoretical assertion of the paper is supported by the analysis of the various districts of Madagascar, Malawi and Mozambique. All of the districts studied displayed their own existing capacity profile (through the agricultural inputs), that in some instances were the same and in others, dramatically different. In each instance every district displayed variations in the coping strategies compared to the agricultural inputs used, making each community uniquely resilient.

The paper showed that the presence of such non-linearities provides an adequate basis for disaster theorists and practitioners to question the applicability of linear theories and policy interventions as a means to reduce disaster risk and build disaster resilience. On the basis of the findings of this article and articles 1, 2 and 3 that preceded it, it is argued that a paradigm shift is needed towards a more holistic understanding of how individual communities' resilience profiles are comprised and what the true contribution of individual capacities are to generating resilience. This process is crucial as the paper illustrates that more capacity does not necessarily equal greater resilience, as per conventional Disaster Risk Management Theory. A failure to take a more holistic systems approach (and the application of systems analysis tools such as a non-linearity into account will perpetuate the current status quo of theories and policies that achieve very little success in reducing disaster losses.

The section to follow summarises the findings in terms of the research question formulated for the thesis.

6.2 Conclusion per research question

The table below briefly links the research questions formulated for the thesis with answers that emerged from the research process.

Table X: Research Questions and summary of findings

6.3 Recommendations

The thesis provided an in-depth analysis of theoretical concepts associated with disaster resilience and Complex Adaptive Systems Theory (CAST). Theoretical concepts associated to CAST was subsequently applied to subsistence agriculture communities in Southern Africa, to determine the possible contribution of CAST in fostering a holistic understanding of disaster resilience. The main recommendations are presented below:

- The thesis determined that contemporary disaster risk reduction models and policies aimed at improving disaster resilience are often formulated from traditional mechanistic paradigm of scientific inquiry. This traditional paradigm, in a quest to foster understanding of disaster resilience, often oversimplify and reduce the concept and practice of resilience building to a pre-determined set of steps or processes. This leads to resilience building policies and models that do not take cognisance of contextually specific variables and complex variations they can foster in resilience profiles of different communities. It is therefore recommended that new conceptualisation and applications of disaster resilience be based on theoretical bases such a CAST as the theory is comprised of tools that specifically takes into account variations and complexities in individual communities. Therefore allowing for community specific resilience building projects to be formulated.
- The thesis established that adaptation, learning and change, all of which are key indicators of resilient behaviour, are driven by information feedback loops and interaction between variables within a system. This finding is significant in as much as it point to the fact that resilient behaviour is not just the sum of an amount of capacities available to a community, but that there are a complex array of interactions and information exchanges present that cause individual capacities to work in unison to generate more complex behaviour such as disaster resilience. It is therefore the recommendation of the thesis that the amount of capacities available to a community should not be treated as the sole determining factor towards disaster resilience. Instead the focus should be placed on understanding the information feedback and interactive processes that could optimise the available capacities of communities towards resilience, or identifying capacities that could be added that would foster more information feedback and interaction.
- It was also shown that the interactions between variables at a micro level often lead to complex emergent behaviours such disaster resilience at a macro systems levels. Importantly it was found that the emergent behaviour that arises form the interactions at a micro level often do not bear resemblance to the variables from which it arose. This indicates that that there is a more complex process that underlies a communities resilience profile. It is recommended that disaster

resilience tools and frameworks incorporate concepts of emergence to gain a more in-depth understanding of the composition of a communities resilience profiles.

- The concept of non-linearity illustrated contrary to conventional disaster risk theory, having more capacity does not always mean greater resilience. Results from subsistence agriculture communities in Southern Africa, show that in some instance communities with less capacity have a better overall resilience profile and risk coping behaviour than communities with more capacity. This findings supports the theoretical argument made in the thesis that “one size fits all” approach to building disaster resilience, will have limited success in building resilience. The notion of non-linearity therefore points to the need to develop resilience theories and projects, that takes cognisance of contextual factors and is flexible enough to be adapt to different contexts.
- Future research should aim to develop concrete resilience building models and tools based on the system concepts outlined in the thesis

If one is to reflect back on the overall research question formulated for the study, the main focus of the study was to determine if a Complex adaptive systems paradigm of disaster resilience could provide and alternative understanding of how disaster resilience can be understood and built. The thesis endeavoured to prove the usefulness of CAST in understanding resilience on two levels, theory and practice. On a theoretical level it was evident that CAST would be an appropriate theoretical tool to explore disaster resilience, as is ideally suited to provide insight into systems that are subject to constant change, learning and adaptation. This capability of CAST is consistent with operation definition of resilience presented in the thesis and contemporary thinking of disaster resilience as a process of “building back better” or “bouncing forward” (see article 1). On a practical level the thesis showed that systems tools such as information feedback loops, emergent behaviour and non-linearity provide disaster scientist with a means to explore deeper dynamics and process that underlie resilience behaviour in disaster affected communities. To this end, information feedback loops aids our understanding of interactions that drive adaptive behaviour, emergence allows us to understand micro-level systems interactions and how these interaction lead to resilience in different contexts and finally non-linearity places an emphasis on resilience and the building thereof as something that should be treated as flexible concept and interventions that should be taylor-made to each community. Though the application of CAST tools it is apparent that a Complex Adaptive Systems paradigm of disaster resilience, is useful as it provides a means to focus on the underlying drivers and dynamics associated with resilient behaviour. This is a departure away from traditional paradigms of resilience which often spoke only to the capacities needed to build resilience in isolation. Introducing a Complex adaptive systems paradigm to our understanding of resilience, is a recognition of the basic systems principle of “ *the whole is more than the sum of its parts,*” or there is more to understanding a systems than merely understanding the individual components. A complex adaptive systems paradigm of disaster resilience will

therefore give us a greater depth of understanding of the “*more than the sum of its parts*” aspects which are often the real drivers of resilient behaviour in disaster affected communities.

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Appendix A: Editors Letters

April 20, 2016

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CERTIFICATION

To whom it may concern:

I, JC Gaillard, Editor of *Disaster Prevention and Management: An International Journal*, hereby grant to Christo Coetzee the permission to include the papers which details are appended below in his PhD thesis at North West University.

Towards a disaster risk assessment methodology for communities underlain by dolomite published in issue 22(4) of *Disaster Prevention and Management*

Disaster resilience and complex adaptive systems theory: Finding common grounds for risk reduction published in issue 25(2) of *Disaster Prevention and Management*

Do not hesitate to come back to me should you need any further information.

Truly yours,



JC Gaillard, Ph.D.
Associate Professor
Editor of *Disaster Prevention and Management: An International Journal*



18 April 2016

Mr Christo Coetzee
African Centre for Disasters Studies
North West University
Potchefstroom, South Africa

Dear Mr Coetzee,

I understand that you would like to include the following article in your doctoral thesis:-

Christo Coetzee, Dewald Van Niekerk, Emmanuel Raju 2016. Emergent system behaviour as a tool for understanding disaster resilience: the case of Southern African subsistence agriculture. *International Journal of Disaster Risk Reduction* 16: 115-122.

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Book

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Book chapter

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Online document

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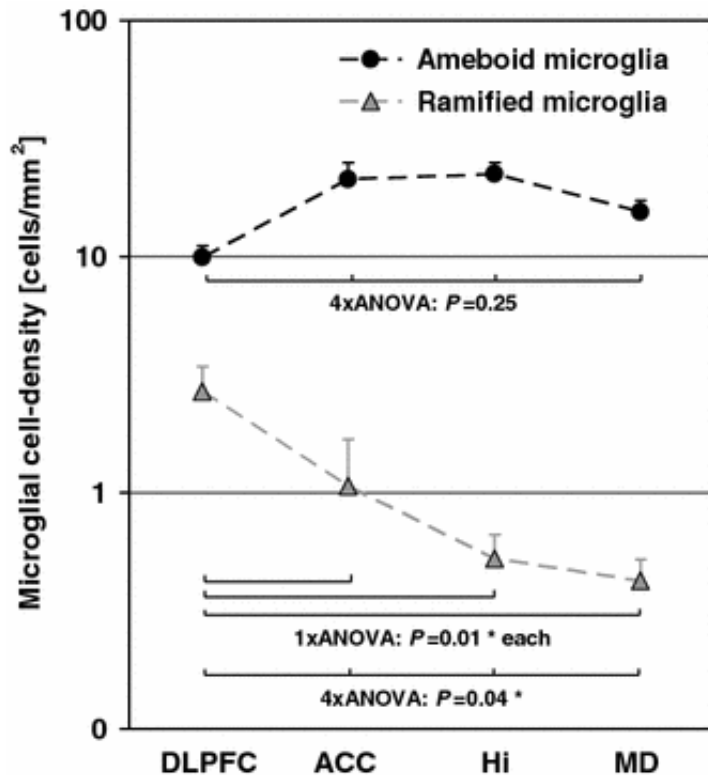
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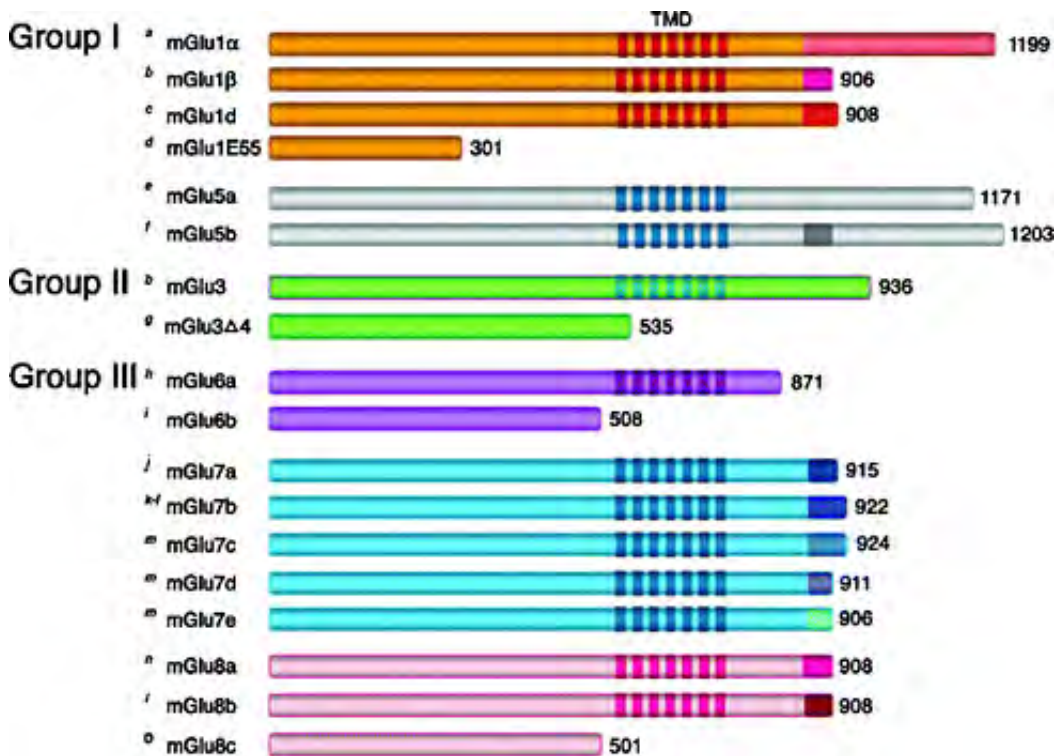
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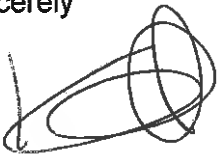
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To Whom It May Concern

**CONFIRMATION OF LANGUAGE EDITING OF ARTICLE: DISASTER RESILIENCE AND
COMPLEX ADAPTIVE SYSTEMS THEORY- FINDING COMMON GROUNDS FOR RISK REDUCTION**

Herewith confirmation that the abovementioned article, by Coetzee, Van Niekerk & Raju has been language edited.

Sincerely

A handwritten signature in black ink, consisting of several overlapping loops and a long horizontal stroke, characteristic of the name K.N. Groenewald.

K.N. Groenewald

INVOICE

Margaret Elizabeth Linström
ID number 6106230041088
Tax number 035 111 6405
Language Practitioner
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FOR ATTENTION: Focus area: Social Transformation – Simone Roos

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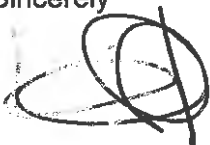
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**CONFIRMATION OF LANGUAGE EDITING OF ARTICLE: Reconsidering Disaster
Resilience: A non-linear systems paradigm in agricultural communities in Southern
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Sincerely

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Katherine Nicole Groenewald:

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PERMISSION CONFIRMING USE OF CO-AUTHORED ARTICLES IN PHD THESIS

This letter serves as confirmation that my PhD student, Mr Christo Coetzee (12996513) may submit the following co-authored research articles as part of his PhD thesis entitled, “ *Towards a complex adaptive systems paradigm of disaster resilience: A study of Southern African subsistence agriculture communities*”.

:

- Disaster Resilience and Complex Adaptive Systems Theory - Finding common grounds for risk reduction
- Information feedback functions within farmers’ associative mechanisms and their role in fostering disaster resilient behaviour: Selected cases from Southern Africa.
- Emergent system behaviour as a tool for understanding disaster resilience: The case of Southern African subsistence agriculture
- Reconsidering Disaster Resilience: A non-linear systems paradigm in agricultural communities in Southern Africa.

My co-authorship in the above mentioned articles was mostly focused around study leading duties and the student, Mr. Coetzee, remains the main contributor to the academic work contained in the articles.

Kind regards and best wishes



Prof. Dewald van Niekerk

Director: African Centre for Disaster Studies

North-West University
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