A Transdisciplinary-Based Coupled Approach For Vulnerability Assessment in the Context of Natural Resource-Based Conflicts Using Remote Sensing, Spatial Statistics and Fuzzy Logic Adapted Models

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28 And we know that all things work together for good to them that love God, to them who are the called according to his purpose. Romans 8:28 (KJV)

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List of Acronyms

Acronym		Translation
ACLED	=	Armed Conflict Location Event Data
ADR	=	Alternative Dispute Resolution
AHP	=	Analytical Hierarchical Process
AI	=	Artificial Intelligence
ANN	=	Artificial Neural Network
BAU	=	Business as Usual in Peacebuilding
BU	=	Built-up
CAQDAS	=	Computer Assisted Qualitative Data Analysis
CARSBM	=	Community Assisted Remote Sensing-Based Mapping
CAS	=	Complex Adaptive System
CIA	=	Central Intelligence Agency
CM	=	Conflicts Management
CMS-P	=	Crises Situation Management in Peacebuilding
COG	=	Center of Gravity
COW	=	Correlates of War
CSR	=	Corporate Social Responsibility
CSMND	=	Center for Sustainable Management of the Niger Delta
CTP	=	Computational theory of Perceptions
CVL	=	Conflict Vulnerability Likeliness
CWN	=	computing with numbers
CWW	=	Computing with Words
DFID	=	Department of International Development
DPR	=	Department of Petroleum Resources
EIA	=	Environmental Impact Assessment
ETLF	=	Ethnolinguistic Fractionalzation
ELOBCONDATA	=	Exponent of Logarithm of Observed Conflict Data
ENVSEC	=	Environment and Security Initiative
ESA	=	European Space Agency
ESDA	=	Exploratory Spatial Data Analysis
ESRA	=	Earth System Research and the Anthropocene
ETM+	=	Enhanced Thematic Mapper Plus
EU	=	European Union
FA	=	Fuzzy AND
FuAS	=	Fuzzy Algebraic Sum
FAS	=	Factors, Actors, and Sectors
FGDs	=	Focused Group Discussions
FL	=	Farmland Loss
FLAME-CM	=	Fuzzy Logic Adapted Modelling for Conflict Management
FLM	=	Fuzzy Logic Modelling
FLMENS	=	Fuzzy Logic Model for Environmental Subsystem
FLMPOS	=	Fuzzy Logic Model for Political Subsystem (

FLMSOS	=	Fuzzy Logic Model for Socio-economic Subsystem
FLT	=	Fuzzy Logic Theory
FMIC	=	Federal Ministry of Information and Culture
FO	=	Fuzzy OR
fsQCA	=	Fuzzy Set Qualitative Comparative Analysis
FUZZYCONDATA	=	Fuzzy Conflict Data
GDP	=	Gross Domestic Product
GIS	=	Geographic Information Systems (GIS)
GPS	=	Global Positioning System(GPS)
HES	=	Human and Environmental Systems
HESP	=	Human and Environmental Security and Peace
HIIK	=	Heidelberg Institute
HPV	=	Holistic Perspective on Vulnerability
HUGE	=	Human, Gender and Environment Security
HVA	=	Holistic Vulnerability Assessment
Iev	=	CVL Index for Environmental Risk Drivers
IevRBC	=	CVL Index- Environmental (Iev) Drivers vs. Rebel Based Conflicts
IevTBC	=	CVL Index- Environmental (Iev) drivers vs. Territorial based Conflicts
ILWIS-GIS	=	Integrated Land and Water Information System and GIS
IPCC	=	Intergovernmental Panel on Climate Change
Ipo	=	CVL Index for Political Drivers
IpoRBC	=	CVL Index- Political (Ipo) Drivers vs. Rebel Based Conflicts
IpoTBC	=	CVL Index- Political (Ipo) Drivers vs. Territorial Based Conflicts
IR	=	Interdiction Rates
Ise	=	CVL Index for Socio-economic Drivers
IseRBC	=	CVL Index-Socio-economic (Ise) Drivers vs. Rebel Based Conflicts
IseTBC	=	CVL Index- Socio-economic (Ise) Drivers vs. Territorial Based Conflicts
ITC	=	Faculty of Geo-Information and Earth Observation, Netherlands
JVs	=	Joint Ventures
LGAs	=	Local Government Areas
LULC	=	Land Use and Land Cover
MAUP	=	Modifiable Areal Unit Problem
MCE	=	Multi-criteria Evaluation
MEND	=	Movement for the Emancipation of the Niger Delta
MFs	=	Membership Functions
ML	=	Mangrove Loss
MLRM	=	Multiple Linear Regression Model
MMR	=	mixed Methods research
MNDA	=	Ministry of Niger Delta Affairs
MNLR	=	Multinomial Logistic Regression Models
MNOCS	=	Multinational Oil Corporations
MOVE	=	Methods for the Improvement of Vulnerability Assessment in Europe
MSVP	=	Multi-Stage Validation Process
NAOC	=	National Oil Company
NATO	=	North Atlantic Treaty Organization
NBS	=	National Bureau of Statistics
NDBDA	=	Niger Delta Basin Development Authority

NDDB	=	Niger Delta Development Board
NDDC	=	Niger Delta Development Commission
NDES	=	Niger Delta Environmental Survey
NDPVF	=	Niger Delta People's Volunteer Force
NDRDMP	=	Niger Delta Regional Development Master Plan
NDV	=	Niger Delta Vigilante
NGOs	=	Non-Governmental Organizations
NL	=	Natural Language
NLNG	=	Nigerian Liquefied Natural Gas Company
NNPC		Nigerian National Petroleum Corporation
NOSCP	=	National Oil Spill Contingency Plan
NOSDRA	=	National Oil Spill Detection Response Agency
NPPEP	=	National Policy on Poverty Eradication Programme
NRM	=	Natural Resource Management
NSEDP	=	Non-Spatially Explicit Distance Parameters
OECD	=	Organization for Economic Cooperation and Development
OMPADEC	=	Oil Mineral Producing Areas Development Commission
OSCE	=	Organization for Security and Co-operation in Europe
PAP	=	Presidential Amnesty Programme
PBC	=	Perception Based Computing
Pc	=	Perceptual computer
PGLOLU	=	Persistence, Gain, Loss and other land use
PRA	=	Pressure and Release Approach
PS	=	Problem Structuring
PSM	=	Problem Structuring Methodology
PT	=	Probability Modelling
QG	=	Qualitative Geography
QM	=	Qualitative Methodology
QUASTA	=	Qualitative Start
RH	=	Relative Humidity
RMSE	=	Root Mean Square Error
SAS	=	Story and Simulation
SDG	=	Sustainable Development Goals
SEDP	=	Spatially Explicit Distance Parameters
SEFLAME-CM	=	Spatially Explicit Fuzzy Logic Adapted Modelling for Conflict Management
SES	=	Social-ecological Systems
SF	=	Secondary Forest
SL	=	Sustainable Livelihoods
SLA	=	Sustainable Livelihood Approach
SMCE-CM	=	Spatial Multi-Criteria Evaluation for conflict Management
SODA	=	Strategic Options Development and Analysis
SoVI	=	Social Vulnerability Index
SPDC	=	Shell Petroleum Development Company
SPSS	=	Statistical Package for the Social Sciences
SSM		Soft Systems Methodology
TCND	=	Technical Committee on the Niger Delta
TD	=	Transdisciplinary

TDA	=	Transdisciplinary Approach
TDR	=	Transdisciplinary Research
TF	=	Thick forest
TFVA	=	Theory of Fuzzy Vulnerability Assessment
TM	=	Thematic Mapper
UCDP GED	=	Uppsala Conflict Data Programme Geo-referenced Event Dataset
UCDP/PRIO	=	Uppsala Conflict Data Programme /Peace Research Institute Oslo (PRIO)
UN	=	United Nations
UNDG	=	United Nations Development Groups
UNDP	=	United Nations Development Programme
UNEP	=	United Nations Environment Programme
UNU	=	United Nations University
UNU-EHS	=	United Nations University's Institute for Environment and Human Security
US	=	United States
UTM	=	Universal Transverse Mercator Coordinate System
VA	=	Vulnerability Assessment
VAF	=	Vulnerability Assessment Framework
VSES	=	Vulnerability of Socio-ecological Systems
WGS	=	World Geodetic Systems
WP	=	Water Pollution
WPF	=	Wicked Problem Framework

1 Introduction

1.1 A Transdisciplinary Approach to Risks and Vulnerability Assessment in the Context of Natural Resource-Based Conflicts.

Scientific investigations on the nexus between natural resources and conflicts, as well as their management strategies for long-term peacebuilding has finally emerged in the sustainable transition research paradigm (UNEP, 2009, UNDG, 2013, Brauch, 2016a, Brauch, 2016b, Stephenson, 2016). Goal 16 of the Sustainable Development Goals (SDG) is dedicated to the promotion of peaceful and inclusive societies for sustainable development, but this goal lacks actionable strategies (Brauch, 2016b). Given the SDG goal 16 therefore, researches on integrating Natural Resource Management (NRM) into Conflict Management (CM) strategies for sustainable peace have become all the more paramount.

According to Heidelberg Institute- HIIK (2002), the post-Cold War era has witnessed a growing number of Natural Resource-Based Conflicts (NRBCs), over water, timber, oil, and other minerals. The United Nations Environment Programme (UNEP) stated that across the globe, at least 40% of all conflicts in the last 60 years are linked to natural resources, due to the extraction of high-value resources and competition over renewable resources (UNEP, 2012, UNEP, 2015). As clearly shown (see Figure 1.1), globally there is a dramatic increase in NRBCs since the 1990s, while the non--NRBCs and international power related conflicts have decreased during this period. With a recent report showing that Sub-Saharan African countries were the region most affected by highly violent conflicts relating to natural resources HIIK (2018), an analysis of NRBCs with case studies in the Niger Delta region of Nigeria, therefore, gives insights on a conflict-ridden and unstable natural resource-endowed region of our globe.

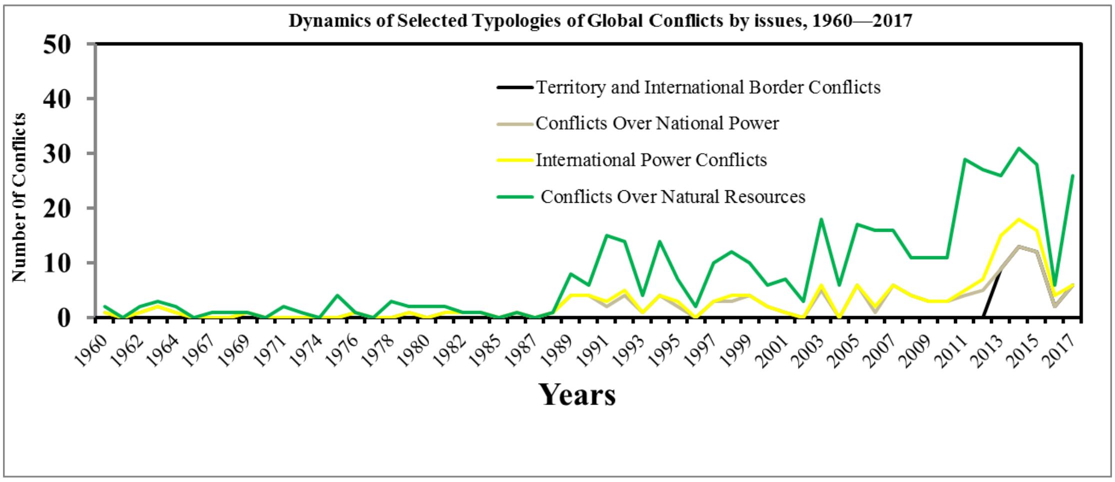


Figure 1.1: Dynamics of conflicts by issues, 1945—1995, according to Heidelberg Institute (HIIK, 2002).

But despite the pursuit for sustainable development and climate adaptation strategies through several international summits, not much is heard about a growing attention in the natural resources-conflicts linkage. UN reports show a number of international organizations that unsuccessfully addressed the NRBCs. These include UNEP, Organization for Security and Co-operation in Europe (OSCE), Organization for Economic Co-operation and Development

(OECD), UN University (UNU), European Union (EU). The reports also recommend a human-centered approach to anthropogenic problems such as NRBCs (see Annan (2000) for an overview). Yet international and local natural resource disparities and conflicts still remain a major challenge to mankind. Moreover, scientific approaches which pursue sustainability neglect politics and social processes, while social scientists and humanities researchers either leave out the environment or lack skills to measure it quantitatively (Brauch *et al.*, 2011).

To achieve sustainability and peace requires not only the environment but the integration of other pillars of sustainability. Such integration will help understand why some communities/regions are vulnerable to NRBCs and others are resilient (see Section 3 for clarification of concepts). However, to date, there are limited integrative modeling researches that engage transdisciplinary approaches in the context of NRBCs (Okpara et al., 2017). This is a complex spatial vulnerability problem that requires a holistic assessment with the objective of explicitly engaging a transdisciplinary-based coupled approach, modeling the historic and the current drivers of NRBCs, the mechanisms, and evaluation of models for future CM. This thesis, therefore, draws on the knowledge of local actors and insights from natural sciences disciplines (remote sensing and physical geography); social sciences disciplines (human geography, political science, and social psychology); and sustainability (Mauser *et al.*, 2013, Grove *et al.*, 2015) to investigate the NRBCs holistically.

In order to situate this research problem, a decision was required on the choice of terminology across the existing concepts. NRBCs are used to represent competitions over resources which lead to armed resource violence or unarmed low-intensity conflicts such as protests. The conflict typologies modeled include the rebel-based and the territorial-based NRBCs (see Sections 2.5 and 6.4 for details). The concept of NRBC is drawn from scholars' works which denote natural resources and conflict nexus, as follows, but not limited to:

- Natural Resources and Conflicts (Bannon and Collier, 2003, Humphreys, 2005).
- Conflicts and Renewable Resources (Gleick, 1993, Reuveny and Maxwell, 2001)
- Environmental Change and Armed Conflicts (Homer-Dixon, 1994, Gleditsch, 1998).
- Environment-induced/Environmental conflicts (Diehl, 1998, Martinez-Alier, 2001).
- Environmental Security (Swatuk, 2004, Bocchi *et al.*, 2006, Brauch, 2010).

Among these concepts, environmental conflicts and environmental security are recently used to link the field to policy (Swatuk, Bocchi *et al,* and Brauch). However, these and related studies have been criticized for implying a causative agent to conflicts with eco-centric and anthropocentric conceptions (Allenby, 2000, Hagmann, 2005). To induce anticipatory learning, the problem of NRBCs is framed in this thesis as a practical research beyond the traditional liberal peace in developing societies, e.g. the Human and Environmental Security and Peace (HESP) (Brauch, 2005, Brauch, 2016b). Already, political scientists observe the failure of the liberal peace approach to peacebuilding as creating superficially effective political/social institutions (Ginty, 2010, Jarstad and Belloni, 2012). Thus, peace research should shift from being multi and interdisciplinary, towards transdisciplinarity, anticipatory science and knowledge creation (Brauch, 2016a). This alternative approach embedded in holistic perspectives is referred to as a “hybrid peace”(Ginty, 2010). The “hybrid peace” conceptualizes peace where actors coalesce to produce a “fusion peace” (Ginty, 2010, Mac Ginty and Richmond, 2013), and forms an intertwined process involving the local vs. the global, the formal vs. the informal, the liberal vs. the neo-liberal, moving away from binary notions of human societies in explaining the political World e.g.: Western vs. non-Western (Mac Ginty and Richmond, 2013:397). In hybridity of peace, co-creation of local and scientific knowledge into models is indispensable and requires a high priority right from the joint problem framing phase of the research process (Mauser et al., 2013). Knowledge co-creation was proposed as a Transdisciplinary Research (TDR) in the context of global change and management transitions (Mauser *et al.*, 2013), but is applicable as an alternative approach to sustainability and peace at any geographic scale (Grove *et al.*, 2015, Page *et al.*, 2016).

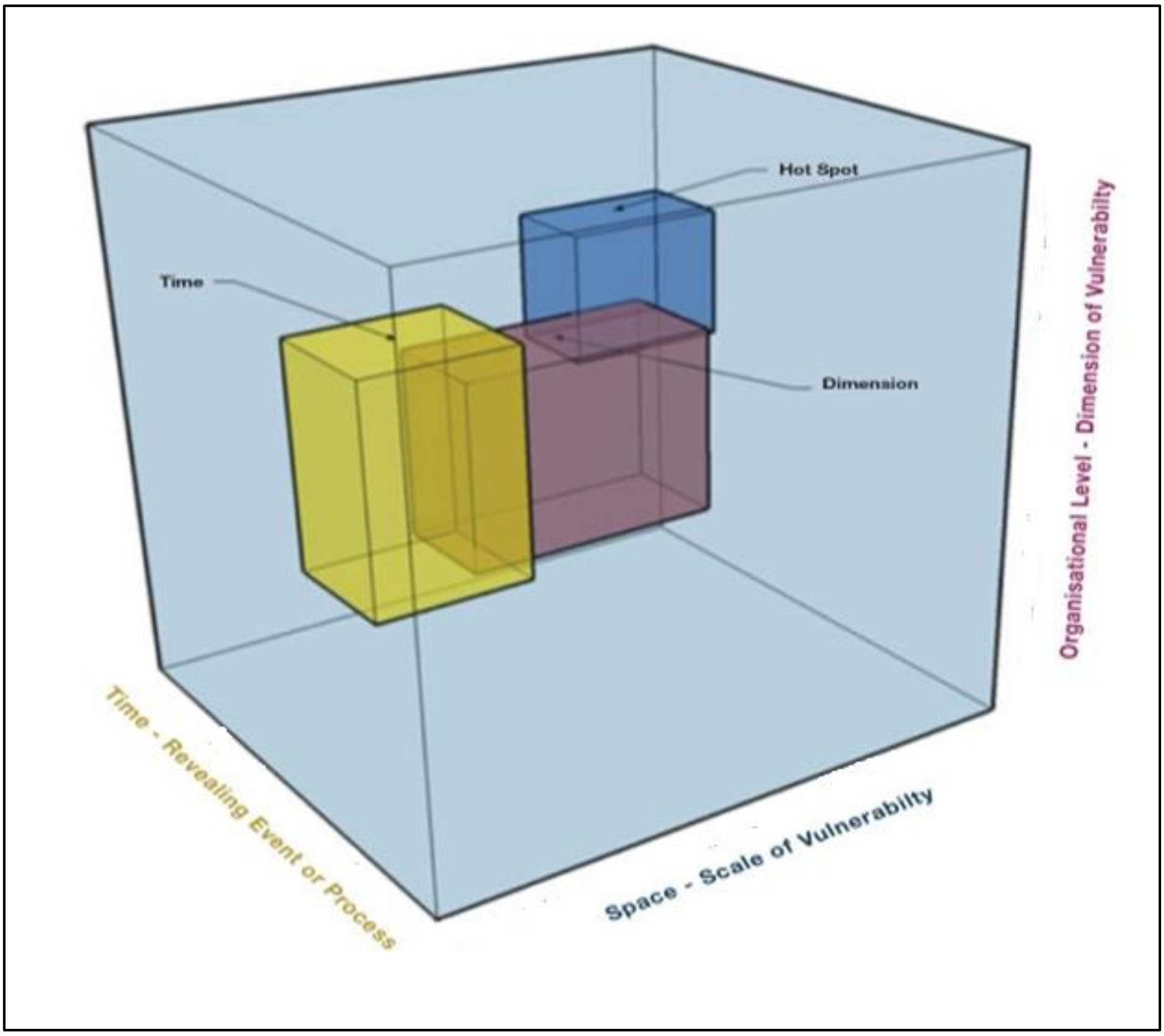


Figure 1.2: “Vulnerability Cube” in the context of natural resources based conflicts: hotspot i.e. space (individual, household, community, municipal, global); time (decadely, yearly, monthly, daily); dimension (environmental, physical, political, social, economic, institutional) of vulnerability assessment, according to Kienberger et al. (2013).

The co-creation processes deal with local actors' perceptions of NRBCs. This holistic vulnerability assessment (HVA) of NRBCs is referred to as “Vulnerability Cube”. This deals with space, time and dimensions of vulnerability (see Figure 1.2, Section 3, and Kienberger *et al.* (2013)). In this thesis therefore the HVA of NRBCs is implemented with a transdisciplinary-based coupled approach using the Niger Delta region of Nigeria as case studies (see Section 2 for details on test sites).

1.2 State of the Art on Natural Resource-Based Conflicts (NRBCs)

Scientific investigations on NRBCs have evolved in scope, theory, and methodology since the post-Cold War era. Four phases have been identified and discussed (Brauch, 2003b, Brauch, 2010). The first phase: from 1970s—1980s; the second phase: during the 1990s; the third phase: mid—1990s till the end of the 20th century; and the fourth phase: post—2000 (the Anthropocene era).

Different approaches have been used to identify and assess the drivers of NRBCs. These include the "resource abundance" or "resource curse" (Collier and Hoeffler, 1998), and the "resource scarcity" approaches, albeit with inconclusive results (Homer-Dixon *et al.*, 1993). The third phase research is particularly critical to progressing the field of NRBCs using "resource abundance" approach. In this third phase models such as the multiple linear regression models (MLRM) and the multinomial logistic regression models (MNLR) have been used to analyze the drivers of NRBCs at a country level (Fearon, 2005, Collier and Hoeffler, 2012). In this case socio-economic and political factors are used to explain "greed and grievance" with a hypothesis that conflicts are more likely in countries with low GDP. These contributed to an understanding of NRBCs but only at the global scale. Resource scarcity and political ecology approach, on the other hand, used mainly qualitative case studies through an in-depth analysis of individual conflict cases. These neo-Malthusian arguments stipulate that the reduction of access to renewable resources increase frustration in communities and creates grievances against the state. But, in contrast to the Cornucopians, humans are believed to be able to adapt to negative environmental and social impacts of resource extraction on human well-being, through market mechanisms, technological or institutional innovations (Simon, 1989, Lomborg,2001). The qualitative case studies are largely critiqued because of the low external validity of their findings (Gleditsch and Urdal, 2002, Koubi *et al.*, 2014). Also their synthesis of using single case studies have been hampered by the diversity and incongruence in terms of data quality and metrics (Kok *et al.*, 2015).

The fourth phase of the research on NRBCs which started since the turn of the twenty-first century presents the need to use views from the earlier phases for developing strategies that promote NRM and CM (Spring et al., 2009, Spring and Brauch, 2011). For example, recently, OSCE, UNEP, and UNDP launched a joint initiative called Evaluating the Environment and Security Initiative (ENVSEC) (http://envsec.rec.org/). This initiative promotes the integration of environmental management as a strategy for reducing insecurity in the South Eastern Europe, using methodologies drawn from vulnerability assessment of environmental monitoring-security linkages and policy implementation. However, the outcome has contributed less to conflict prevention in the region. There are therefore recent calls for middle ways where quantitative models and fine-grained qualitative single-case studies are complemented (Ide, 2015b, Kok *et al.*, 2015), with regard to the key issue of concern, on how the environment in combination with socio-political issues explain NRBCs typologies. Kok et al. (2015) proposed vulnerability assessment as an intermediate level of spatially explicit assessment which improves the current available methods. This has led to a more holistic and systematic analysis of the dynamics and the patterns of NRBCs using multi-methods at fine-grained scale thereby advancing the field of research (Balcells et al., 2014, Kok et al., 2015).

1.2.1 From the Top-down (Large-N) Global Assessment to the Bottom-up (Community Based) Disaggregated Assessment

The fine-grained conflict studies open up opportunities for the use of literature on conflict to cooperation and sustainable peacebuilding (Matthew et al., 2003). According to Bernauer et al. (2012), the gaps in both qualitative and quantitative empirical studies lend credence to the need for bottom-up conflict analysis with respect to the following:

Firstly, the scale of Large-N studies has affected results of NRBCs because of low spatial resolution at the national level (Buhaug and Lujala, 2005 , Bernauer *et al.*, 2012). Secondly, the conflict datasets commonly used for Large-N studies were largely from the Correlates of War (COW) which only captures rather high-intensity conflicts using MLRM (Collier and Hoeffler, 2004). More so, the data sets do not explicitly identify whether the issue over which a level of conflict broke out is more linked to environmental changes or social dynamics. While conflicts can be coded, environmental parameters from land use-models of remotely sensed data are useful for validating the modeled conflict problems. These environmental data can also be combined with the social drivers of NRBCs (Bernauer *et al.*, 2012).

Given the above, scientific researches cannot identify to what extent environmental changes and social-political drivers can be integrated for understanding conflict or cooperation or for developing indices of NRBCs that link conflict research to practical policy interventions (Bernauer et al., 2012). According to Adger *et al.* (2004), vulnerability assessments are largely based on the use of a single index in a defined geographical area. But the local knowledge allows both the objective and the subjective specifications of thresholds with richer information than a single index that is often derived at a Large-N scale (Sicat *et al.*, 2005). As will be shown (see Section 1.2.2), the fuzzy logic-based modeling can be used to develop indices of NRBCs thereby linking sustainability and peace through the cooperation of actors (Adger *et al.*, 2004, UNEP, 2004).

1.2.2 From Conflict to Cooperation: Knowledge Co-creation for Sustainable Peace

Peace is categorized as positive peace (a peaceful society and the absence of structural violent conflicts achieved through cooperation, integration, and peacebuilding), while negative peace (the end of physical violent conflicts achieved through peacekeeping) (Galtung, 1969, Gleditsch et al., 2014). These studies acknowledged the limitation of negative peace for being a largely short-term peace. Hence positive peace is emphasized in this thesis. However, achieving positive peace through traditional approaches such as Alternative Dispute Resolution (ADR), liberal peace or military strategies are unsuitable particularly in the context of NRBCs as they are embedded in values and multiple stakes. Similarly, the engineering approach based on optimization and factual knowledge is inadequate for dealing with ill-structured problems. Therefore, knowledge from various hypotheses already tested about NRBCs can be used to develop strategies to enhance sustainability and peace. This can be done by using resource management strategies to support positive peace (Maxwell and Reuveny, 2000, Rustad and Binningsbø, 2012). The assumption by past authors that actors are driven by predatory ambition pays limited attention to their attempts to create or cooperate in local governance processes. But conflict can be transformed into cooperation and sustainable peace (Johansson, 2015, Brauch, 2016b), through adequate knowledge about the relationship on the natural resources-conflicts nexus. In support of this, for example, Ratner *et al.* (2013) argue that researchers need to move from hitherto causative and negative aspects of natural resources and civil conflicts to how the contested resources can be channeled into the improvement of cooperation and resilience, which can be achieved through modeling (see (Ekong *et al.*, 2012) and Sivakumar (2011) for the use of modeling in CM and in water management issues and Gray *et al.* (2012) for the benefits and the limitations of integrating knowledge systems into conflict modeling with the stakeholders).

With NRBCs being a complex problem in terms of multiple actors, factors, space and time (Wittmer *et al.*, 2006, Giordano *et al.*, 2007, Voinov and Bousquet, 2010, Hospes *et al.*, 2017), a solution lies in integrating the views of the actors. The actor's actual or perceived conflict levels matters and can be integrated to support community-based CM. In risk perception, the estimates of the psychophysical analysis can produce quantitative representations or "cognitive maps" of attitudes in a social space, which departs from the traditional Bayesian way of thinking (Slovic, 2000, Raaijmakers *et al.*, 2008) (see Section 3.1.1 and 3.2.1 for details on conflict risk perception). Drawing on social psychology studies, people can express their judgments about the current and desired levels of risk problems or estimate their level of vulnerability at which conflict occurrence can be explained (unlikely, likely, very likely or most likely) and this can be used to generate the desired regulation for each estimated levels (Raaijmakers et al., 2008). This assumption links conflicts to a fuzzy logic modeling for integrating the different drivers of NRBCs as opposed to binary logic in dealing with vulnerability to NRBCs. Fuzzy logic models (FLM) are expressed as an extension of a classical set, if X is the universe of discourse and its element are denoted by x then a fuzzy set A in X is defined as a set of ordered pairs *(Equation 1.1)* (Zadeh, 1965, Zadeh, 2008b, Zadeh, 2009). The membership function, therefore maps each element of x to a membership value between 0 and 1, in case of conflict vulnerability likeness such as (unlikely, likely, very likely, most likely). See Figure 1.3 for example of membership functions. Thus, using an adapted FLM, the model- Spatially Explicit Modelling for Conflict Management (SEFLAME-CM) is developed according to Zadeh (2009) and implemented under a transdisciplinary- based coupled approach (see Section 5 for details).

$$A = \{x, \mu_A(x) | x \in X\} \qquad \textit{(Equation 1.1)}$$

where

X	=	*The universe of discourse with x element*
A	=	*A fuzzy set in X*
$\mu_A(x)$	=	*Membership function (MF) of x in A.*

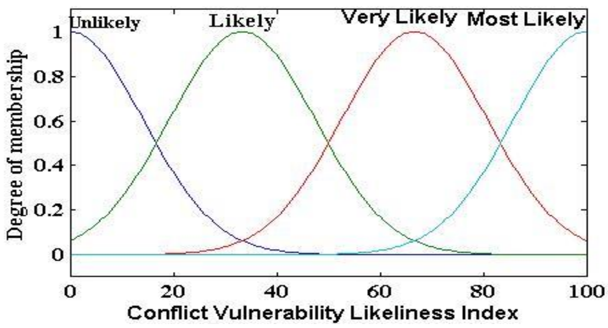


Figure 1.3: Sample fuzzy logic membership functions: conflict vulnerability likeliness (unlikely, likely, very likely, most likely).

1.3 A Transdisciplinary Research (TDR) Process

A TDR process is presented as a basis for the modeling set up. TDR substantially addresses the knowledge demands for studying NRBCs as complex societal concerns (Hadorn et al., 2006), It deals with NRBCs as a socially relevant real-world, “wicked” problem (Binder et al., 2015). A common denominator among the definitions, perspectives, principles, and challenges of implementing a TDR is that it is an approach, not a theory or method, and that it represents a move from science for/on/ and about society towards science with society (Wiek, 2007, Pohl *et al.*, 2007, Lang *et al.*, 2012, Mauser *et al.*, 2013). TDR contributes to mutual learning among scientists and society by integrating different epistemics and experiential knowledge (Scholz and Steiner, 2015b). This contribution makes TDR differ fundamentally from similar research approaches such as the interdisciplinary or the applied research, and the collaborative approaches, such as the multi-stakeholder discourses or the triple helix approach (Scholz and Steiner, 2015a, Scholz and Steiner, 2015b). There are two types and modes of the TDR conceived by Scholz and Steiner (2015a): integration of branches of disciplines (mode 1 transdisciplinarity), and integrating or relating different epistemic from science and practice (mode 2 transdisciplinarity). The latter takes root from the aspiration for “full transdisciplinarity” with knowledge integration as the core component (Scholz et al., 2006). Some of the integration methods are identified (see Section 3.3.2). Knowledge integration is a core of innovative scientific investigation such as the implementation of TDR (Wiek, 2007, Scholz and Steiner, 2015a). Binder et al. (2015) identified several strands on the processes of TDR implementation. However, recent implementations are based on three co-creation steps (Mauser *et al.*, 2013) (see Section 1.5). This is in line with the agreement by many authors that a typical TDR project consists of three phases (Binder *et al.*, 2015),

1.4 Knowledge Integration and Co-creation Processes for Sustainable Peace

Knowledge co-creation is an inclusive, iterative process involving interactions between actors, for an integrated or transformational understanding of a sustainability problem (Mauser et al., 2013, Schuttenberg and Guth, 2015). Sustainable peace is described as the manifold links between peace and the environment, where humankind and the environment as two interdependent parts of the Earth, face the social consequences of resource extraction and pollution (Brauch, 2016a, Brauch, 2016b, Stephenson, 2016). Sustainable peace is understood in the context of this work as the combination of sustainability and peace, where positive peace is conceptualized in sustainable transition by emphasizing long-term peace. It considers the environment, socio-economic and political dimensions, and the ability of future generations to make a decision regarding their own resources, and this requires developing strategies that integrates NRM into CM (Brauch, 2016a).

Knowledge co-creation in peacebuilding has to be salient, legitimate and credible (Cash et al., 2003, Cash et al., 2006, Serrao-Neumann et al., 2015). TDR does not have to engage with all the knowledge types in the literature (e.g. system knowledge, target knowledge, and transformation knowledge) (Brandt *et al.*, 2013). Thus with the goal of using the roles of science and society to effectively contribute to sustainable peacebuilding, a sustainable transition paradigm could enhance the utility of these types of knowledge in a transdisciplinary management manner (Wiek et al., 2006), by building capacity at the science-policy interface, and by applying new skills and developing new understanding through shared knowledge (Nesshöver *et al.*, 2016).

To implement the transdisciplinary approach which entails the integration of scientific and societal knowledge, the three phases of knowledge co-creation process as proposed by (Mauser et al., 2013), is presented in Figure1.4. They consist of three fundamental steps where both academia and actors are involved. For the full design and implementation process of these phases see Section 5.

1.4.1 Co-Design and Joint Problem Framing

The co-design process starts with the joint problem framing (see Section 4). This co-design phase focuses on developing a viable research problem in the broader scientific community (Mauser et al., 2013). During the co-design phase, stakeholders and academic participants work in a coordinated, integrated way and establish a common understanding of the research goals, identify the relevant scientific integration steps necessary to approach the NRBCs problems and operationalize the parameters (Armitage et al., 2011, Mauser et al., 2013).

1.4.2 Co-Production of Knowledge

According to Schuttenberg and Guth (2015), knowledge co-production (see Figure 1.4) requires creating new information. It also focuses on developing an integrated understanding of a sustainability problem (Lang *et al.*, 2012, Pahl-Wostl *et al.*, 2013). This entails assisted stakeholder workshops for assessing and weighing the factors/drivers of NRBC. This shifts self-focused perspectives into a holistic and collective understanding (Blackstock *et al.*, 2007). The result is actionable for policy decisions that create more acceptability to stakeholders (Meadow et al., 2015).

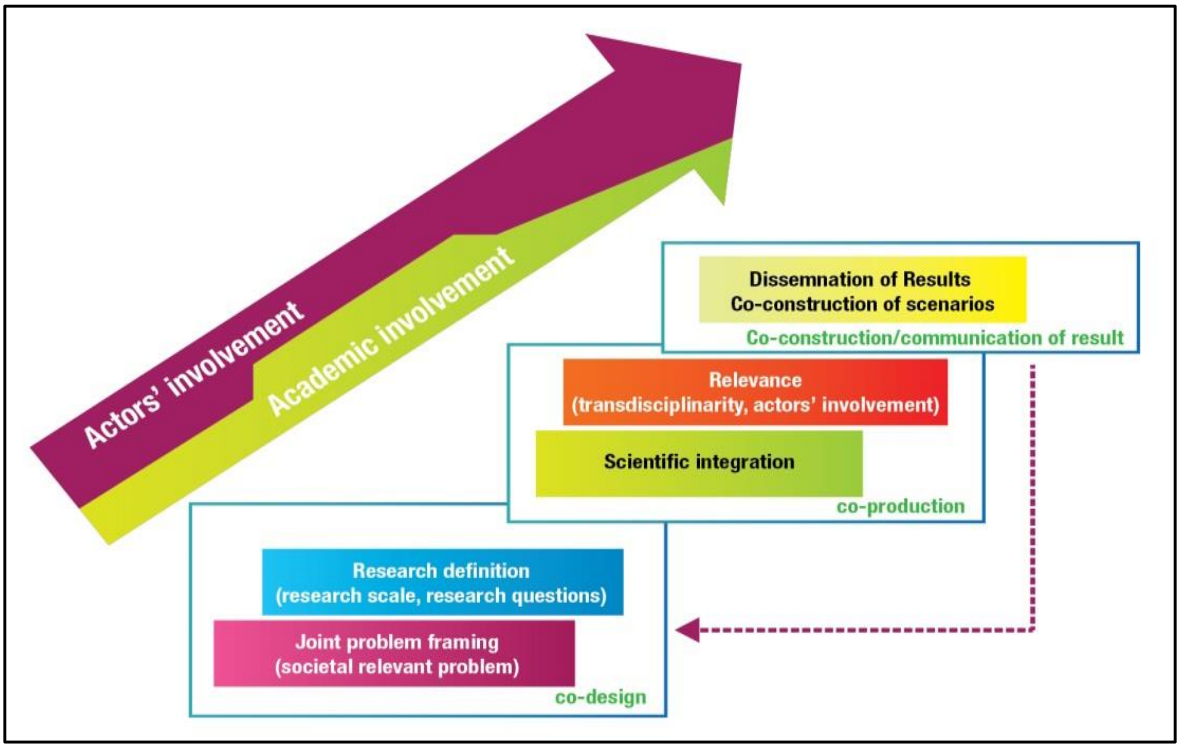


Figure 1.4: The Process of transdisciplinary co-creation of the knowledge castle, according to Mauser *et al.* (2013).

1.4.3 Co-Construction and Co-Communication of Conflict Management Scenarios

Co-dissemination of results is the next step after knowledge co-production (Mauser *et al.*, 2013). It involves identifying potential synergies and cross-disciplinary connections between the adaptation options. Drawing on Mauser et al. (2013), this entails translation of the results into usable information for the different stakeholders and requires applying the results in an open discussion among the vulnerable groups in order to consider future management scenarios. For example, the co-produced model in phase 2 is applicable for future CM scenarios which inform decisions that reduce community vulnerabilities to NRBC and enhance resilience. See Section 3 for details on the definition of risk, vulnerability, resilience and other concepts applied in this thesis.

1.5 Motivation, Scientific Objectives, and Structure of this Thesis

As the available information reveals, there is a dearth of research that focuses on developing a model implemented under a transdisciplinary approach for enhancing sustainable peace as recommended in the fourth phase of NRBCs research (Brauch, 2016b). The only exception is the recent work under the Earth System Research and the Anthropocene (ESRA), Human, Gender and Environment Security (HUGE), and HESP (Spring et al., 2009). But these projects only attempted a reconceptualization of NRBCs without further practical or empirical research on the assessment and implementation of NRBCs. A transdisciplinary approach (called a transdisciplinary-based coupled approach in this thesis) is used to couple the three vulnerability components in the context of NRBCs. These are space, time and dimensions of a vulnerability assessment (see Section1.1).

The main objective of this thesis is thus: the investigation of vulnerability assessment in the context of NRBCs and integrating the environment, the socio-economic, and the political drivers of conflicts into the developed and validated model-SEFLAME-CM. It is hypothesized that the knowledge of the actors is capable of improving the understanding of vulnerability assessment of NRBCs more than the previous linear models such as MLRM. To achieve this objective, specific questions are answered as drawn from issues raised by scholars on the management of NRBCs and sustainable peace (Matthew *et al.*, 2003, Spring *et al.*, 2009, Spring and Brauch, 2011, Brauch, 2016b):

- How can we reconceptualize NRBCs for a holistic vulnerability assessment using a transdisciplinary-based coupled approach? NRBCs are reconceptualized based on the integration of holistic vulnerability assessment concepts into an adapted FLM with the concepts applied to the Niger Delta test cases of NRBCs (see Section 3).
- How can we develop a spatially explicit model for simulating the NRBCs as a decision support for NRM and CM by integrating the actors' knowledge of the conflict drivers and applying the model to conflict cases in the Niger Delta? Answering this question began with a joint problem framing; combining qualitative method, (e.g. discourse analysis) and quantitative methods (e.g. remote sensing). The results are presented in Section 4. These findings helped to operationalize the parameters for developing the algorithm for SEFLAME-CM. The overall method and the coupling process are presented in Section 5.
- To what extent is SEFLAME-CM better when compared with linear models such as MLRM, in view of uncertainty and the multiple dimensions of vulnerability to NRBCs? The findings of the model validation are presented in Section 6.
- How can the above-developed model be adapted for co-constructing plausible future management scenarios with the actors in an attempt to build community or regional resilience and sustainable peace? This is addressed in the conclusion and outlook on the

future applications of SEFLAME-CM (Section 7), while the thesis ends with a summary in English and German in Sections 8 and 9 respectively.

Thus to answer the first research question, this work began with a reconceptualization of NRBCs (see Section 3). The main areas of focus in the design and implementation include the following:

Firstly, the findings of the reconceptualized NRBC and joint problem framing informed the modeling system of the thesis. Thus, as shown in Section 4, NRBCs is framed as a complex, "wicked" problem and a socio-ecological system (SESs) (Rittel and Webber, 1973). It is considered that solutions to complex environment-society relations require integrating knowledge across disciplines and with the actors (Funtowicz and Ravetz, 1993, Head *et al.*, 2016, Kaiser *et al.*, 2016, Moran and Lopez, 2016). Thus, NRBCs cannot be literally determined singly by environmental conditions (Buhaug and Theisen, 2012, Gleditsch, 1998, Homer-Dixon, 1991). On the one hand, environment is of less importance to poor people in the villages of developing societies because community resistance to high-value resource extraction, for example, oil and inter-community rivalry is perceived as mainly related to socio-economic issues such as "money", lack of well-being, and politics such as political exclusion or repression (Douma, 2006, Justino, 2009). On the other hand, NRBCs are considered as a "wicked" problem which require a new kind of science, since "values are many and stakes are high" (Funtowicz and Ravetz, 1993). This requires an understanding that is far from a simple linear modeling. The importance of the environment needs to be placed side by side with socio-economic issues in order to unravel the actor's knowledge and the motivation for different levels of conflicts. Such an approach seems very helpful to craft strategies for managing or resolving future NRBCs.

There is a detailed analysis of the environmental changes using land use and land cover (LULC) models. The derived environmental drivers (distance to specific resources as parameters) and socio-economic and political components are integrated into the models (see Section 5).

Secondly, the adapted fuzzy logic based models (Zadeh, 2009) developed in this thesis are called Fuzzy logic Adapted Modelling for Conflict Management (FLAME-CM) and a Spatially Explicit Fuzzy Logic Adapted Modeling for Conflict Management (SEFLAME-CM). A validated FLAME-CM established the main target model, SEFLAME-CM. The FLAME-CM and SEFLAME-CM represents the calibrated content of the model and the spatially explicit component respectively (see Figure 6.7). All the drivers and input parameters are weighted to develop conflict vulnerability likeliness (CVL) Index.

Thirdly, the validated model-SEFLAME-CM is proposed for adapting a plausible scenario for future management of NRBC problem at a community or regional scale.

Prior to the modeling processes in this thesis, there was firstly a review of the Large-N and the micro studies in the case study (Niger Delta Region), and other African and non-African studies in the globe. The findings helped to develop the algorithm for this work. See Section 5 for the adapted FLM algorithm. Secondly, the publications on FLM which began with Zadeh (1965) were very relevant. FLMs have been successfully applied across disciplines at different spatial scales. The knowledge co-creation process by Mauser et al. (2013) is reproducible with successfully applied case studies (Bracken *et al.*, 2015, Reyers *et al.*, 2015, Schuttenberg and Guth, 2015, Page *et al.*, 2016). The model parameters are limited to the spatial extent of parts of the Niger Delta Region of Nigeria (see Section 2). The temporal dimension is divided into three-time scales. The first segments are used as "reference" period to test and validate the model. It ranges from 1986 to 2000 and 2000 to 2016. The choice of the reference periods considered the temporal data availability; both remotely sensed data and census datasets for the socio.-economic drivers (see Section 5). Also, the 1980s-1990s period is the time of intense conflict, which preceded the popular Ogoni protests of the early 1990s (Agbonifo, 2011). The "scenario" proposal for future CM is a period from 2016 to 2060 (see Section 7.3 for justification of the time scale of the proposed scenarios).

The Niger Delta Region, as a heterogeneous territory with geographic, environmental, socio-economic and political significance is suitable for this investigation (see Section 2 for details). Geographically, it is defined as a delta, with its anthropogenically affected water emptying itself into the Atlantic Ocean. It has large mangrove areas and major commercial cities, (e. g Port-Harcourt and Warri and many towns and villages, with a variegated land use formed by the active industrialization, the presence of oil and allied companies and agricultural activities. Economically, it is the economic hub of the country. Importantly, this is where I was born and studied and worked as a scientist which is the reason why I am personally interested in the changes and how NRBCs can be modeled for future peace.

The entire modeling and validation process is perceived to be capable of giving quantitative relationship and answers to NRBCs investigations. The transdisciplinary-based coupled approach is well suited under a research in geography. As Harlan Barrows stated long ago, "[G]eography . . . properly can claim the title of Mother of the Sciences' (Barrows, 1923:1). Such a cross-disciplinary approach as offered in geography is necessary when interdisciplinary research is necessary but not sufficient to address complex human-environmental problems and sustainable transformations of a current system (Seidl et al., 2013). Such a methodological pluralism and policy relevance approach is highly sought after in NRBCs investigations (Schwartz *et al.*, 2000, Ide, 2015a, Reynolds, 2016).

2 The Niger Delta Region Case Studies

Since this work is a test case, the entire Niger Delta was not used because of its large geographic extent. As a result, parts of the Niger Delta (Ogoni and Okrika Territories in River State) were selected to apply the transdisciplinary-based coupled approach. The selection of this area was based on various reasons, among them being the representation of the diversity of the Niger Delta with respect to the environmental and the socio-economic characteristics. The characteristics of the selected territories, communities and villages give an insight into the natural and anthropogenic realities and diversities of the Niger Delta region. It is located within the Gulf of Guinea, approximately between longitude 5° east to 8° east and latitude 4° north to 6° north. It is a wetland that is rich in oil deposits, mangrove, and fisheries resources. It occupies a total land area of 75,000 km². Geo-politically, it consists of nine states/provinces: Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and the Rivers States. Among the 11 sites designated as wetlands of international importance, three are found in this region. For a more detailed characterization of the Niger Delta region (see Udo, 1970). Figure 2.1 shows the map of the case study, with Niger Delta, Rivers State and the selected communities and villages for investigations.

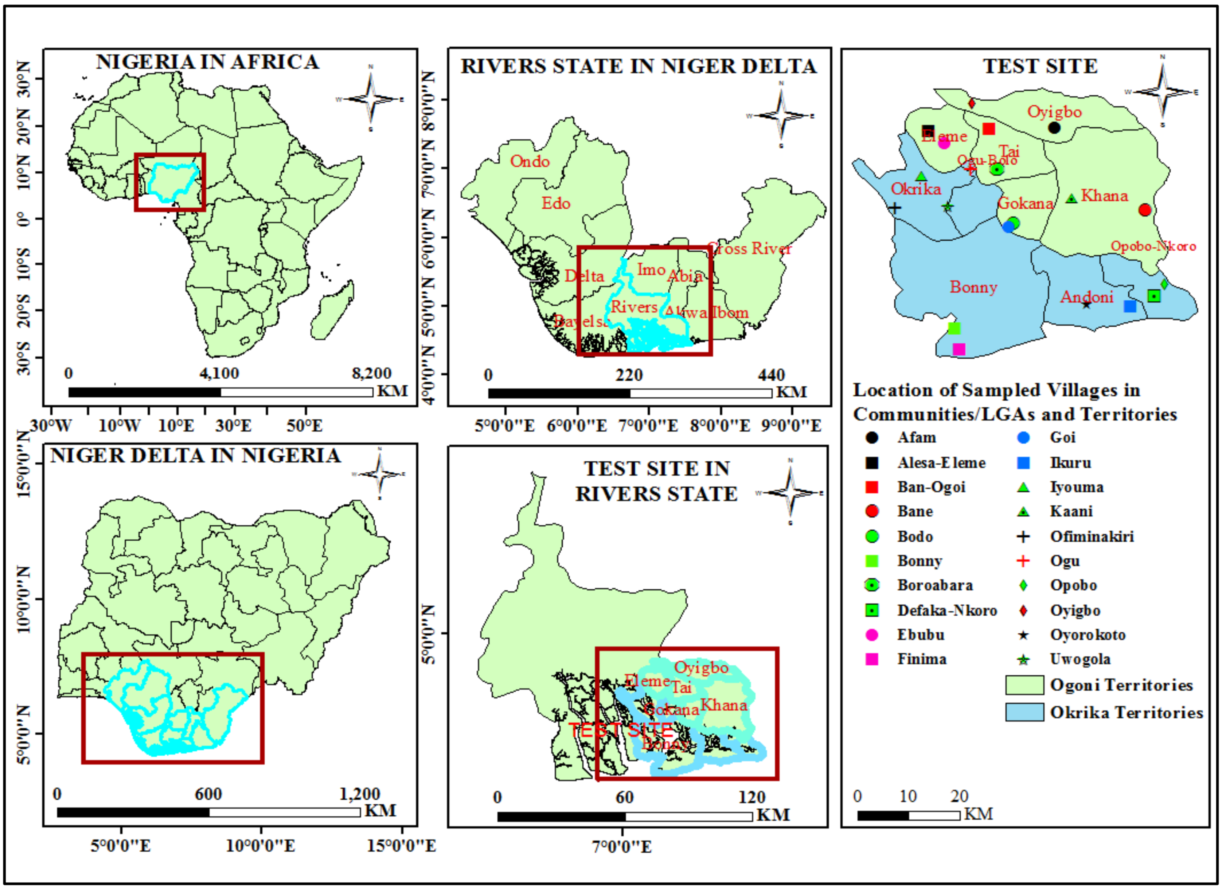


Figure 2.1: Location of Nigeria in Africa (top left); Niger Delta in Nigeria (down left); Niger Delta States with the nine States (top middle); Rivers States with test site (down middle); case study with two territories and communities/Local Government Areas (LGAs) and villages.

According to World Bank (1995), there are three core states of the Federal Republic of Nigeria that make up the Niger Delta region: Rivers, Delta and Bayelsa states. These are also hot spots in terms of deltaic features and oil production (World Bank 1995), with more than 60% of the incidences of increased resource conflicts occurring since the 1990s (Oyefusi, 2010). Records of Natural Resource-Based Conflicts (NRBCs) gathered on the study area from Uppsala Conflict Data Programme Geo-referenced Event Dataset (UCDP GED) (http://ucdp.uu.se/downloads/) and Armed Conflict Location Event Data (ACLED) (https://www.acleddata.com/data/), show that more than 253 conflicts have been reported alone from the 1980s till 2016. Damages caused by conflicts within the Niger Delta region, including the case study communities are estimated at $60million per day since the 1990s (Watts, 2004). Among the three core states mentioned above, Rivers State, in particular, is a key state in the entire region. It has the highest population and contributes the highest revenue through the oil sector of the nation's economy (see Table 2.1). The revenue generated from River State alone is more than that of some countries in Africa (Table 2.1).

Table 2.1: Rivers State's revenue compared with that of four other African Countries.

Area	Population (Millions)	2007 Revenue (US$)
Nigeria	135	20.5 Billion
Rivers State	5.2	1.7 Billion
Burundi	6.4	259.4 million
Togo	5.7	478.1 million
Eritrea	4.6	232.7 million
The central African Republic	3.8	250.0 million

Source: CIA (2007).

2.1 Location and Size of Case Study

As mentioned earlier, the research focused on two territories in Rivers State (Ogoni and Okrika territories) (see Figure 2.1). Rivers State occupies a land mass of about 10,361km2 with Port-Harcourt as the capital. Each LGA interchangeably referred to as communities, has an average population size of about 150,000 inhabitants. LGAs are made up of villages. See Table 2.2 for the projected coordinate of the location of villages in UTM WGS 1984 Zone 32N. Figure 2.2 shows the map of the territories and the LGAs/communities and villages. The villages are of various sizes. They can be reached mostly by walking distance in the dry land areas, or by boat in the remote coastlands. The NRBCs of this region is not ubiquitous (Agbonifo, 2011), its pattern is explainable. The two territories selected are made up of 10 LGAs (Figure 2.2).

Two representative villages were selected based on oil presence as identified by Agim (1997) and based on conflict events from each of the LGAs (see Table 2.2). According to Agim (1997), communities in the region can be divided into three principal groups, each of which claims equal rights to the oil extracted from their land. These are:

- The oil-producing: These are communities where onshore oil exploration takes place.
- The terminal communities: These are communities whose coastal territory has terminal oil-related facilities, sometimes because oil exploration takes place offshore;
- Transit communities: These are communities whose territory transit pipelines pass.

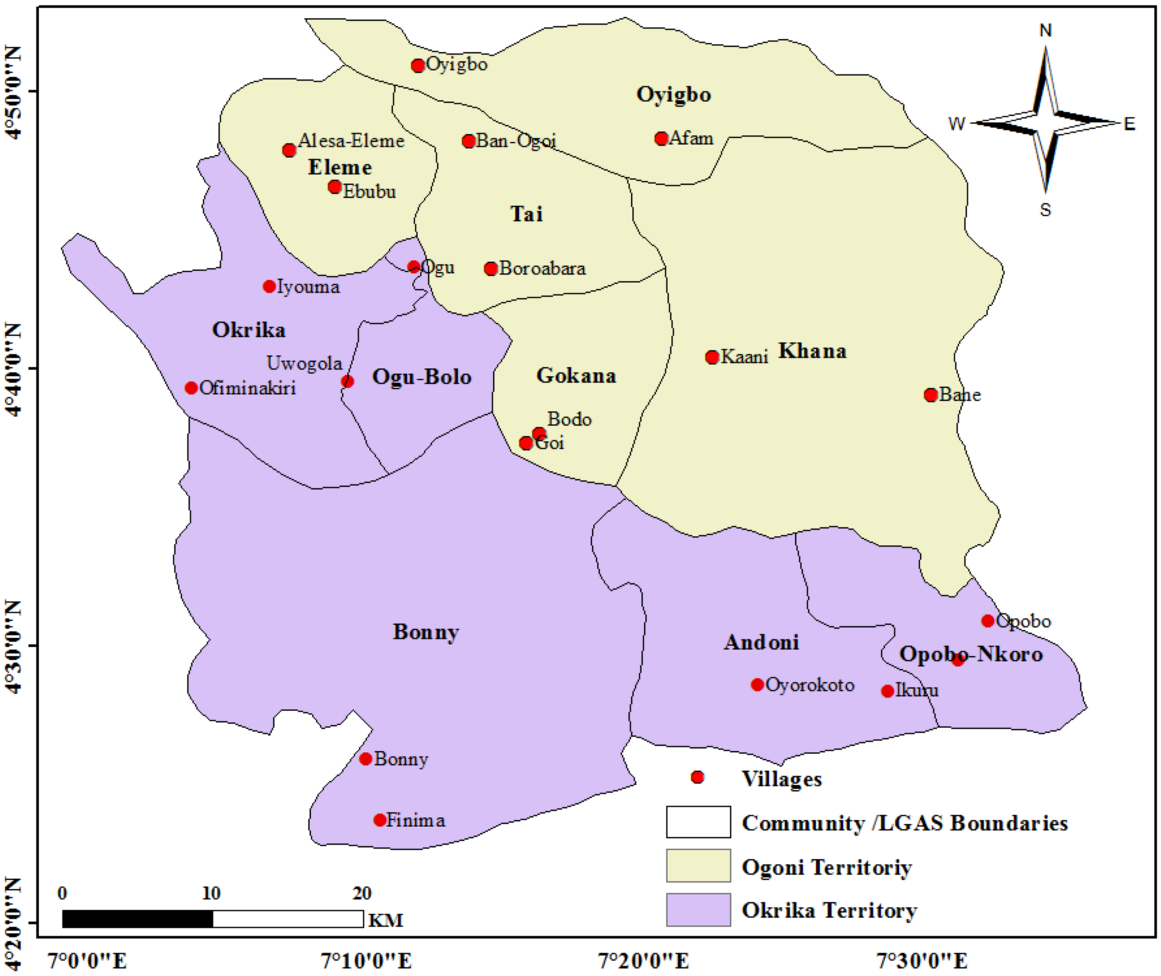


Figure 2.2: Map of the case study.

2.2 Natural Realities

2.2.1 The Physical Characteristics and the Four Ecological Zones

The ecology of the Niger Delta are classified into four ecological zones (World Bank 1995, Okonkwo *et al.*, 2015). The selected territories cut across these zones of the region. River State, in particular, is basically made up of two categories of ecological zones: the landward and the seaward territories. These are subdivided into the four ecological zones of the Niger Delta, These are coastal barrier islands, mangroves, freshwater swamp forests, and lowland rainforests (World Bank 1995). See Figure 2.3 for the ecological zones of the study area.

Table 2.2: Territories and selected LGAs and villages.

Territory	LGA	Village	Latitude (M)	Longitude (M)
1. OGONI	Eleme	Alesa-Eleme	291498.54	530802.17
2. OGONI	Eleme	Ebubu	294382.50	528288.62
3. OGONI	Gokana	Bodo	308095.88	511901.62
4. OGONI	Gokana	Goi	307143.38	511246.78
5. OGONI	Khana	Bane	334067.77	514373.17
6. OGONI	Khana	Kaani	319595.03	516940.16
7. OGONI	Oyigbo	Oyigbo	299753.55	536358.43
8. OGONI	Oyigbo	Afam	315787.33	531437.17

9. OGONI	Tai	Ban-Ogoi	303246.06	531437.17
10. OGONI	Tai	Boroabara	304860.02	522904.34
11. OKRIKA	Andoni	Ikru	331306.50	494778.64
12. OKRIKA	Andoni	Oyorokoto	322614.92	495208.59
13. OKRIKA	Bonny	Bonny	296566.64	490293.94
14. OKRIKA	Bonny	Finima	297480.02	486147.15
15. OKRIKA	Ogu-Bolo	Ogu	299422.40	523002.53
16. OKRIKA	Ogu-Bolo	Uwogola	296323.30	515053.98
17. OKRIKA	Okrika	Ofiminakiri	284936.86	514847.76
18. OKRIKA	Okrika	Iyuoma	289884.57	521541.74
19. OKRIKA	Opobo Nkoro	Defaka-Nkoro	335966.87	496813.76
20. OKRIKA	Opobo Nkoro	Opobo	337911.50	499378.66

(1) Coastal barrier Islands: This is a chain of low sandy barrier islands that protect the coast of the Niger Delta. The dominant vegetation is fresh-water swamp forest with occasional salt marshes where sea water washes over the beaches.

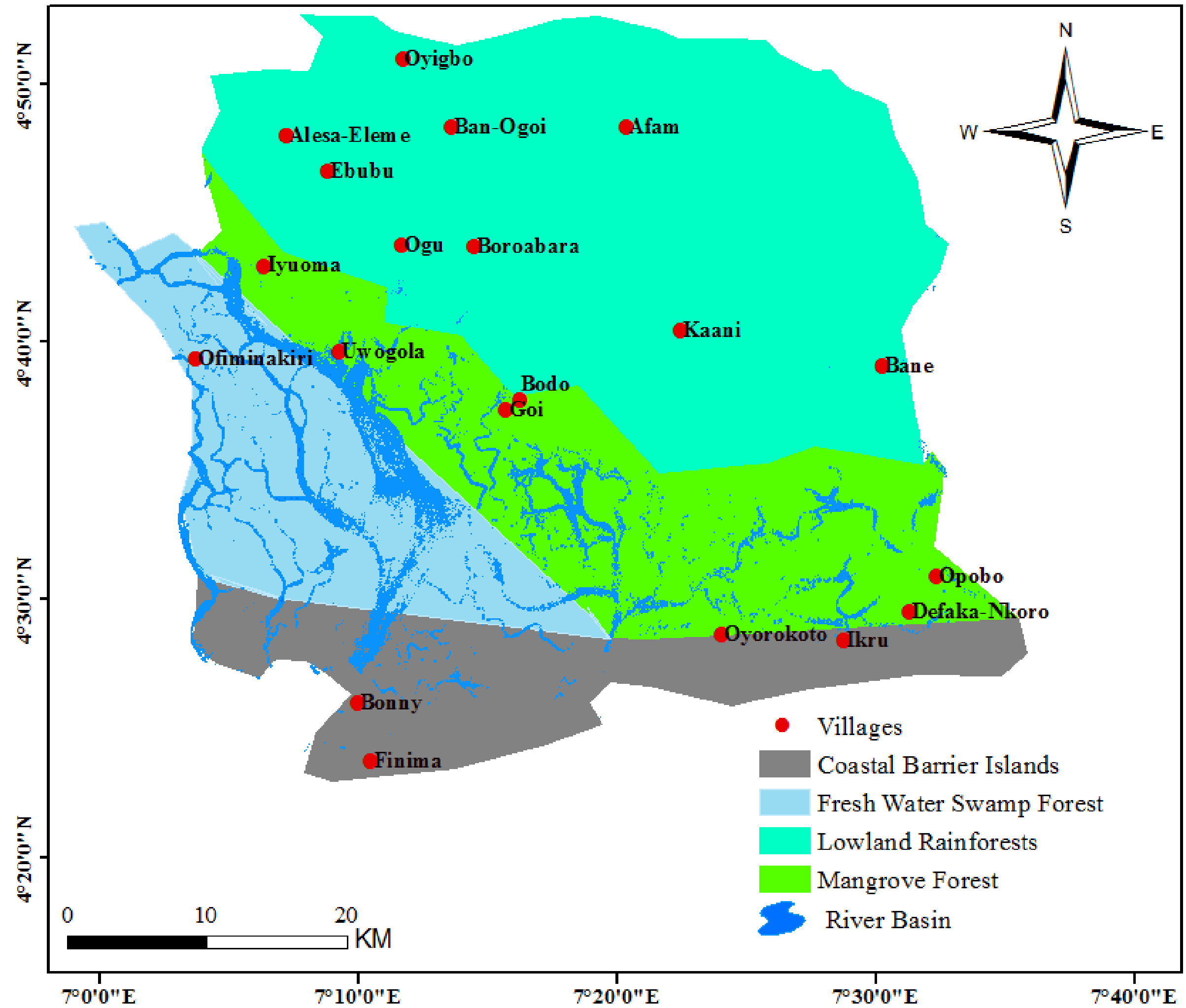


Figure 2.3: Map of the ecological zones of the case study adapted from (Udo, 1970, Ugochukwu and Ertel, 2008).

Important biodiversity resources are fisheries resources which are often relied upon by the rural people (artisanal fishermen). Besides fisheries of various species, the seawater is also rich in other seafood, which makes many local inhabitants travel to these territories. Okonkwo et al. (2015) reported that: “more than 70% of the fish stocks targeted by the industrial fishery are caught in coastal zones of the Niger Delta region". Common species exploited by artisanal fishermen are *Ethmalosa fimbriata* (Bonga), *Ilisha africana* (West African shad), *Sardinella maderensis* (Flat sardine) and some *Carangnids*. According to Tobor (1997) citing the report by the Federal Department of Fisheries, Bonga fish is the most abundant and widely exploited fish species in Nigeria. Others are clupeid species. The barrier islands also provide fresh water, which is critical for human habitation of the coastal and mangrove zones.

(2) Mangrove forest: According to the World Bank (1995), Nigeria has the third largest mangrove forests in the world and the largest in Africa, a majority of which are found in the Niger Delta including the Rivers State communities (World Bank 1995, Ebeku, 2004). Mangrove swamps lie at the center of a sensitive and complex ecosystem and the resource is critical to the livelihood of the communities. It is vital for the fishing industry and a major source of income for the indigenous people of the Niger Delta. It harbors important flora and fauna of the country and acts as one of the most economically rich parts of the region's ecological zone (World Bank 1995). Typical mangrove forests consist almost entirely of the red mangrove trees with its characteristic stilt or prop roots. The trees grow tallest along creek edges with fresh mud deposits. In the old-growth swamp areas, trees are very stunted; especially in areas not receiving nourishing waters from the oceans (World Bank 1995). The swamp areas have other smaller mangrove species, such as the white mangrove and the black mangrove. Many invertebrate species such as crabs and shrimps are found on the mangrove floor with eel fish hidden in the mud. Shallow depressions near the creek edge provide habitation to microscopic algae while mangrove leaves and associated microfauna provide food for many animals that inhabit the mangrove forests, including crabs, periwinkles, and mudskippers. These have recently been affected by oil extraction pollution. Higher areas of the swamp contain unique salt fern and salt grass otherwise called "Savannah" and are bound by an area of shrubs and non-mangrove trees. Besides the economic value, many local people derive great social and spiritual services from mangrove ecosystem which they are ready to protect against any intruders trespassing into their mangrove lands.

(3) Freshwater swamp forests: This zone is the major source of forest products, such as timber. It is also rich in endangered wildlife species. The swamp forests, which are subject to silt-laden "white water" of the Niger floods, have the potential for fishery and agricultural activities. Within this whitewater section, there are two sub-zones (Smith, 1933). These include (a) the upper delta or flood forest zone and (b) the swampy tidal freshwater zone.

a) The upper delta or "flood forest" zone is made up of large sandy river channels, high flood levels, and numerous floodplain lakes. These features include flood-free levees, "black swamp", and "cane forests". They help to give the zone a high diversity of habitat types (Okonkwo et al., 2015). Large areas of the forest are also inundated during the floods, becoming vast seasonal nursery areas of fish. The shortened season for farm crops is compensated for by the fertile silt from the flood, which allows for annual farming without fallow periods. With the high rates of deforestation in the area, the fresh-water swamp forests are seriously under threat

b) The swampy tidal freshwater zone is a swampland inundated with water for the greater part of the year and it is the most heterogeneous ecological zones, with diverse species of flora and fauna (Okonkwo et al., 2015).

(4) Lowland rainforests: This occupies the non-revering, “upland” or landward areas of the study area. The natural rain forest of the area has been largely cleared for agricultural systems (for shifting cultivation) and settlements. The agricultural practices include tree crops, oil palms, and other tree plantations. The World Bank ‘s (1995) report stated that Ogoni land used to be covered with rainforest but has since been largely converted to degraded forests and farmlands. The dominant vegetation types are now secondary forests and a mosaic of cropped and fallow areas such as banana plantations. There are also patches of thick forests seen on recent satellite imageries on the coastlines of some of the river tributaries within the territory. The open farmland areas lead to the entry of the invasive grassland or “savannah” species. In areas unsuitable for farming, a few minor vegetation types persist in semi-natural conditions, which are seasonally flooded depressions and riparian forests along the edges of rivers, and occasional Savannah. These areas are, however, increasingly under pressure for marginal farming of short-season crops and wood.

2.2.2 Climate

The climate of Nigeria including the Niger Delta region is equatorial and semi-equatorial in nature. It is characterized by the interplay of two contrasting air masses —the south-westerly tropical-maritime air mass that blows across the Atlantic Ocean; and the dust-laden tropical continental air mass that blows across the Sahara desert from the Arabian Desert. The temperature is generally high and constant throughout the year in the region. The warmest months are between February and April with this period coinciding with the passage of the overhead sun. Maximum temperatures increase northwards from the coast. The annual mean maximum temperature was put at 31.8^{0}C (National Bureau of Statistics, 2017). When compared to the upland parts of River State, the coastal Relative Humidity (RH), particularly during the rainy season, is very high. While the figures for coastal areas fluctuate between 80-90%, the RH of upland is between 71—86%.

There are two seasons: the wet (April to October) and the dry (November to March). These are determined by the dominance of a tropical air mass and the continental air mass respectively, with rain intensity decreasing from the coast northwards. Due to the proximity of the Niger Delta to the Atlantic Ocean, annual mean rainfall is about 4500mm (Adejuwon, 2012). When compared to the high rainfall figures, the coastal communities of River State have low evaporation rates, and thus high and regular rainfall makes oil spills sip into the soil or leads them being washed off into the streams and the rivers that the people depend on for their daily livelihoods. The hydrological boundaries between ecological zones are fluid and depend on seasonal river flows (World Bank 1995). The river tributaries connect to the Niger River (Figure 2.4).

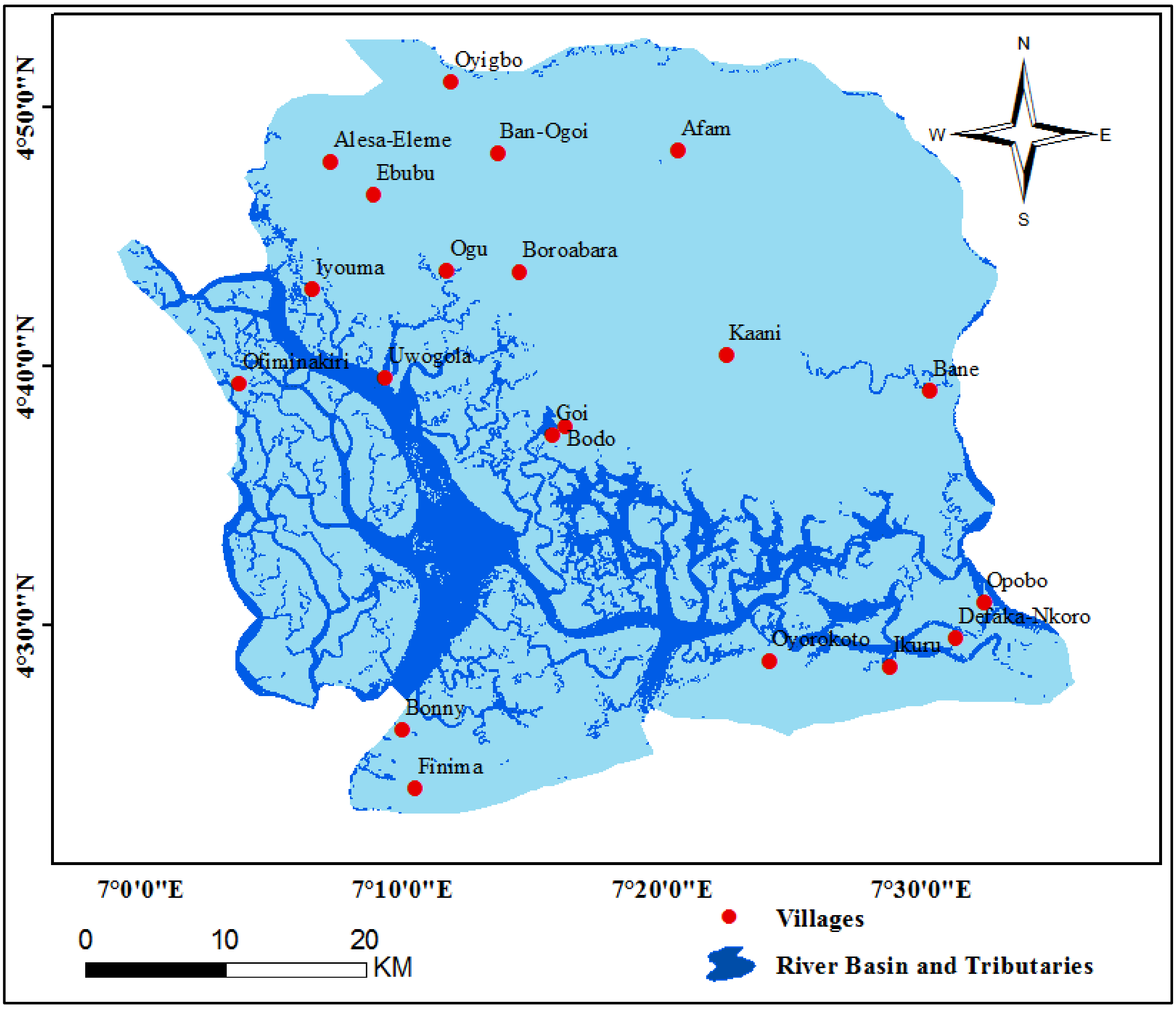


Figure 2.4: River Basin and tributaries.

This flows from north to empty into the Atlantic Ocean (see Figure 2.5). As several villages are located by the river basin, high rainfall and river discharge combine with the flat terrain and poorly drained soils, to causing widespread seasonal flooding and erosion. During most years, only select elevated areas remain dry. When the flood waters recede, the channels that spread out across the delta, leave swamps and pools that drain only poorly, if at all. A dynamic equilibrium between flooding, erosion, and sediment deposition is the defining characteristic of the delta ecosystem. However, construction of dams along the Niger River (the main river in the region) during the last twenty-five years has disrupted the hydrological balance by significantly modifying water-flow regimes and sediment deposition.

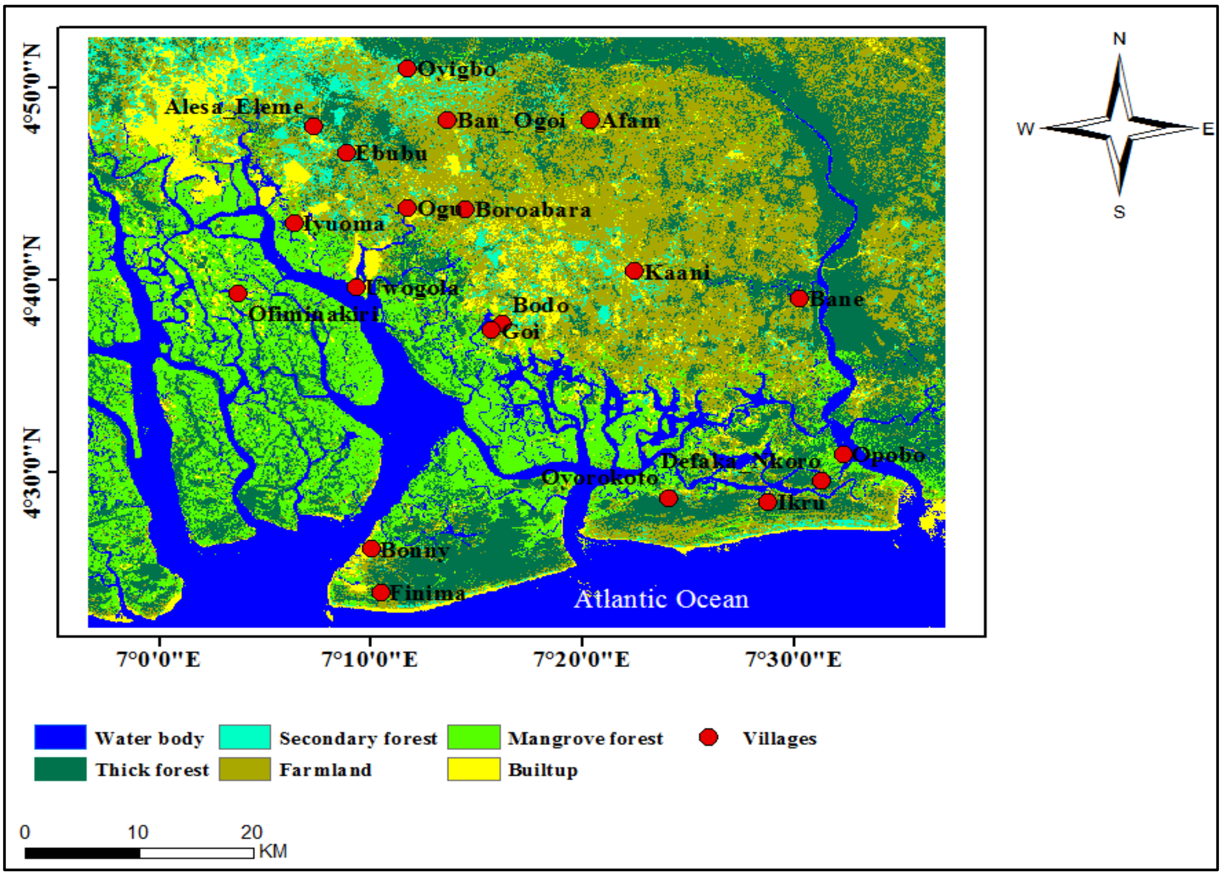


Figure 2.5: Landsat 1986 classified image of the case study with water emptying into the Atlantic Ocean.

2.2.3 Factors of Ecological Changes in the Case Study

Several studies have documented the environmental problems of the Niger Delta with resultant socio-economic impacts including resource conflicts (World Bank 1995, Ugochukwu *et al.*, 2008, Opukri and Ibaba, 2008, Omofonmwan and Odia, 2009, Anejionu *et al.*, 2015, Ejiba *et al.*, 2016). These studies show a myriad of drivers threatening the ecology of the area and as well as socio-ecological implications in the region. The environmental problems include, but are not limited to these:

- Disturbance of the ecology due to oil extracting activities, such as: crude oil transport, gas flaring and the escape of other chemicals used in production processes in the air, due to oil spill, sabotage, equipment failures, pipeline interdictions e.t.c.
- Air pollution from oil, gas, fertilizer, steel, and brewing companies.
- Land pollution, degradation through poor agricultural practices, oil explorations industrial waste dumping and indiscriminate disposal of urban wastes.
- Water pollution, contamination of the rivers, flooding, and erosion.
- Wetland reclamation,
- Large-scale farming and plantation farms, such as banana.

2.3 Anthropogenic Realities

Combined factors of industrialization, oil extractive activities and allied industries, dredging, and construction activities and agricultural activities have led to the changes in the region resulting in its present state.

2.3.1 Industrialization and Oil Industry

The oil industry is the key economic activity of the Niger Delta region. It accounts for over 90% of Nigeria's total foreign exchange revenue. The estimated crude oil reserve is put at 35 billion barrels, most of which is from the Niger Delta region, from the onshore and offshore locations. Production from joint ventures (JVs) between the state-owned Oil Company, Nigerian National Petroleum Corporation (NNPC), and the Multinational Oil Corporations (MNOCs) accounts for nearly all of Nigeria's oil output with only 5% attributable to indigenous companies operating within the marginal fields. The expansion of the oil frontiers has consequently attracted more MNOCs for oil exploration, extraction, distribution processes, refining, and marketing. The main MNOCs under the JVs with NNPC include Shell Petroleum Development Company (SPDC), National Oil Company (NAOC), Total Oil, and Chevron (Idemudia, 2009b). Crisscrossing the different ecological zones in the communities are oil infrastructures which are useful for various onshore and offshore oil activities. Examples of the oil infrastructure include oil wells, oil fields, oil flow stations, and oil pipelines Figure 2.6 shows a map of the study area with oil infrastructure locations.

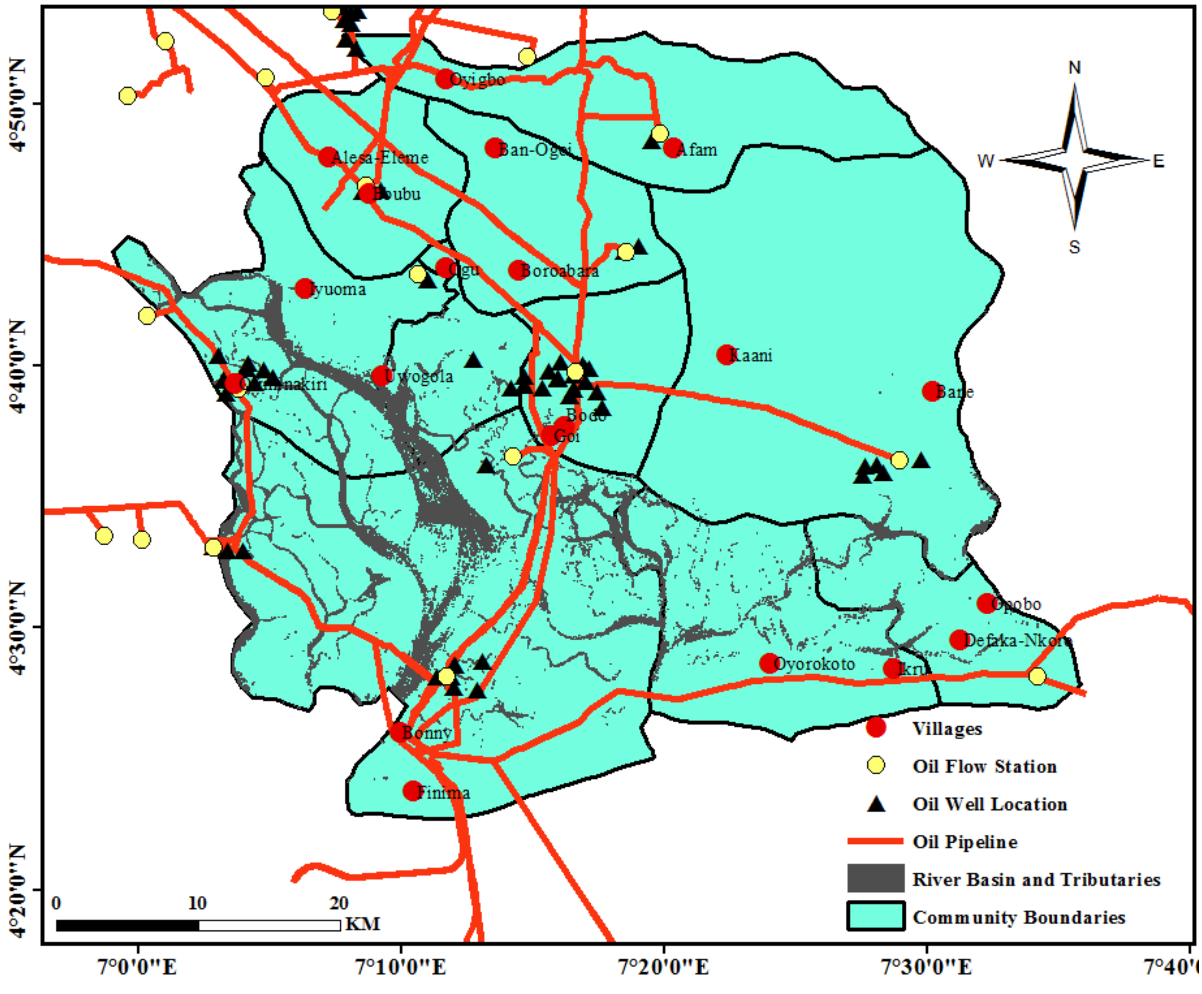


Figure 2.6: Map of oil infrastructure in the study area.

Figure 2.7 and Figure 2.8 show the trend of the oil spill in the Niger Delta and the case study respectively. Despite regulatory agencies and policies guiding oil resource extraction, studies have shown significant effects on the flora and fauna of freshwater ecosystems (World Bank 1995, Ugochukwu *et al.*, 2008). Environmental pollution has equally impacted negatively mainly on the biodiversity through oil production processes (Anifowose et al., 2014). High interdictions of oil pipelines are a key problem in the global petroleum industry, in particular, the region of the Niger Delta, with its spatial-temporal reality contributing to environmental and socio-political problems of communities (Anifowose et al., 2014).

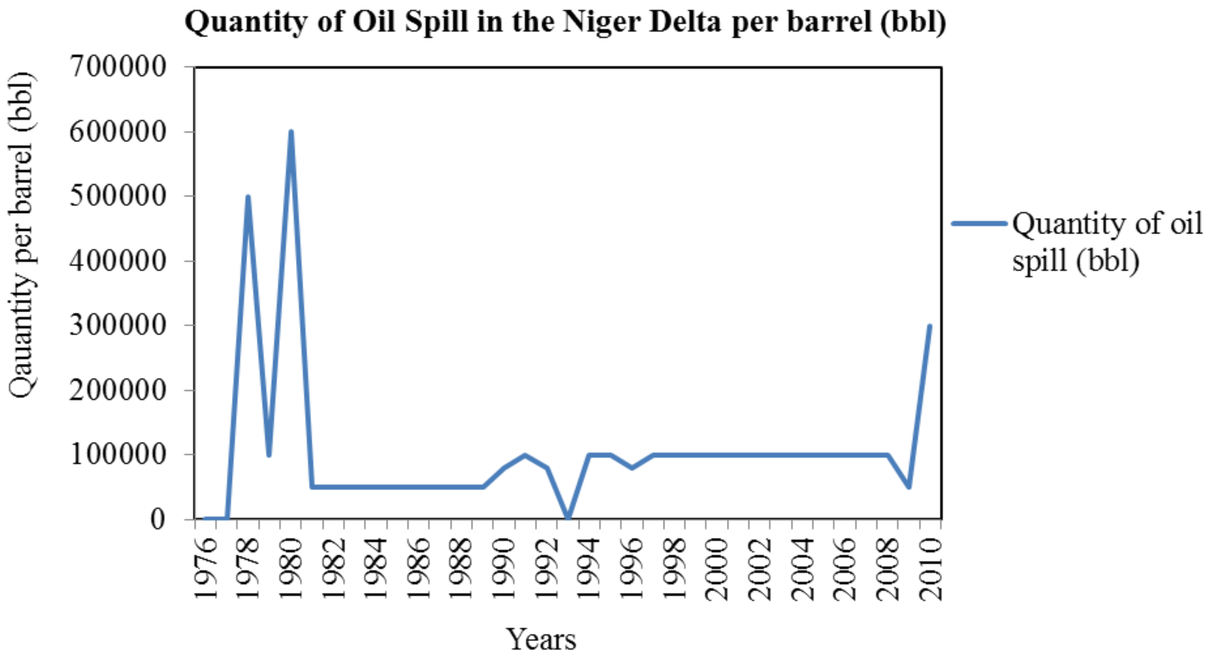


Figure 2.7: Trend of the oil spills in the Niger Delta. Source: Fieldwork, 2014, DPR, 2014, National Oil Spill Detection Response Agency (NOSDRA), 2014

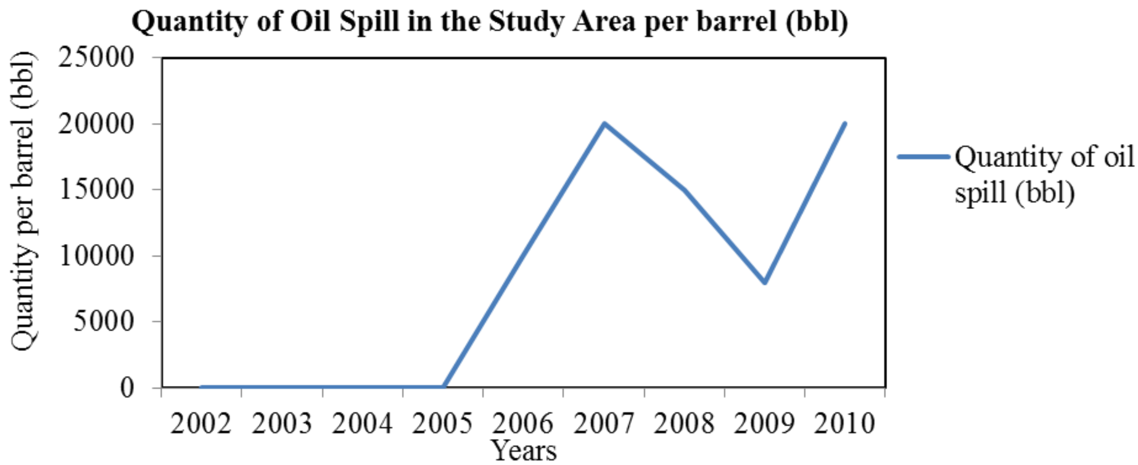


Figure 2.8: Trend of the oil spills in the study area, Source: Fieldwork, 2014, DPR, 2014 and National Oil Spill Detection Response Agency (NOSDRA), 2014.

The complex problems associated with oil pipelines partly exists because the Environmental Impact Assessment (EIA) in Nigeria was only promulgated in 1992 (Anifowose *et al.*, 2014). The restiveness of the territories has recently affected the oil production activities. With oil being a mainstay of the Nigerian economy, there are clear indications that the investments in the oil and gas sector are likely to increase in the future in the Niger Delta. This situation may not even be affected by the current global discussion on the implementation of decarbonization policy in the oil sector. In other to ameliorate the expected negative impacts of oil extraction, there are recent calls for sustainable corporate social responsibilities (CSR) of companies from the communities where they operate in (Idemudia, 2012, Idemudia, 2014, Idemudia, 2017).

2.3.2 Corporate Social Responsibility (CSR) Models in Oil Extractive Communities

Different models of CSR have been employed by the various oil companies in their core business operations with the motive of developing the host communities (Idemudia and Ite, 2006, Ite, 2007, Idemudia, 2014, Idemudia, 2017). However, implementation has not helped to alleviate the sufferings of the villages from the adverse socio-ecological impacts of oil exploration. The local actors believe that oil companies are contributing to community development, but not in terms of improving their livelihood with regards to the oil production externalities (Idemudia, 2010).

2.4 People and Culture and other Socio-economic Activities

River State comprises three main ethnic groups: Ogoni (the largest group in the study area), Ikwerre, and Ijaw. Other ethnic groups are Ogba, Ibani, Opobo, Eleme, Okrika, Kalabari, Etche, Engenni, Gokana, Andonis, Okrika, and Obolo. Centuries of intergroup relations have led to similar traits among them. For example, with an exception of Andoni, the groups have a common language affinity.

2.4.1 Socio-economic Characteristics

The Niger Delta region has been intensely influenced, formed and transformed by anthropogenic activities. Although the oil industry has contributed most to the economy of Nigeria, this has not been reflected in the livelihood of the oil host communities. It is reported that in Ogoni one of the territories of the study area, Shell had a total of five major oil fields, containing 96 oil wells capable of yielding 28,000 barrels of crude oil daily (FMIC, 1996). If we take a relatively conservative oil price of US$13 per barrel, Shell and the Nigerian government have lost US$133 million per year in oil revenues from the Ogoni area, and according to this conservative estimate, the JVs have lost about US$1.3 billion in oil revenues from Ogoni during the past decade of Shell's withdrawal from the Ogoni communities (Omeje, 2006).

2.4.2 The Pre-Oil Discovery Era: Aspects of Traditional Economy

The traditional economy of the study area may be discussed under two broad categories: the economy of the "landsmen" who occupy the drier land of the delta, and the simpler economy of the "watermen" who occupy further south (Udo, 1970). These are often referred to as the "upland" and the "rivering" areas. The landsmen consist of the Ogoni whose occupation traditionally includes farming, fishing, collecting and processing palm fruits and hunting. The watermen, on the other hand, include the Okrika, the Adonis, and the Bonny who are essentially fishermen and traders. The watermen depend on the landsmen for such essential food items as yams, grains, and fruits. In the past, they produced salt which they traded with the landsmen for food-crops. Yams and cassava are the main food-crops grown by the landsmen. Farming activities begin around mid—December when the floods are receding. Yams are the first crop to be planted. But later, maize, beans and groundnuts are inter-planted in the same fields. While yam is cultivated mainly by the menfolk, cassava and other crops are cultivated by the womenfolk. Another important occupation of the landsmen and one for which they are best known in areas where they temporarily migrate to settle the collecting of palm fruits which they process and sell (Udo, 1970).

2.4.3 The Post-Oil Discovery Era

Since the discovery of oil in 1956 to date, villagers in the study area still engage in different forms of agricultural practices. But this has reduced since the local economy of the communities began to be hugely driven by oil extraction due to oil spills. Farming systems are still basically the traditional subsistence crop. This is characterized by small-sized farm holdings of less than one hectare per household, with the cultivation of cassava, yam and maize oil palm trees, African pears, oranges, guava, mangoes and cassava as staple foods. The common farming system includes rotational bush fallow, tree crop production, and, wetland farming (Okoji, 2000). There are also a few large-scale and plantation farms, sponsored by the state governments and the oil companies. While the local economy has been positively affected by the oil industry, the impacts are believed to be in the interest of future generations.

2.4.4 Population and other Demographic Characteristics

In the 1991 census, the total population of all nine states of the Niger Delta was 20.5 million with 10.133 million males and 10.329 million females. The projected total population by 2015 is 39.2 million and rising to 45.7 million by 2020. River State is the most populous State in the region and contributes the highest oil generating revenue of the region. There is an increasing rural-urban migration, especially to the State Capital of Port-Harcourt and rural-rural inter-village migration in the study area. However the population increase in the villages is very insignificant compared to the State capital. The region is one of the poorest parts of the developing world and getting poorer. Over 70% is living at subsistence level in rural areas (NDDC, 2017). Per capita income is very low (66% of the population earn less than 10,000 Naira (approx.US$75) per month and 76.6% earn less than 20,000 Naira) (NDDC, 2017). Life expectancy in the region is low and set at 46.8 years. But this is lower in more remote wetland areas with limited access to health care with poor infrastructure (NDDC, 2017). As of 2006, access to health care was worse than that of any other region in Nigeria (Aigbokhan and Wohlmuth, 2008). Housing, too, continues to be of poor quality (UNDP, 2006). As of 2006, unemployment was extremely high in the Niger Delta and was higher than the rest of the country (UNDP, 2006, Aigbokhan and Wohlmuth, 2008). In terms of settlements and land use types, most of the settlements are small in size and dispersed, about 1, 000 persons per settlement. This is a situation explained by a number of factors (UNDP, 2006). The environment provides limited space for human settlement, given the fragmentation of land into islands and the occurrence of dry land in isolated pockets (UNDP, 2006). Fishing communities all over the world characteristically dwell in small fishing villages close to their fishing grounds. Each group is composed of numerous clans, cherishing its own private space as they attach importance to natural resources such as land and mangrove within their territory. As such, any trespasses by neighboring communities or external parties often trigger resistance.

2.5 Understanding Natural Resource-Based Conflicts in the Case Study: A Reflection on Historical Context

NRBCs in the Niger Delta are deeply rooted in the destabilization of the traditional institutions of the indigenous people (Idemudia, 2012, Okwechime, 2013). A more worrisome challenge is the failure of oil companies to address their corporate social and environmental responsibilities, with impacts on displacing people from their sources of livelihood with no sustainable alternative (Idemudia, 2012). Understanding the NRBCs will not only help to gain a better insight into the drivers but also into its dynamics as well as into how to begin to resolve or manage it. Idemudia (2012) draw upon the nested theory to explain the Niger Delta conflict as a system-wide structural conflict with manifestations at different levels. He identified three phases in the dynamics of the Niger Delta conflict:

Phase 1: Era of needs (the root of conflicts) (the 1950s—1980s)
Phase 2: Era of creed-grassroots mobilization (1980s/1990s—2000)
Phase 3: Era of grievance/greed and rise of insurgency (2000—20115/2016).

To the three phases of conflicts in the Niger Delta, one can add a fourth, which is the phase of local awareness of the reality of the impacts of environmental degradation and its socio-economic implications. Thus, Phase 4 is the Era of post-conflict and community awakened consciousness of the environment (post—2016). As noted by Idemudia (2012) the drivers/pressures responsible for the conflict are stand-alone variables but are linked to other structural, subsystem and systemic pressures. This is particularly important with regard to the Niger Delta conflicts. It is important to account for not only the recent socio-political and economic pressures that define the immediate issues of the present phase of the conflict, but also the different historical pressures that underlie every phase in the metamorphosis of the conflicts (Idemudia, 2012).

2.5.1The Typologies of Natural Resource-Based Conflicts on the Case Study

The NRBCs revolve within and between indigenous groups/communities, militias and military, government and oil companies amid environmental devastation from destructive oil extraction practices (Omofonmwan and Odia, 2009, Babatunde, 2010, Bagaji *et al.*, 2011, Babatunde, 2014, Obi, 2014a, Acey, 2016) Many types of NRBCs can be identified in the study area. These include:

- Intra-community conflicts over oil benefits or land issues, and boundary shifts,
- Oil allocation conflicts and compensation.
- Communities vs. MNOCs due to compensation packages and allocation of corporate social responsibility projects.
- Chieftaincy conflicts: A tussle that also links to natural resources; contests for the chieftaincy of communities that have oil on their land.
- Youth demonstrations and protests. Youth mobilizations to attract the interest of the oil companies and the international community.
- Land conflicts. For example, inter and intra-community conflicts related to land and territorial resources, e.g. claims of fishing sites, mangrove sites and oil field locations.
- Rebels and militancy organizations, e.g. Movement for the Emancipation of the Niger Delta (MEND), Niger Delta People's Volunteer Force (NDPVF), the Niger Delta Vigilante (NDV) etc.

These above-mentioned resource conflict types range from demonstrations to large-scale violence that claims several deaths. For analytical convenience and based on the typology of conflicts with existing observed conflict data, two main conflict typologies can be identified.
These include:

(a) Rebel-based conflicts (governmental conflicts).
(b) Territorial-based conflicts.
Rebel-based conflicts are organized conflicts against government forces and the MNOCs. These are also referred to as governmental conflicts by the Uppsala Conflict Data Programme (UCDP) (Figure 2.9). On the other hand, the territorial-based NRBCs are also referred to as the civilian-based conflicts by the Armed Conflict Location Event Data (ACLED) (see Section 6.4 for details on description). Figures 2.9 and 2.10 show the dynamics of the conflicts and the map of the distribution of all conflicts respectively. As seen in Figure 2.9, there is a reduction in conflicts in 2010. This is due to the introduction of the Presidential Amnesty Programme (PAP) where all youths with arms are forgiven and rehabilitated. However this approach is believed to be unsustainable (Agbiboa, 2013, Ushie, 2013, Obi, 2014b, Oyefusi, 2014).

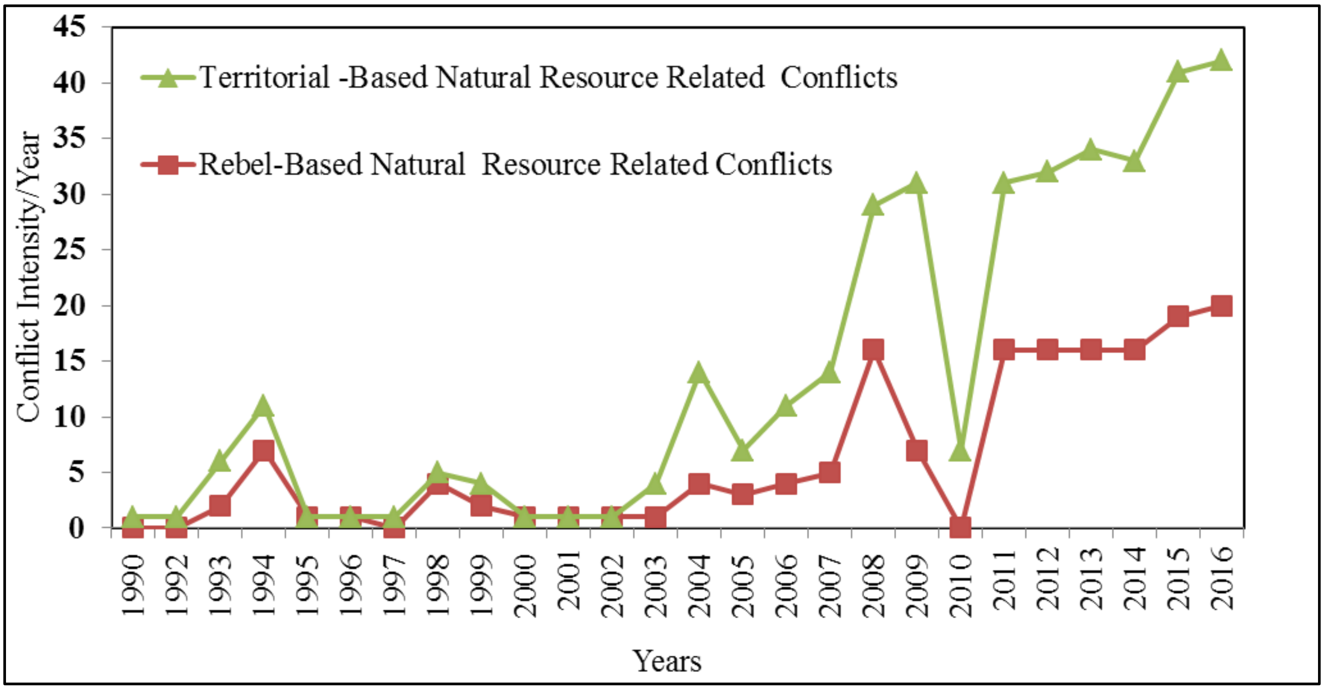


Figure 2.9: Dynamics of natural resource-based conflicts in the study area.
Source: Fieldwork, 2015, ACLED and UCDP

For example, Ikelegbe and Umukoro (2016) concluded that the commitment of the government into securing amnesty is not based on best practices. Also that it does not integrate the people, harness synergies and effectively address challenges of post-conflict development and peacebuilding. As a result, this does not satisfy the hopes, expectations, and aspirations of all stakeholders and citizens.

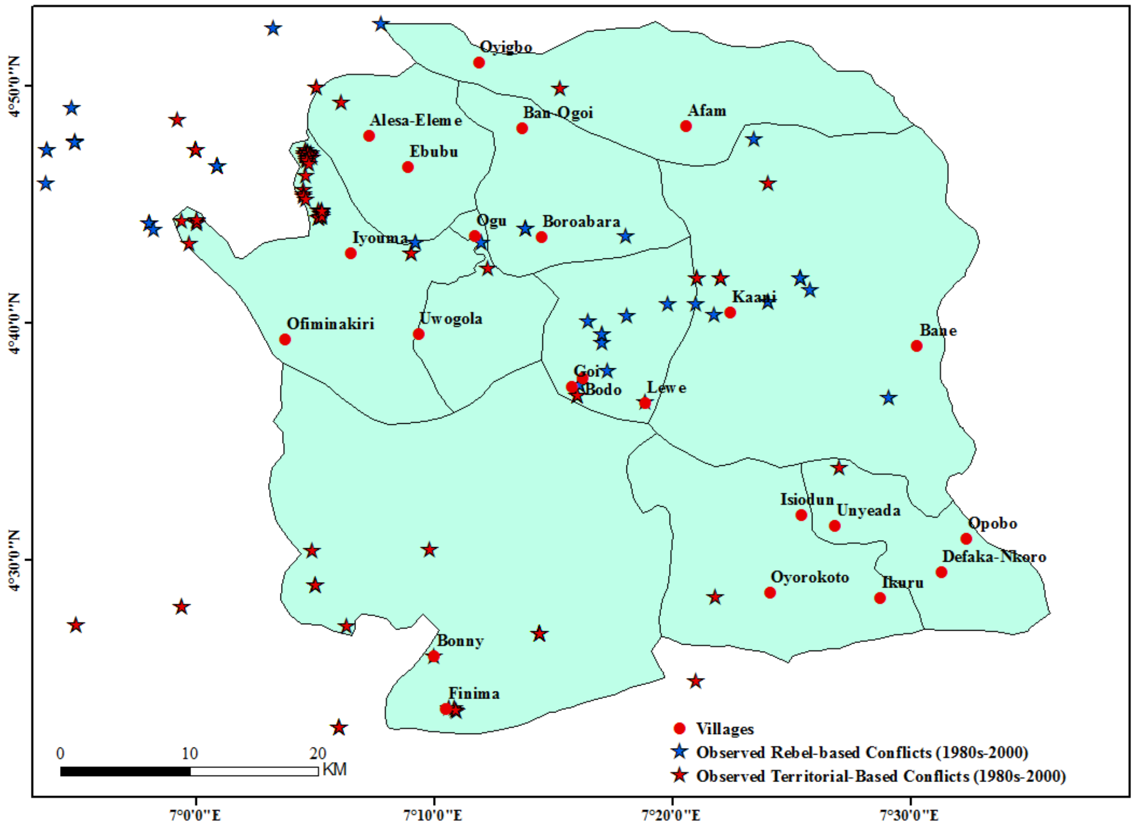


Figure 2.10: Natural resource-based conflicts in the case study (1980s-2016)
Source: UCDP GED and ACLED.

2.5.2 Some Cases of Natural Resource-Based Conflicts in the Study Area

A number of conflict cases have been documented in the case study (Okwechime, 2013) (see Appendix A.12.1 for cases of conflicts with dates). Some of the examples are presented as follows:

Ogoni vs Shell Company Conflicts

The Ogoni vs. Shell crisis is a well-known environmental campaign in the Niger Delta region. It is a case of local community versus the most powerful and highly influential oil company in the Niger Delta. Shell alone has an estimated production of 150,000 barrels of crude oil per day in Ogoni land. Thus Ogoni is said to have yielded over nine hundred million barrels of crude oil to Shell in thirty-five years (Yornawue, 2000). It is reported that since 1958 when petroleum was first discovered in Ogoni by Shell, "an estimated US hundred billion dollars' worth of oil and gas has been carted away from Ogoni land" (Okwechime, 2013). The conflicts were initially marked by petitions and complaints of oil pollution to the Federal Ministry of Mines and Power (as it was then known) in Lagos and State Ministries in Rivers State. Thus the first crises at Kegberekere in Ogoni in 1962 was localized; and only six community members were rounded up and jailed for six months for organizing a riot against Shell (Mitee, 1997). But it progressed over time to violent demonstrations and destruction of properties leading to the killing of youth protesters and activists such as Ken Saro-wiwa by the military.

Ogoni Banana Plantation Conflicts: Ogoni people vs. State Government and a Mexican company.

This was a case of land grabbing by the government for commercial agriculture. The government's argument for grabbing land for commercial agriculture instead of supporting subsistence farming (which provides food and direct income to people), was that they want to create jobs and generate revenue. But this had hardly resulted as conceived. The Land Use Act of 1979 grants power to the government to take any land for "overriding public interest". As a result, lands are often taken by governments but only to be abandoned by their successors. Thus a crisis started on the 15th day of May 2011. On that Sunday when members of Sogho, an Ogoni community in Khana Local Government Area (Ogoni land) were resting, attending church services and to family matters, the traditional ruler of the community received a letter from the Government of Rivers State of Nigeria through its Ministry of Agriculture. The letter stated that the government had acquired their farmlands for the development of a banana plantation to be operated by a Mexican company. Without any prior consultation with farmers and other community members, by the next morning, in less than 24 hours, workers and government representatives were already on site to begin work. The traditional ruler and a few individuals sent a response to the government refusing the request. At the same time, the government sent the military to surround the territory where the land was located. This led to a protest that led to widespread killings and destruction of properties.

Goi vs Shell Conflicts

In October 2004, a major oil spill occurred in the Trans-Niger pipeline, which runs through the Ogoni land to the Bonny Export Terminal. Following the oil spill, a fire broke out. The flow of the oil spills and the fire reached the mangrove forest in the tidal region of the village of Goi. For three days Shell unsuccessfully attempted to extinguish the fire. After four days the disastrous aftermath could be seen. About 15 hectares of mangrove forest were devastated, 20 canoes destroyed, all fishes killed, and hundreds of trees with high economic value (palm trees, mango trees, coconut palm, avocado and more) had gone up in flames. This sparked off protests of the villagers leading to the destruction of properties and infrastructure of the oil companies.

Batter vs Kedere Land conflicts:

This conflict started at a football viewing center by youths. On the 4th October 2010, youths were watching Premier League in one of the local viewing centers. There was an argument between youths from different communities. The argument was heated up that it led to an exchange of words that one community where one of the youths came from had taken a land with oil deposits from the other community. This led to violence that eventually led to the loss of lives. It was obvious that the remote cause of the conflict was related to land not the disagreement between two fans of two opposing Premier League clubs. It is worthy of note that several resource-related conflicts are hidden until it results in violence.

2.5.3 Drivers and Impacts of Natural Resource-Based Conflicts on the Case Study

The drivers of NRBCs in the Niger Delta have been addressed by many authors (Agim, 1997, Boele *et al.*, 2001, Idemudia and Ite, 2006, Obi, 2008, Omofonmwan and Odia, 2009, Obi and Rustad, 2011, Nwankwo, 2015, Gonzalez and Derudder, 2016, Nyiayaana, 2016). . These studies have concluded that the Niger Delta conflicts have complex drivers. However, what is not clear is the root and proximate drivers of conflicts in the region as derived from the local actors. For example, Obi and Rustad (2011) identify five interrelated aspects of NRBCs that feature prominently in much of the relevant literature. These are: (1) the struggle for resource control and ownership by the oil-bearing communities, and its increasingly militant and violent nature; (2) severe environmental degradation; (3) the abject lack of political participation and democratic accountability, (4) infrastructural underdevelopment, and (5) deep and widespread poverty, especially youth unemployment. These drivers of conflicts are therefore varied and diverse, ranging from environmental degradation, socio-economic, political/institutional and legal related issues (Idemudia and Ite, 2006).

Suffice it to say that more than 90% of the conflicts in the Niger Delta region are linked to resources in one way or the other. Even political conflicts such as election violence have a strong bearing on resources because of the revenues generated from oil. Nyiayaana (2016) reported that communities with oil deposits are more prone to leadership crises than others. This is not only as a result of revenue from oil but also over scarce landed resources for cultivation. When renewable resources such as water, forests or productive lands are degraded, contaminated or overexploited, the resulting competition between users becomes a basis for tension and conflicts. Grievances over renewable natural resources can contribute to instability and violent conflicts when they overlap with other factors such as ethnic polarization, high levels of inequality, injustice and poor governance (UNDG, 2013). In other words, competition over renewable resources tends to drive, reinforce or further compound security, economic, and political stresses which lead to violent conflicts.

The land is not only a vital economic asset and a key source of livelihoods in the Niger Delta; it is also a function of community identity, history, and culture. Community members can easily mobilize against trespasses on their land by MNOCs or other communities. Conflicts, therefore, result when competition for resources are combined with wider processes of political exclusion, social discrimination, economic marginalization, and the perception that peaceful action is no longer a viable strategy for change (UNDG, 2013). It can thus be concluded that conflicts in the Niger Delta are located between environmental degradation, the struggle of ethnic minority groups for local autonomy and the control of their natural resources (including oil), and the contradictions spawned by the MNOCs (Obi, 2008).

2.5.4 Development Policies and Research-Based Conflict Management Strategies in the Niger Delta

Given the precarious problems of environmental degradation, unemployment and resource conflicts, various development policies have been made. Also number international organizations have shown interest in the Niger Delta. For example there are specific recommendations and strategies from communiqués of international aid organizations e.g. DFID, UNDP, and World Bank. Locally, various development interventions and institutions have been set up to address the problems of the Niger Delta since the 1990s, among which include:

- Niger Delta Development Board(NDDB)
- Niger Delta Basin Development Authority (NDBDA)
- Oil Pollution Act of 1990
- The Environmental Impact Assessment Act (Decree No. 86 of 1992
- National Oil Spill Detection and Response Agency for National Oil Spill Contingency Plan(NOSCP)
- Niger Delta Environmental Survey (NDES)
- National Policy on Poverty Eradication Programme (NPPEP).
- Oil, Mineral Producing Areas Development Commission (OMPADEC)

- Niger Delta Development Commission (NDDC)
- Ministry of Niger Delta Affairs (MNDA) and launching of the Technical Committee of the Niger Delta (TCND).
- Niger Delta Regional Development Master Plan (NDRDMP)
- Presidential Amnesty Programme (PAP)

However, these above-mentioned efforts have not improved the region. As earlier stated (see Section 2.5.1), interventions such as Presidential Amnesty Programme (PAP) and other related development policies do not reflect the management needs of the people and thus failed to address the complex issues underlying the conflicts (Osaghae *et al.*, 2007, Ikelegbe and Umukoro, 2016). The reactive solutions are hugely challenged by the complexities of the problem of NRBCs with myriad factors that are difficult to pin down. For any initiatives to succeed it must be integrated into comprehensive policies that speak to those underlying drivers (Mähler, 2012, NDDC, 2017). Researchers and scholars have also responded to the need to develop management strategies that address the problems of the Niger Delta. Appendix A.14.2 shows a summary of some of the publications on conflicts Niger Delta since 2000 to date. From the various literature, the trend of the emerging approaches could be characterized thus:

- There is a shift from the competition of stakeholders to collaboration for sustainable peace, and a dominance of resource curse and political ecology approaches.
- There is a dominance of theoretical analysis which is devoid of real world analysis or researches that inform policy and future planning
- There is an absence of researches that address the territorial aspect of the conflicts such as those relating to land use conflicts, conflicts over farmlands, fishing locations or mangrove sites.
- There is a recent proposal for the use of sustainable approaches and collaborative frameworks, with a recommendation for a new approach arising in the light of contemporary issues from a broad and interdisciplinary perspective.

Importantly, most of the papers reported are theory-based research. They though prepare the ground for an applied research; the problem with those studies is that they give limited room for outputs that inform conflict management strategies. For instance, the resource curse theories and political ecology approach were recently used to provide the context for the many conflicting values and perspectives on the crisis in the Niger Delta (Acey, 2016). The methodology in most of those studies is limited to qualitative methods (Ikelegbe and Umukoro, 2016). An integrated bottom-up participatory process that addresses the quality of life of the communities vulnerable to issues of NRBCs, their health, and their environment is undoubtedly the pathway to peace in the Niger Delta. Such an approach to studying NRBCs particularly in the fourth phase of the research programme on NRBCs should draw from international literature on vulnerability and risk perception. But this approach would require a reconceptualization as a starting point (Brauch, 2010, Spring and Brauch, 2011).

3 Reconceptualizing Natural Resource-Based Conflicts (NRBCs)

This section presents a reconceptualization of the Natural Resource-Based Conflicts (NRBCs): The section begins by presenting the clarifying of vulnerability and other related concepts and how they are applied in this thesis. Next, the bridging of the gap between Holistic Vulnerability Assessment (HVA) and NRBCs is presented. Lastly, the section presents how vulnerability assessment of NRBCs is integrated into the fuzzy logic theory and this is implemented with the adapted fuzzy logic modeling (see Section 5). The main argument of this section is that the complex characteristics of the vulnerability of communities to NRBCs require the use of a non-linear theoretical model that is adaptable and capable of addressing complexity, multi-dimensionality, and uncertainty which are the hallmarks of vulnerability assessment in the context of NRBCs.

3.1 The Need for Reconceptualizing Natural Resource-Based Conflicts (NRBCs)

It is considered in this thesis that a transdisciplinary approach is neither a method nor a theory (Mauser *et al.*, 2013) (see Section 1.3). Therefore its use for vulnerability assessment in the context of Natural Resource-Based Conflicts (NRBCs) requires a theoretical construction in view of implementation for sustainable peace. Studies have shown that the field of peace studies and environmental studies which developed into sustainable peace have been treated as separate fields until recently (Stephenson, 2016). This contributed to why it took a long time before researchers began to link NRBCs to "sustainable peace". Even though this is beginning to gain prominence in scientific and political contexts, the definition of sustainable peace still gives room for a construction of the concept based on the context of use (Brauch, 2003a, Dean et al., 2008, Stephenson, 2016).

There are therefore a number of reasons why the NRBCs should be reconceptualized for sustainable peace (Brauch, 2009). Firstly, a reconceptualization of NRBCs is provided for by the recent global change studies in the context of the environment, security and peace (Brauch, 2009, Fisher and Rucki, 2017). Secondly, it is supported by the fundamental changes in studying resource conflicts in the social sciences which have moved from positivism to constructivism approaches. The latter requires that knowledge should be socially constructed. Thirdly, as argued by Dean *et al.* (2008) and Brauch *et al.* (2011), in the era of Anthropocene, the NRBCs studies have changed the nature of the threat from "them" to "us", where humankind is now identified as both a driver and the solution. Therefore the existing studies on NRBCs at a Large-N scale needs to be reconceptualized to address the fourth phase of NRBCs at the local level where actual resource conflicts occur.

The reconceptualization of NRBCs draws on the concept of a holistic vulnerability assessment (HVA), also known as the "Vulnerability Cube", i.e. space, the time and the dimensions of vulnerability assessment in the context of NRBC. In this context, NRBCs are viewed as complex problems in terms of measurement as they possess the characteristics of a "wicked" problem, a concept originally initiated by the seminal work of Rittel and Webber (1973). The "wicked" problem concept is useful for addressing NRBCs as an ill-defined and constantly changing socio-environmental problem of humanity (Head and Xiang, 2016) (see Section 4 for the framing of NRBCs as a "wicked" problem). Head and Xiang's study revealed the two main challenges encountered in addressing "wicked" problems are: (1) cognitive challenge (understanding the problem), and (2) practical challenge (policy and planning side). Given these challenges of a "wicked" problem, therefore, researchers need to first understand the problem by reconceptualizing it before solving it. One way of doing this is by clarifying the concepts that will support the basis for this reconceptualization. In the case of NRBCs, vulnerability and other related concepts are found very useful. These concepts have been successfully used in investigating other anthropogenic problems that affect communities and those that involve socio-environmental systems (Cardona, 2004, Eakin and Luers, 2006, Yan and Xu, 2010, Sterzel *et al.*, 2014).

The next section presents vulnerability and other related concepts and how they are applied in reconceptualizing NRBCs as a complex and "wicked" problem (Berkes and Folke, 1998, Adger, 2006).

3.1.1 Clarifying the Concepts of Risk and Vulnerability Assessments in the Context of Natural Resource-Based Conflicts

The concepts of risk, vulnerability, vulnerability assessment, and resilience are seen as a continuum. Thus the aim of the clarification of these concepts is to establish how they are applied at different points in the assessment of NRBCs.

Risk: Wherever risk is discussed in disciplinary literature. There seems to be a consensus that risk consists of the probability of an adverse event and the magnitude of its consequences (Rayner and Cantor, 1987). According to Rayner and Cantor, there are however shortcomings of in the use of the concept of risk because of much focus on natural hazards. These shortcomings have led to the use of vulnerability (Blaikie *et al.*, 1994, Birkmann and Wisner, 2006, Blaikie *et al.*, 2014).

Vulnerability: The definition of vulnerability derives from a complex environmental, social and political conditions that surround the occurrence of risk (Blaikie et al., 1994, Blaikie et al., 2014). There are various definitions as well as a lack of common measurement methodologies of vulnerability (Birkmann and Wisner, 2006). Eakin and Luers (2006), defines vulnerability as being characterized by a function of both a system's exposure and sensitivity to stress and its capacity to absorb or cope with the effects of these stresses. Bohle (2001) gave a similar but a simplistic and more holistic definition of vulnerability from which many further studies derive their definitions from. Bohle defined vulnerability as having the "external" side and the "internal" side (see Figure 3.13). The "external" side of vulnerability focuses on exposure. For example, in the context of NRBCs, this implies an exposure of a community or any region to the problems of environmental changes and the shortage of vital resources. This then triggers the need for resistance against the intruders responsible. The "internal" side of vulnerability is the ability to overcome or at least mitigate the negative effects of the ecological changes with socio-economic and political capabilities of the community or region concerned.

Resilience: Resilience in the literature is considered as a flip side of vulnerability. This implies that resilience provides insights on what could make a system less vulnerable (Gallopín, 2006, Berkes, 2007, Renaud et al., 2010). Resilience deals with the capacity for a system to adapt after undergoing stress and perturbation and the building of resilience focuses on the vulnerable places and people. However, the resilience concept is not as simplistic as occasionally perceived. Resilience is a Complex Adaptive System (CAS) (Folke *et al.*, 2003, Folke *et al.*, 2010). This relates to the adaptive renewal cycle as proposed by Holling (1986) and the more recent concept of panarchy (Gunderson and Holling, 2002). Brand and Jax (2007) discussed resilience as a boundary object by linking CAS as a heuristic conceptual model, particularly in relation to the panarchy of cross-scale dynamics and the interplay between a set of nested adaptive cycles (see Figure 3.1). Therefore, resilience as a CAS or an adaptive cycle can be both an analytical tool and as a heuristic conceptual model that is applicable to problems involving dynamic socio-ecological systems (Folke, 2006). Since the problem of NRBCs cuts across environmental, socio-economic and political components, it is both an SES and a CAS where resilience building concept is applicable. Where there are vulnerable and resilient communities to NRBCs, the goal of sustainable peace is to enhance the resilience in the vulnerable groups. This process requires coupling the different components of vulnerability and the connections among the system elements, which can be enabled with an algorithm to produce for example an index of resilience or an index vulnerability ((Bennett and McGinnis, 2008), see Section 5).

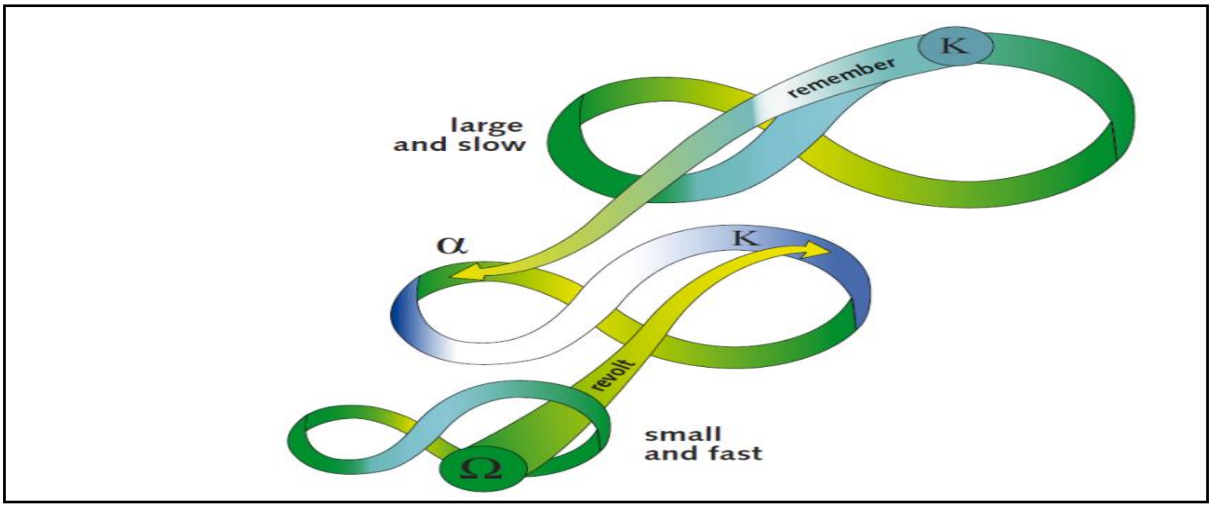


Figure 3.1: Panarchy, a heuristic model of nested adaptive renewal cycles emphasizing cross-scale interplay, according to Folke (2006) with modification from Gunderson and Holling (2002).

Risk perception and Conflict Vulnerability Likeliness (CVL): Risk perception is necessary for this thesis as a response to the complexity of NRBCs (see Section 3.2.1 for more explanations on the perceptions of risk and vulnerability by the actors in the context of NRBCs). Since NRBCs are dynamic and complex, the expression of the vulnerable groups represented by the actors is critical to addressing the vulnerability of people and places. However, the experiential knowledge of the vulnerable group is not easily derived or measured without intensive community engagement (Bollin *et al.*, 2006, Badera and Kocoń, 2014, Berkes and Ross, 2013) (see joint problem framing of NRBCs in Section 4). Risk perception as a concept in social psychology is defined based on the assumption that those who manage the riskiness of events should understand the ways in which people think about and respond to risks (Slovic, 1987). Under risk perception, "riskiness" means more to people than "expected number of fatalities". Therefore risk perception is a subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences (Sjöberg *et al.*, 2004). In this vein,, a common challenge of the immeasurability of vulnerability can be addressed by risk perception where the subjective assessment can be determined by the residents of the vulnerable areas (Bronfman and Cifuentes, 2003, Cutter, 2003, Burgess, 2015).

As stated in Section 1.2.2, when the risk of conflict is perceived by the vulnerable groups, the outcome shifts from a binary logic to a fuzzy logic. This leads to CVL Index. CVL Index thus assumes that vulnerability is a fuzzy logic as opposed to a binary logic where the output CVL Index is developed based on the available knowledge of the perceiver and the way the perceived vulnerability to NRBCs by the actors can be integrated (Buckle *et al.*, 2000) in space, time and dimensions.

3.1.2 Vulnerability Assessment and The "Vulnerability Cube": The Spatial, Temporal, and Dimensions of Vulnerability

While vulnerability is a state as described earlier in Section 3.1.1, vulnerability assessment is a process that has been used in development studies e.g. in the context of natural hazards, climate change or socio-ecological systems. Vulnerability assessment has been used as a vulnerability of socio-ecological systems (VSES) (Turner *et al.*, 2003, Yan and Xu, 2010), or as a Holistic Perspective on Vulnerability (HPV) (Birkmann and Fernando, 2008, Cardona *et al.*, 2012). Several similar approaches have been conceptualized in disciplinary literature such as risk-hazard approach (RHA) (Turner *et al.*, 2003), risk-society (Beck, 2004), pressure and release approach (PRA) (Blaikie *et al.*, 1994), sustainable livelihood (SLA) (Alwang et al., 2001) and Neo-ecological or new ecological approach (Zimmerer, 1994, Zimmerer, 2000). However, recently, the vulnerability assessment approach to anthropogenic problems is conceptualized as a "Vulnerability Cube" (Kienberger *et al.*, 2013, Birkmann *et al.*, 2013). See Figure 1. 2 for "Vulnerability cube".

A review of vulnerability assessment shows that NRBCs should be constructed according to the views of the vulnerable group (Eakin and Luers, 2006). Eakin and Luers pointed out that vulnerability assessment is a relative concept with cultural, political-economic, and spatial characteristics that are essential to its evaluation. According to these authors, there is no single recipe that appears more successful—or perhaps most relevant—when vulnerability assessment is carried out on human-environment systems and on particular places, and with particular stakeholders in mind. Rather, vulnerability assessment is likely to come from the recognition that the research process itself involves the integration of paradigms and worldviews. In this thesis, therefore, based on the submission by Eakin and Luers (2006), vulnerability assessment is conceptualized beyond its conventional use, rather it is viewed as an expression of communities that are exposed to environmental degradation (the external) side of NRBCs and the impacts on socio-economic and political capabilities (the internal) side of the exposed group. Vulnerability assessment is further recognized as being 'immeasurable', but not as a result of impossibility in measurement but in terms of complexity(Bell and Morse, 2008). NRBCs shares the same characteristics (Homer-Dixon, 1996, Schwartz *et al.*, 2000) with vulnerability assessment as described in Birkmann and Wisner (2006) and Warner (2007). These characteristics include complexities, multidimensionality and lack of thresholds and uncertainty. See Section 3.3.3 for the explanation of the characteristics of vulnerability assessment as they relate to that of the NRBCs and how they fit into the use of adapted fuzzy logic models.

Importantly, the state-of-the-art of vulnerability assessment shows that the scope of vulnerability assessment has widened from the intrinsic level to multidimensional vulnerability (Figure 3.2) making it a more complex concept. Similarly, there are expanded key dimensions of vulnerability assessment that now requires a holistic measurement approach (Birkmann *et al.*, 2013). Such key components are applicable to the NRBCs (see Figure 3.3). The key thematic components of vulnerability assessment are given as follows:

- Environmental dimension: Damage to all ecological systems and their different functions. For example, environmental change can occur due to resource extraction, oil spills, and population increase. These may affect the ecosystem functions and environmental services.
- Social dimension: Impacts on social and human well-being may be affected by the disruptions to the individuals (their mental and physical health).
- Economic dimension: Loss of economic value due to damage to physical assets and/or disruption of productive capacity.
- Physical dimension: There is also the potential for damage to physical assets, including built-up areas, infrastructure, and open spaces as a result of resource extractive activities.
- Cultural dimension: Impacts and damage to intangible values, including meanings placed on artifacts, customs, habitual practices, and natural or urban landscapes.
- Institutional vulnerability. Impacts on governance systems, organizational forms, and functions as well as guiding formal/legal and informal/customary rules.

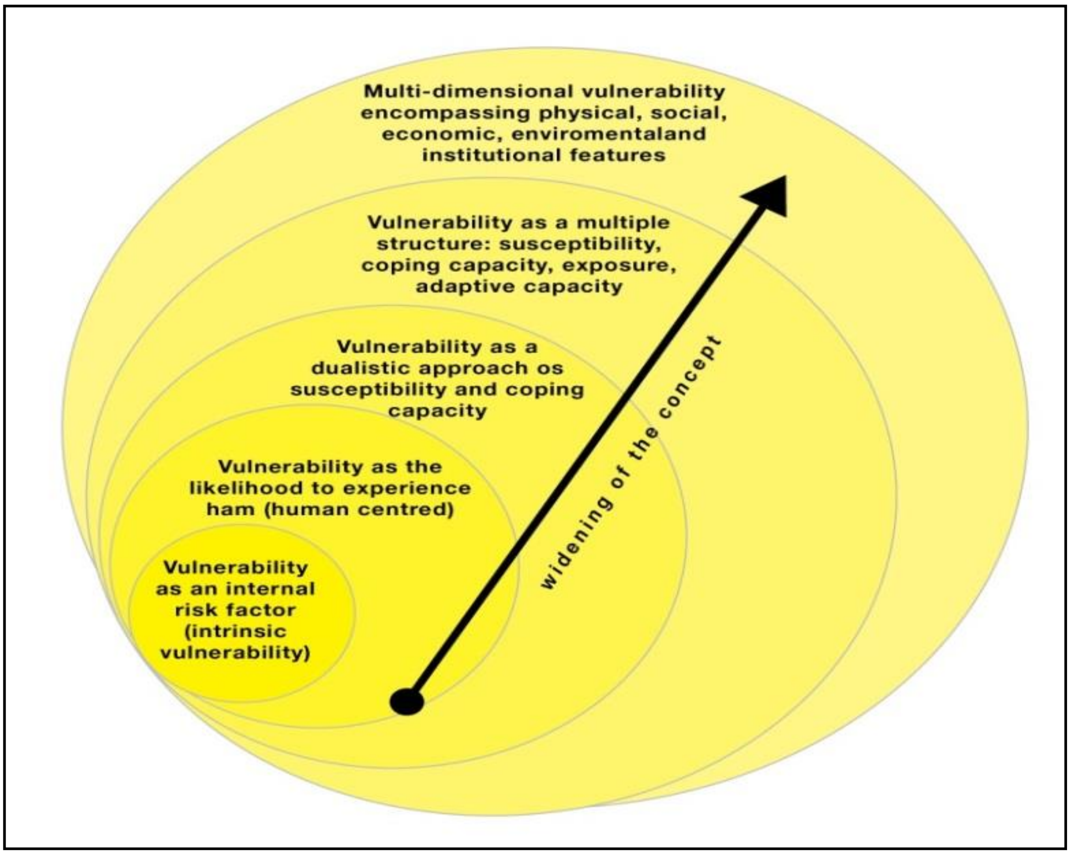


Figure 3.2: Widening the scope of vulnerability adapted from Birkmann and Wisner (2006).

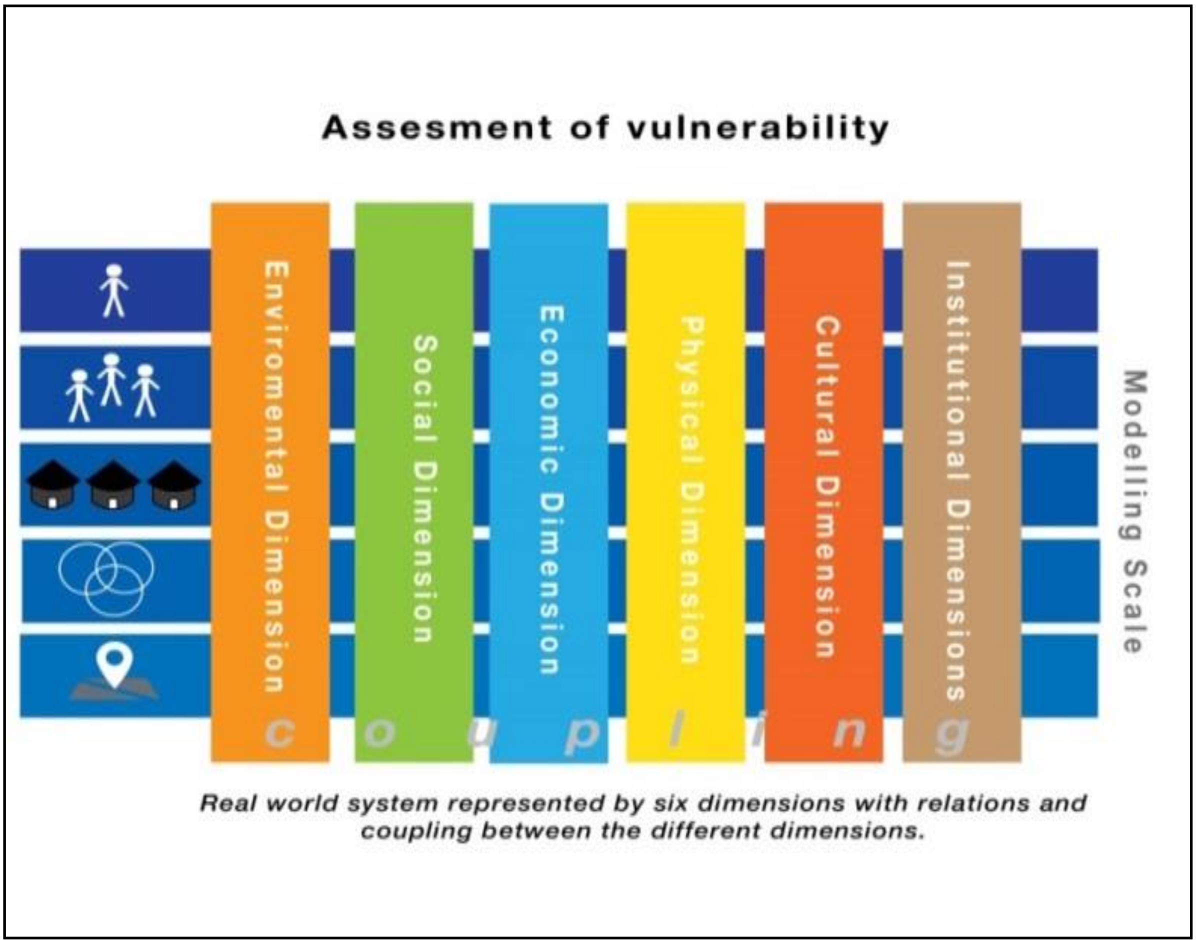


Figure 3.3: From the intrinsic scale towards the modeling scale: the integration of different dimensions of vulnerability and representative indicators, according to Kienberger et al. (2013).

As mentioned earlier, as a result of the different dimensions of “Vulnerability Cube”, the concept requires a holistic assessment comprising the components, the linkages, and as well as the coupled systems (Turner *et al.*, 2003), Figure 3.4 shows the basic architecture of the components and the linkages that comprise a coupled system of vulnerability. As seen in Figure 3.4, the spatial scale comprises of “the place” shown in (blue), “the region” shown in (yellow) and “the globe” shown (green). The various components are elaborated in Figure 3.5. As seen in Figure 3.5, there is an interactive and scale-dependent relationship which will be affected by the way in which the system can be understood when coupled in a study.

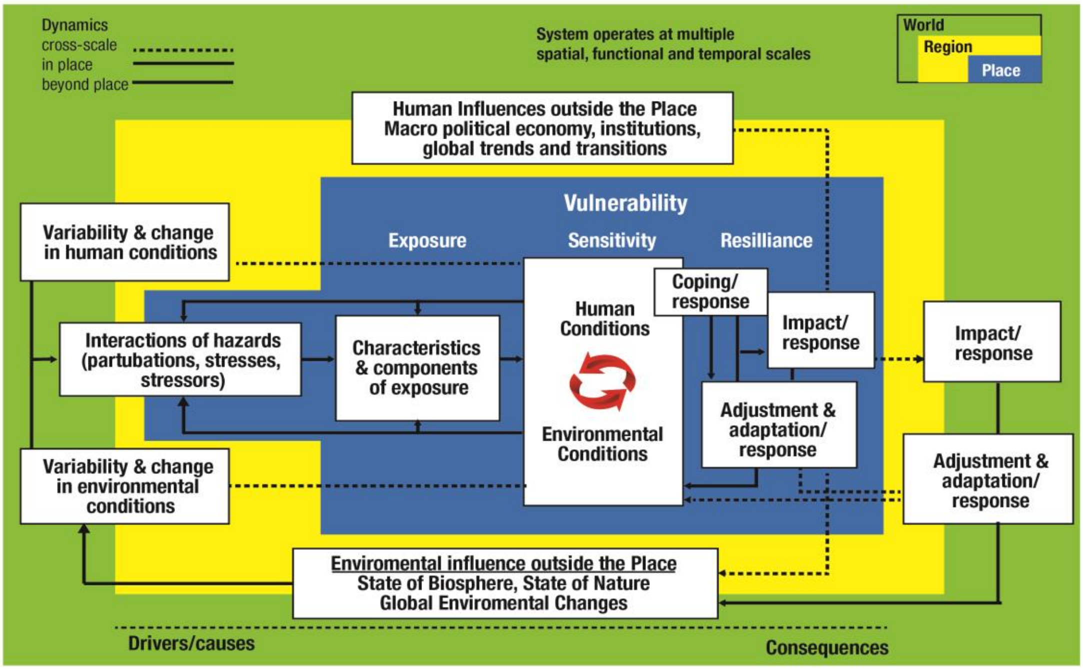


Figure 3.4: Dimensions/components of vulnerability identified and linked to factors beyond the system of study and operating at various scales according to Turner *et al.* (2003).

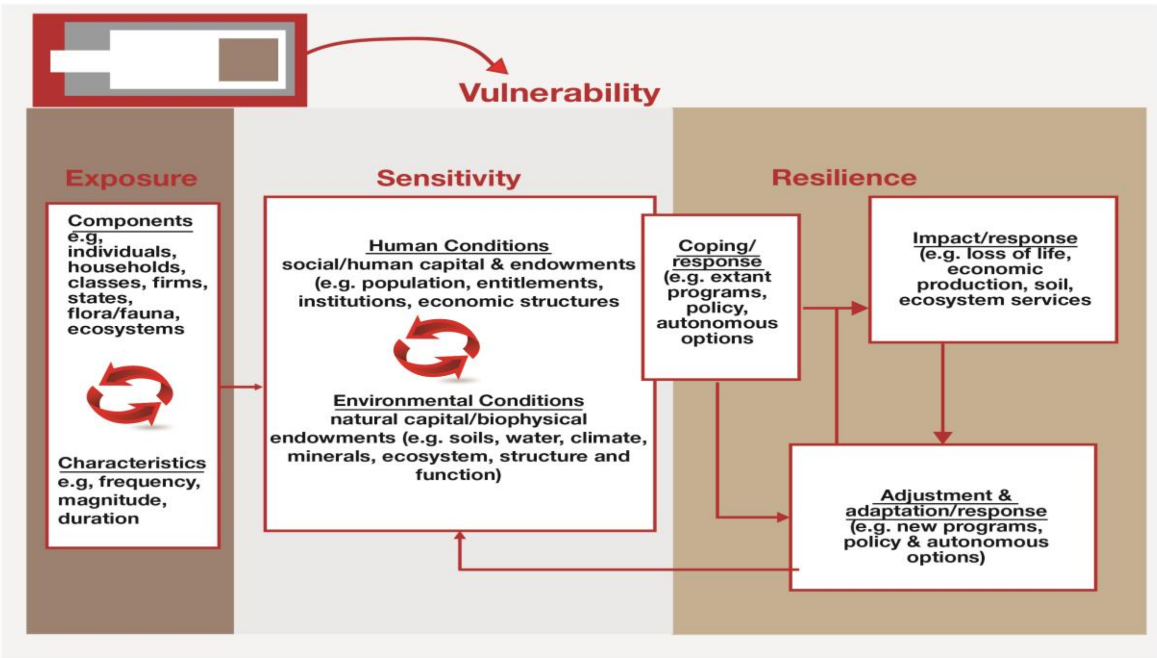


Figure 3.5: Details of the exposure, sensitivity, and resilience components of the holistic vulnerability assessment, according to Turner *et al.* (2003).

For detailed elements of the HVA, see Turner *et al.* (2003). Turner *et al* showed that analysts on HVA must remain aware that vulnerability rests on a multifaceted coupled system operating at different spatiotemporal scales and commonly involving non-linear processes. There are recent studies on social vulnerability by social scientists. For example, the development of a Socio Vulnerability Index (SoVI) (Cutter, 2003) and others. But such studies do not consider the transdisciplinary depth of vulnerability by holistically looking at the spatiotemporal, ecological, socio-economic and political dimensions (Birkmann and Fernando, 2008, Berkes and Ross, 2013). The proposal of "Vulnerability Cube" shows a range of application in different problem domains ranging from the global to the community scale (see Figure 1.2 and Kienberger *et al.* (2013)). According to Kienberger *et al,* since vulnerability is human-centered, the "human system" to be addressed need to be defined on how the different scales can be integrated with policy centered aggregation (Figure 3.6). See Figure 3.7 on how the decomposition of vulnerability units leads towards a policy-relevant scale.

As shown in Section 3.1 therefore, the challenge remains on how to approach the problem of NRBCs as a vulnerability problem with spatial, temporal and multiple dimensional characteristics.

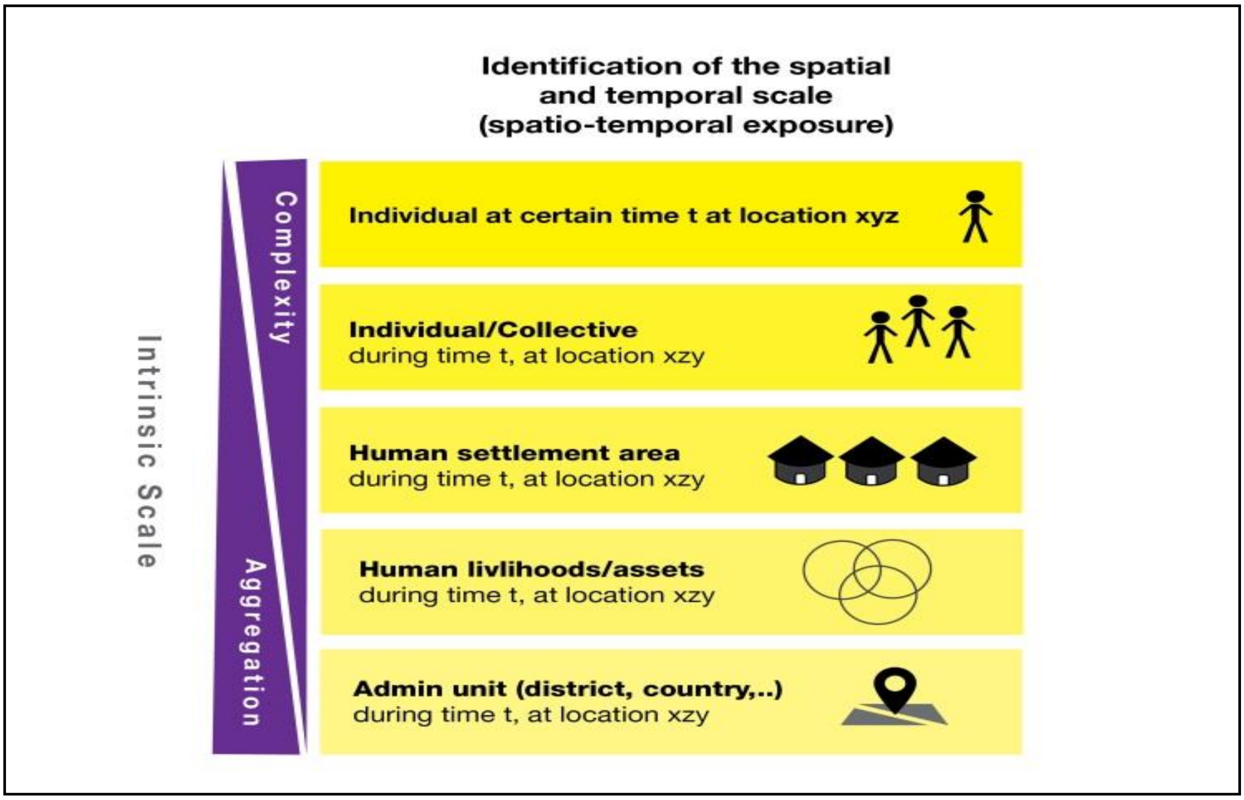


Figure 3.6: The integration of the intrinsic scales towards spatiotemporal conceptualizations of our real-world environment according to Kienberger et al. (2013).

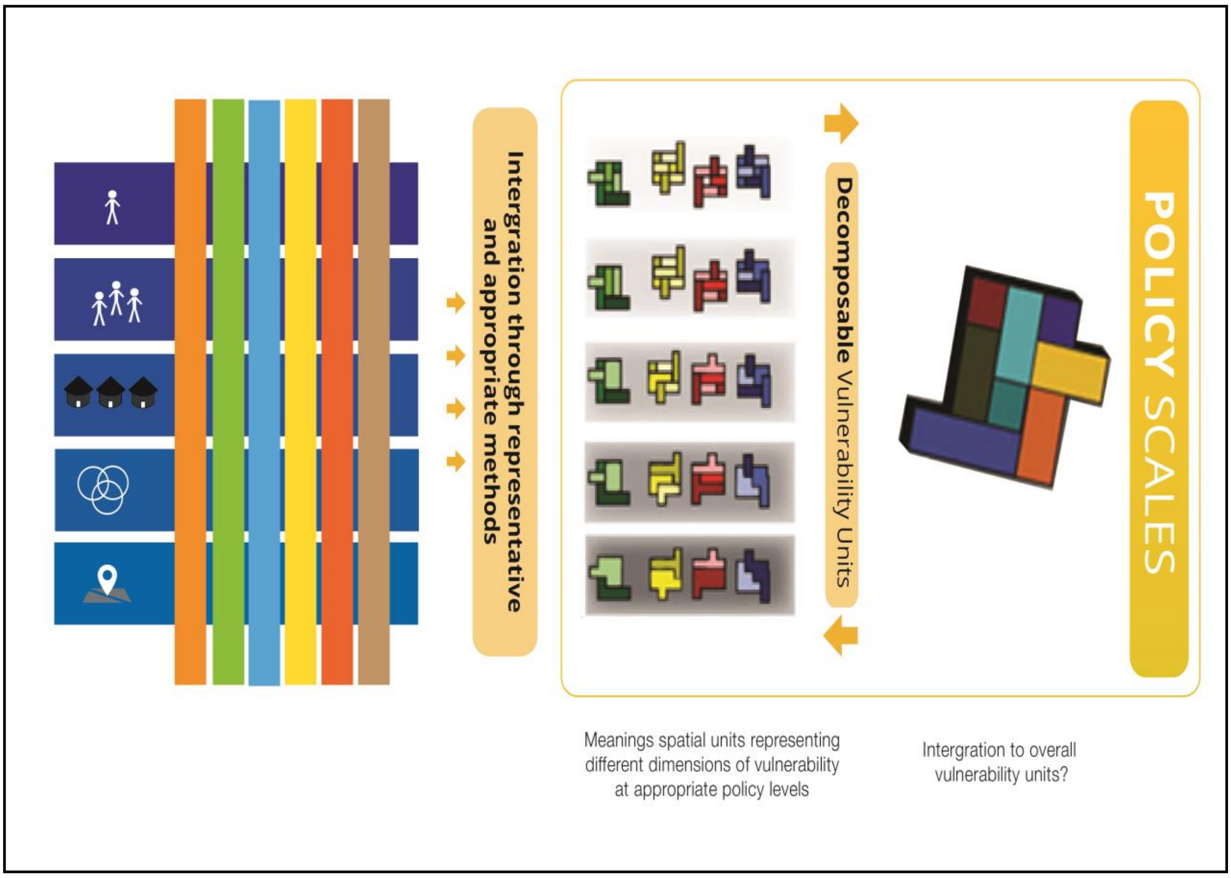


Figure 3.7: Towards policy-relevant provision of information products (e.g. spatial modeling of vulnerability to NRBCs) adapted from Kienberger et al. (2013).

3.2: Bridging the Gap: Vulnerability Assessment in the Context of NRBCs using a Transdisciplinary-based Coupled Approach

This application of the above-clarified concepts for the reconceptualization of NRBCs (see Section 3.1) is presented as recommended in the fourth phase research on NRBCs (Brauch, 2003a, Spring *et al.*, 2009, Brauch, 2016b). The analysis by Brauch (2003a) argues for a transdisciplinary focus in the study of NRBCs where three critical topics can be identified:

- The actors' perception of NRBCs under a transdisciplinary approach (see Section 3.2.1 for details). This approach helps to integrate the actors' knowledge into a spatial disaggregation of NRBCs. This is in support of the argument that the sustainable management of NRBCs requires exploring new options and strategies (Obi and Rustad, 2011, Rustad et al., 2011, Rustad and Binningsbø, 2012).
- The spatial disaggregation and mapping of NRBCs (see Section 3.2.2). A spatially explicit disaggregation of NRBCs is an innovative way of testing new hypotheses on the influence of both the "external" and "internal" sides of vulnerability components (Bohle, 2001, Buhaug *et al.*, 2008, Korf, 2011, Rustad *et al.*, 2011). Such investigations were not feasible at the Large-N scale of investigating NRBCs (Buhaug and Lujala, 2005, Buhaug *et al.*, 2009, Korf, 2011).
- The scenario typology and their applications for the management of NRBCs. There is a recent effort in applying scenarios for management of NRBCs (Carius and Maas, 2012). Developing scenarios for future conflict management will require the use of the findings from the previous Large-N and the community-based studies (see Section 1 for state-of-the-art on the NRBCs). Section 3.2.3 presents a detailed discussion on the types of

scenarios and the applications, while Section 7 (outlook and discussion) presents the proposed scenarios for co-creating future conflict management strategies.

3.2.1 Actors' Amplification or Attenuation of Natural Resource-Based Conflicts

Risk perceptive models assume that objective measurements of NRBCs do not exist but they are constructed (Raaijmakers *et al.*, 2008) (see Section 3.1.1 for the definition of risk perception). Risk perception of NRBCs entails social and cultural construct that reflect values, symbols, history, and ideology, and experience of one's environment (Sjöberg *et al.*, 2004). It is carried out by comprehensively integrating the technical and laypersons' response structures (Kasperson *et al.*, 1988, Renn, 1992). In addition, risk perception shapes the public experience, such that events perceived by the actors interact with psychological and cultural processes in ways that can heighten or attenuate public perceptions of NRBCs (Slovic, 1987).

The amplification or attenuation of NRBCs can be explained through the conditions of the vulnerable individuals and that of the group (community) involved. For example, drawing on the concept of "bounded rationality", Grüne-Yanoff (2007) argues that the knowledge of NRBCs can be derived from the actors' awareness of the consequences of previous conflicts, both the benefits accrued from the past conflicts and the benefits anticipated in future (Slovic, 2000, Raaijmakers *et al.*, 2008, Justino, 2009). The vulnerabilities and the capabilities of the perceiver (actors) include e.g. the level of access to environmental services, poverty level, and the educational status of the perceiver. These can determine emotions and attitude and contribute to the current and future knowledge of conflict management (Du Nann Winter and Cava, 2006, Basabe and Valencia, 2007). Amplification or attenuation can be distinguished as:

(1). The object of risk,
(2). The message being communicated,
(3) The amplification stations, and
(4) The outcomes such as conflicts.

For example, the vulnerable community members can have contact with "risk object" such as environmental change through resource extraction; a message can be transmitted through direct contact or through "amplification stations", such as the scientists, the media or the NGOs. Resistance such as protests or outright violence is the direct result of the process (Figure 3.8). There are two applicable theories in the social sciences that currently dominate the discussions on risk perception: the "psychometric paradigm" (Slovic, 1992), rooted within the disciplines of social psychology, decision sciences and the "cultural theory" (Marris *et al.*, 1998). Both the "psychometric paradigm" and the "cultural theory" have their merits and demerits. The "psychometric paradigm" in particular is very useful in the quantification of risk perception.

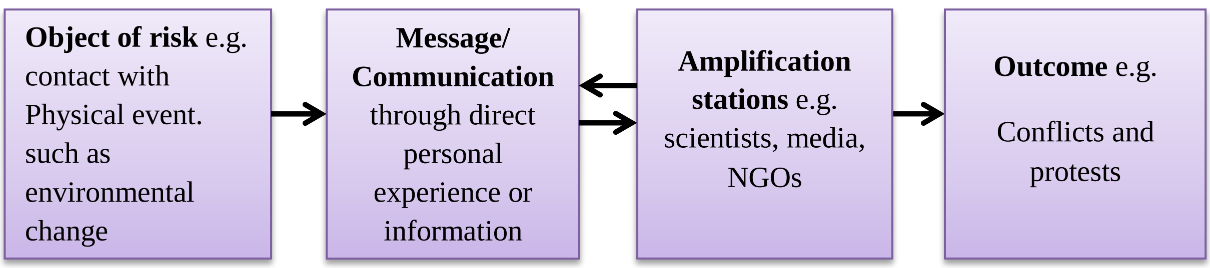


Figure 3.8: Simplified structure of social amplification and attenuation for the understanding the vulnerability of communities developed by Kasperson et al. (1988), Burns et al. (1993).

In discussions on the quantification of risk perception derived from the actors, social psychologists have developed five prototypes of actors, i.e. the grouping of actors in terms of their social responses to risks. This is also referred to as the clusters of related perceptions of actors (Renn, 1992). These prototypes differ in their degree of group cohesiveness (the extent to which individuals take on a group mindset and find identity in a social group) and the degree of the grid (the extent to which someone accepts and respects a formal system of hierarchy and procedural rules). See Figure 3.9 for the prototypes. They include:

- The entrepreneurial prototype: This is based on the opportunity to succeed in a competitive market.
- The egalitarian prototype: This relates to more cooperation and equality rather than a competition of the actors.
- The Bureaucrat prototype: This is where actors rely on rules and procedures to cope with uncertainty and the role of institutions and coping strategies.
- The atomized or stratified individual's prototype: This relates to how actors principally believe in hierarchy, but its members do not identify with the hierarchy to which they belong.
- The Hermit: The hermits are referred to as the self-centered hermits and short-term risk evaluations. These are mediators in risk issues and they build multiple alliances to the other four.

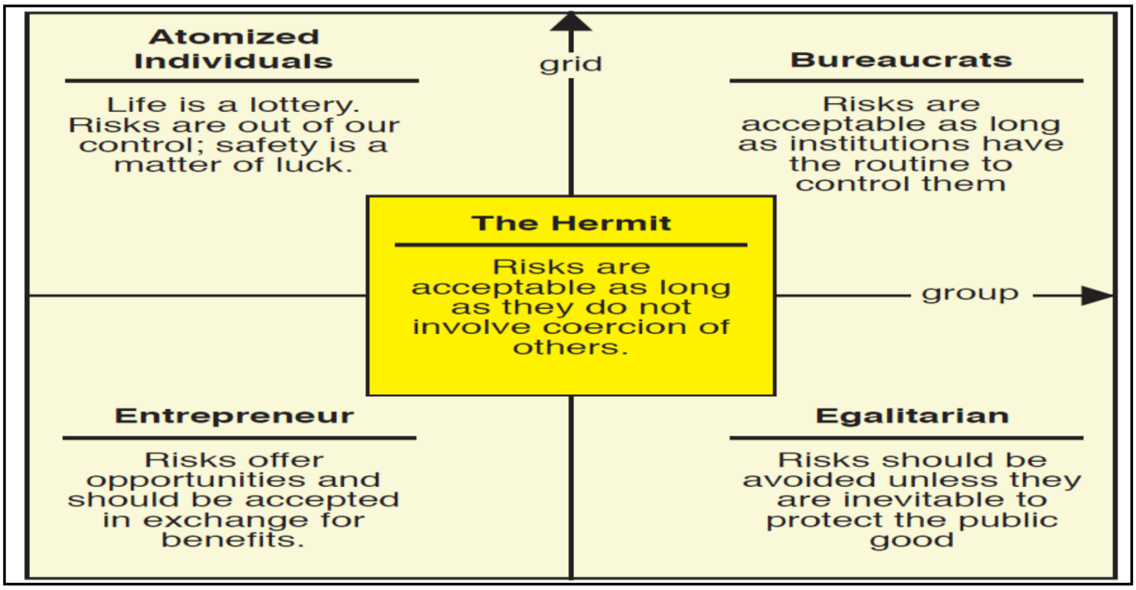


Figure 3.9: Cultural prototypes and grids of risk perception among actors according to Renn (1992).

A question arises on how the disparate information from the different actors over NRBCs can be integrated. The suitability of a transdisciplinary approach for NRBCs has been highlighted in Section 1. According to Scholz and Steiner (2015a), the transdisciplinary process might contribute to a groundbreaking innovation and perhaps even to a reorganization of science, in a coupled Human-Environment Systems (HES). For example, the Transdisciplinary Research (TDR) is needed in knowledge integration; especially in HES (Seidl et al., 2013, Scholz and Steiner, 2015a). Besides the three steps of knowledge integration (see Section 1) proposed by Mauser *et al.* (2013), Figure 3.10 shows five other types of knowledge integration in transdisciplinary processes which are in parts an elaboration of that of Mauser *et al's* approach. These include:

- Mode of thoughts: Related to the architecture of knowledge. They include the intuitive mode of thought that are based on personal experience.
- Mode of knowledge integration: This relates to interdisciplinarity (Scholz and Steiner, 2015a). In Figure 3.10, the icons represent the humanities (∝ sciences), natural sciences (ß science), and social sciences (ɣ sciences).
- The framing of knowledge of different cultures: e.g. a set of implicit and explicit societal rules, e.g. spiritual belief systems, symbols and processes of valuation that underlie human interaction and the valuation of human, biotic, and abiotic entities.
- Different human systems: These include individuals, groups, and organizations that have different perspectives, values, and preferences. Here there are two types of perspectives: value-related (perceived) and epistemic (objective) perspective.
- Viewing systems in a holistic way: Here, TDR processes look at systems in an integrated and holistic way fashion. The "systems" in Figure 3.10 represent the atmosphere (air), lithosphere (land), and hydrosphere (water). These components need to be integrated if we think about a sustainable transformation of an environmental system.

As stated above, therefore, the participation of actors (Renn, 1998, Buckle *et al.*, 2000, Park *et al.*, 2013) is useful in framing NRBCs (values, perspectives, practical knowledge of context). The role of the actors' knowledge is that it helps to show the areas of common agreement (consensus or compromise) while establishing the input parameters for modeling. The integration of the actors' views has shown an improved output in risk perception (Renn, 1998, Rohrmann and Renn, 2000) and it is an integral part of the steps in coupling the components of the "Vulnerability Cube", which are the spatial, the temporal and the dimensional components of vulnerability.

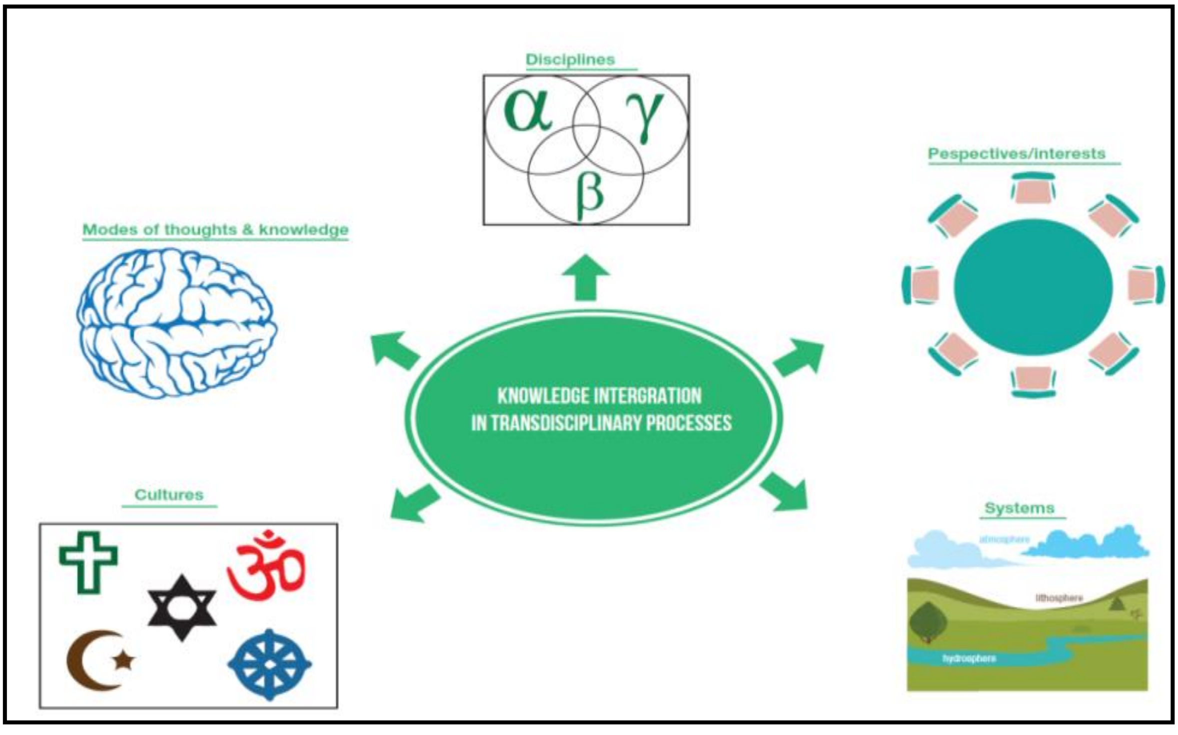


Figure 3.10: TDR process and knowledge integration: modes of thought, (inter-) disciplinary (related to humanities, natural and social sciences), perspectives/interests, systems, and cultures, according to Scholz and Steiner (2015a).

3.2.2 Mapping Natural Resource-Based Conflicts: The Spatial and Temporal Disaggregation

In the fourth phase of the study of NRBCs, scholars have challenged the Large-N (country-scale of analysis) (See Section 1). This is partly because of the inability of the Large-N studies to explain the internal dynamics of conflicts, e.g. the severity, the hidden causes and the outcome of conflicts due to the exclusive reliance on country repressors using mainly the linear models such as MLRMs (Buhaug and Lujala, 2005, Buhaug *et al.*, 2008). At a country-scale, the drivers of NRBCs assume that the observations are independent of one another, As a result, there is a challenge in a spatially explicit assessment of this variable (Buhaug and Lujala, 2005, Buhaug *et al.*, 2008). On the contrary, the space concept in NRBCs can be better addressed explicitly at a community scale (Buhaug and Lujala, 2005).

At a community-scale analysis, it is possible to measure and explicitly assess the many phenomena believed to influence the risk of conflicts, such as environmental degradation and scarcity, income and political structures and how these tend to cluster or diffuse geographically (Rustad *et al.*, 2011). The advantages of spatially disaggregating NRBCs at a local level, therefore, include: Firstly, it allows an inclusive understanding of conflict and the forms of organized violence (namely low-intensity conflicts, social unrest, communal violence, or high-intensity rebel-related violence riots). This sheds more light on new hypotheses that have been tested at a country-scale (Buhaug and Lujala, 2005, De Juan, 2012, Ide, 2015a). Secondly, measuring the spatial clustering of NRBCs at a local scale would show how conflicts do not by itself imply a causal relationship (Buhaug and Gleditsch, 2008), rather the observed spatial clustering of conflicts may be explained due to the corresponding distribution of relevant endogenous characteristics associated with the conflicts, such as group-based social identity, individual and collective reasons for aggression (Du Nann Winter and Cava, 2006). For instance, group-based emotions (as emotions felt by individuals, group or society) can encourage conflicts (Bar-Tal *et al.*, 2007), while an accumulation of many group-based emotional responses to a societal event can easily turn into a collective emotion (Bar-Tal 2007). For example, oil extraction in a typical developing country impacts on the collective emotion of a community which may in turn impact on their perceived “internal” side of vulnerability such as socio-economic and political factors. These are critical to aggression and can only be revealed at a fine-grained scale assessment. at the village or community level.

Regarding the methodological underpinnings of spatially disaggregated studies in NRBCs, it has been shown that one can disaggregate data to a subgroup level (e.g. grid square) and re-aggregate to the defined group level (e.g. ethnic homelands) (Buhaug and Theisen, 2012, Ide, 2015a, Raleigh, 2011). GIS remains an invaluable tool in this regard for mapping resource conflicts (Kwaku Kyem, 2004, Basta, 2012). The spatial relationships of conflicts drivers may help to ascertain for example how the coastal and the inland territories influence the dynamics of resource conflicts. One way GIS can be useful in mapping NRBCs is that it can be combined with Earth Observation tools where environmental, socio-economic, political aspects of people's perspectives of vulnerability can be coupled (Goodchild *et al.*, 1992, Goodchild, 2010, Chang *et al.*, 2014). In addition, with GIS, the units of analyses can be rescaled downward or upwards to the sub-national level and the existing findings can be re-examined in more spatially disaggregated settings by “re-establishing” the causal relationships that were not fully captured in the previous analyses. This is possible through a modeling-based approach using the expert's knowledge, the knowledge of the actors or both (Sakamoto, 2013). It has been concluded that the expert domain knowledge is very useful in developing spatially explicit vulnerability interventions. For example, through the use of *geons,* a constructed element is capable of transforming singular domains of information on a specific systemic component to policy-relevant information (Kienberger *et al.*, 2008, Kienberger *et al.*, 2009, Lang *et al.*, 2014). In this context, the layers of data may be required and can be hierarchically analyzed as a decision support system in policy interventions. See Figure 3.11, for example, the different levels of spatial units: indicator level, domain level and spatial vulnerability units.

As described above, therefore, the gap between vulnerability assessment and NRBCs can be bridged with the use of TDR and this knowledge can be incorporated into developing the mapping results with the aid of GIS and other tools. This process may require any or all of the three main processes stated below (Doreian and Hummon, 1976, Fougères, 2013, Sakamoto, 2013):

- Modeling by coupling the different dimensions that take into considerations the explanation of the mechanisms of conflict occurrence.
- Modeling without explicit spatial considerations.
- Modeling the spatially explicit dimensions by transferring the non-spatially explicit model.

Once the locations of those areas of anomalous vulnerability are identified, such as hot spot and cold spot, actors can plan and implement the measures required to mitigate the negative impacts by offering required interventions at the community level (Kienberger *et al.*, 2009, Kienberger *et al.*, 2014). Examples could be local interventions or community-based natural resource management (CBNRM) in developing countries (Pailler *et al.*, 2015, Riehl *et al.*, 2015). Multi-lateral organizations promote NRM in tandem with CM in peacebuilding and environmental conservation (UNEP, 2009, UNEP, 2012, UNEP, 2015). But until now, the role of NRM in CM has been ad hoc with ineffective strategies. Therefore NRM in post-conflict can be vital to supporting the future well-being of the society and in turn build a stronger peace process with a combination of actors and scientific knowledge which can help reduce communities that are more vulnerable to NRBCs and increase resilience in other areas (Oglethorpe *et al.*, 2016). This supports the view that NRM can help maintain and strengthen peace, while the failure to manage natural resources appropriately can destabilize a fragile peace (Bujones *et al.*, 2013).

Such combination of knowledge could also help further the debates surrounding the questions of the immeasurability of vulnerability and realm of sustainability (Andriantiatsaholiniaina et al., 2004, Bell and Morse, 2008). It is thus argued in this thesis that the immeasurable nature of vulnerability in the context of NRBCs requires an integration of the adapted fuzzy logic model. Consequently, the features of vulnerability assessment to NRBCs such as complexity, uncertainty and lack of imprecision can be addressed through the actor's views and through modeling (Adriaenssens et al., 2004, Andriantiatsaholiniaina et al., 2004). In this context, one of such tools through which the perception of actors can be collected and modeled is through the use of scenarios.

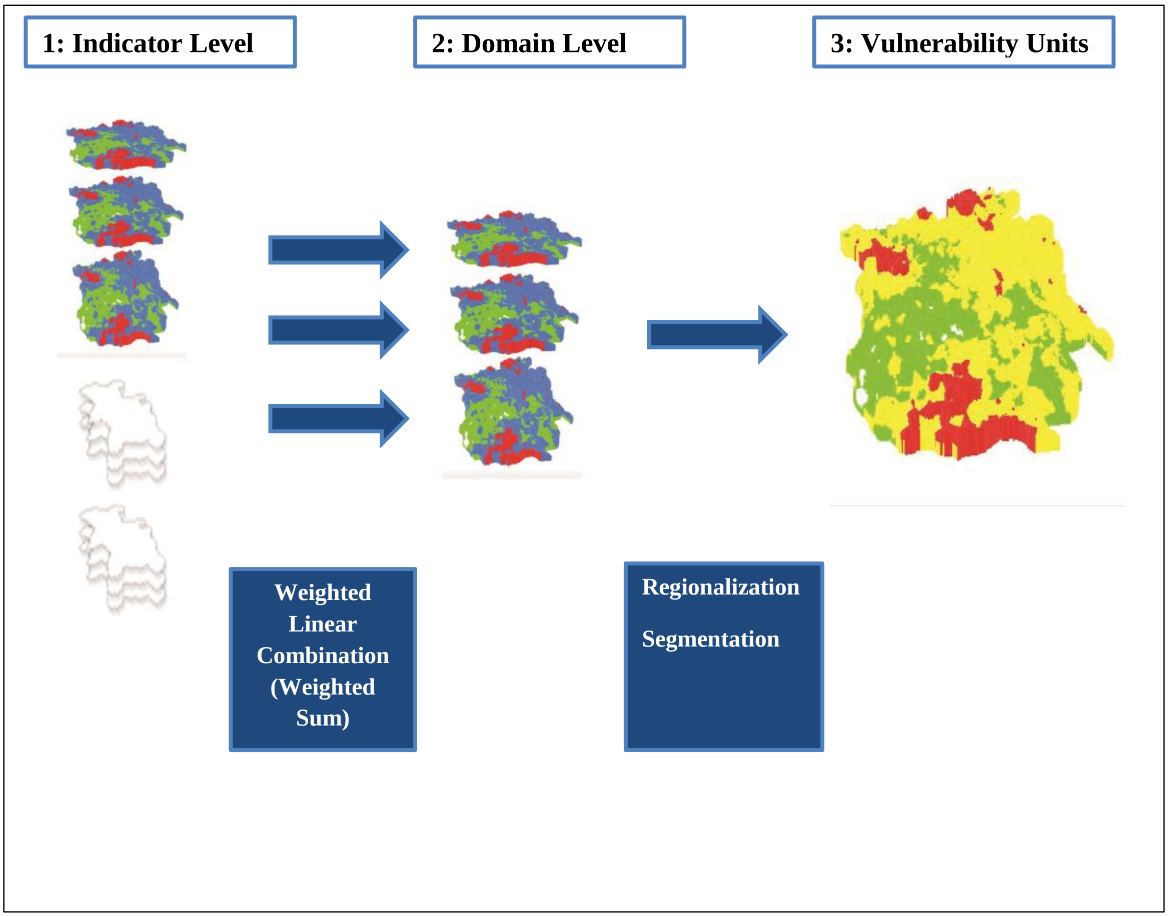


Figure 3.11: Workflow to generate spatial vulnerability units at the different levels (indicator level [1], domain/dimension level [2], and final spatial index of vulnerability units [3]) adapted from Kienberger *et al.* (2009).

3.2.3 Scenarios Typologies and Applications to Natural Resource-Based Conflicts (NRBCs)

Scenarios have increasingly become very useful tools in sustainable management in transdisciplinary research. They were first used for military planning purposes (Kahn and Weiner, 1967), and later refined by Royal Dutch/Shell (Wack, 1985). However, the use of scenarios came to the attention of the general public in the 1970s with the publication of the ground-breaking book, "The Limits to Growth" (Meadows et al., 1972). Since then various typology and characterization of scenarios exist. For example there are methods such as qualitative vs. quantitative, exploratory vs. backcasting, participatory vs. expertly developed scenarios, single vs. multi-scale scenarios (Godet, 2000, Alcamo and Ribeiro, 2001, Van Noordwijk *et al.*, 2003, Van Notten *et al.*, 2003, Bradfield *et al.*, 2005, Alcamo *et al.*, 2006, Miller, 2007, Kosow and Gaßner, 2008, Tompkins *et al.*, 2008, Mahmoud *et al.*, 2009, Amer *et al.*, 2013, Folhes *et al.*, 2015, van Vliet and Kok, 2015).

Studies have also shown that scenario methodologies could be a combination of one or more types. For example, qualitative and quantitative models could be used to complement each other to represent (and test the feasibility of visions and trajectories) (Alcamo and Ribeiro, 2001, Folhes *et al.*, 2015, van Vliet and Kok, 2015) (see Section 7.3).

The normative backcasting scenario and exploratory scenario are also complementary to each other and have been successfully combined with added value (UNEP, 2002, Kok et al., 2011, van Vliet and Kok, 2015, Aguiar et al., 2016). Normative backcasting requires examining the plausible future of conflicts using narratives and working backward from a particular desired future endpoint, i.e., learning about the possible and desirable futures to improve the exploratory scenarios of conflict. In co-constructing scenarios, the factors, actors, and sectors (FAS) are critical. Here the framework of FAS applies (Kok and Van Delden, 2004) as one of the ways of addressing the complexity of a system with scenarios without becoming overwhelmed (Rotmans et al., 2000). Regarding co-constructing scenarios for NRM and CM, the qualitative scenarios produced through the contributions of actors can help to structure the scenarios. An example was the use of a backcasting method (Wollenberg et al., 2000, Vergragt and Quist, 2011).

Apart from using a combination of qualitative and quantitative methods, the proposed CM scenarios can also combine the backcasting and the exploratory scenarios. Backcasting can be defined as generating a desirable future, and then looking backward from that future to the present in order to strategies and to plan how it could be achieved (Quist et al., 2001, Quist and Vergragt, 2006, Vergragt and Quist, 2011). According to Vergragt and Quist (2011), backcasting is about desirable futures and has a strongly normative nature especially well equipped to be applied to sustainability issues. Backcasting can be both qualitative and quantitative and deals with envisioning, analyzing sustainable futures and subsequently by developing agendas, strategies and pathways on how to get there (Wollenberg *et al.*, 2000, Vergragt and Quist, 2011). Exploratory scenarios, on the other hand, sketch plausible futures, showing the implications of several external drivers (Börjeson et al., 2006). The most important feature of exploratory scenarios is their aim to describe distinctively different plausible futures, each showing different developments of social, economic and environmental factors (van Vliet and Kok, 2015). The bottleneck in the use of qualitative and quantitative methods is the translation of scenario descriptions derived from scenario workshops to quantitative models (Walz et al., 2007, Mallampalli et al., 2016). This has been overcome in different ways (Rotmans et al., 2000, Scholz and Tietje, 2002, Mallampalli et al., 2016).

The various scenarios types reviewed above have been applied as valuable tools in environmental management in studies on sustainable transition management, environmental changes, water and ecosystems, LULC modeling and NRM (Wollenberg *et al.*, 2000, Folhes *et al.*, 2015). It has particularly been used in climate change modeling by Intergovernmental Panel on Climate Change (IPCC) but less in peacebuilding (Carius and Maas, 2012). For example, the IPCC scenarios provide quantitative estimates of possible future greenhouse gas emissions (McCarthy, 2001, Gao *et al.*, 2017). However, IPCC scenarios are critiqued partly as a consequence of their strong quantitative focus and global-scale exercises which make them expert-driven, involving stakeholders and decision makers only during review processes rather than in the actual scenario development workshops (Biggs et al., 2007). The use of adaptable tools at the local level, therefore, has the advantage of enhancing ownership of research outcomes in post-conflict situations (Carius and Maas, 2012, Brauch, 2016b). In this case, the outcome of storylines is important for knowledge sharing, empowerment, and visioning. As proposed in Section 7, co-created methods can be used to simulate scenarios for future management NRBCs. The benefits of such co-created methods are very well documented (Voinov and Bousquet, 2010, Mauser *et al.*, 2013, Voinov *et al.*, 2016).

3.3 Integrating Vulnerability Assessment of Natural Resource-Based Conflicts into Fuzzy Logic Model

This section presents fuzzy logic modeling for addressing the uncertainty in vulnerability assessment in the context of NRBCs.

3.3.1 Fuzzy Logic Models (FLM) vs. Probability Models (PM)

Fuzzy logic models are based on the Fuzzy Logic Theory (FLT). The model itself is often referred to as a Fuzzy Logic Model (FLM) or a fuzzy logic methodology (Yalpir and Özkan, 2011, Zlateva et al., 2011). Since 1965 when the first paper on FLM was published (Zadeh, 1965), the methodological tools of FLM have developed through mathematical thinking (Coppi et al., 2006) with a key feature that FLM is beyond the Aristotelian Boolean logic reasoning and that it addresses uncertainty (Verkuilen, 2005). Thus since inception, FLM has been applied in engineering (Zadeh, 1965), environmental sciences (Yalpir and Özkan, 2011, Zlateva. et al., 2011), global food security (Zabel et al., 2014), drought (Acosta-Michlik et al., 2008) and in studies on measuring sustainability and resilience (Phillis and Andriantiatsaholiniaina, 2001, Preston et al., 2011). FLM is known in the social sciences as a Fuzzy Set Qualitative Comparative Analysis (fsQCA) (Ragin, 1987). It has been used to conceptualize the social and political phenomena with imprecise boundaries (Ragin and Pennings, 2005). Similar methods to FLM include Artificial Neural Network (ANN) and genetic algorithms. As opposed to the ANN, the FLM algorithms offer a number of advantages (Acosta-Michlik et al., 2008). It has the ability to address uncertainty by accepting uniform and non-uniform variables. It is transparent, easily implemented and uses the "*If-then*" rules to generate an output based on imprecise inputs. These suggest that FLM can deal with most of the drawbacks in the previous models for modeling the NRBCs such as the MLRM.

In information sciences, apart from FLM, another approach to addressing uncertainty is probability modeling (PM) (Dubois and Prade, 1998, Dubois et al., 2000). Although differences and similarities have been established between the FLM and the PM (Dubois and Prade, 1998, Dubois et al., 2000), both models build bridges and take advantage of their enlarged frameworks for modeling uncertainty and vagueness (Dubois et al., 2000). However, the PM is challenged with widening realization that most real-world problems are far from being precisely known or measurable numbers (Zadeh, 2002). But FL is good at modeling complex real-world problems such as the NRBCs. NRBCs and the related complex problems can best be addressed today using FLM. One reason one modeling complex real-world problems with FLM is now possible is that of a vast increase in the computational power of information processing systems and breakthroughs in computer modeling.

In support of the modeling of real-world problems, Zadeh (2002) proposed a transition from imprecise probabilities to perception-based probability theory—a theory in which perceptions and descriptions in a natural language play a pivotal role. Perception-based theory when applied aims at laying the groundwork for an enlargement in the role of natural languages especially in the realm of decision analysis for analyzing real-world problems (Zadeh, 2002). There are many research questions that can only be addressed using FLM. For example:

- What is the probability that a violent conflict in the oil extractive territory can occur; that rebels can stage a demonstration against government forces or a community can stage a protest over environmental scarcity and environmental pollution?

- What is the probability that when conflict occurs, it will be due to the scarcity of resources in the community or due to lack of political recognition of the community in issues relating to oil extractive benefits?

Questions of this kind are routinely faced and answered but may not be handled with the use of traditional probability modeling (Zadeh, 2002). This is because the answers are not definite numbers but are linguistic descriptions of fuzzy perceptions of probabilities, e.g., *not very high, quite unlikely, about 0.8, etc*. Such answers may only be arrived at through perceptions relating to mathematical constructs such as functions, relations, and counts. As illustrated in Figure 3.12, instead of describing a probability distribution, P, analytically or numerically, as we normally do, P could be interpreted as a perception and described as a collection of propositions expressed in a natural language. As a result, a fuzzy function can be described using a collection of linguistic *if-then rules* (Zadeh, 2002). The function shown in Figure 3.12 may be described by the rule-set:

if X is small then Y is small;
if X is medium then Y is large;
if X is large then Y is small;

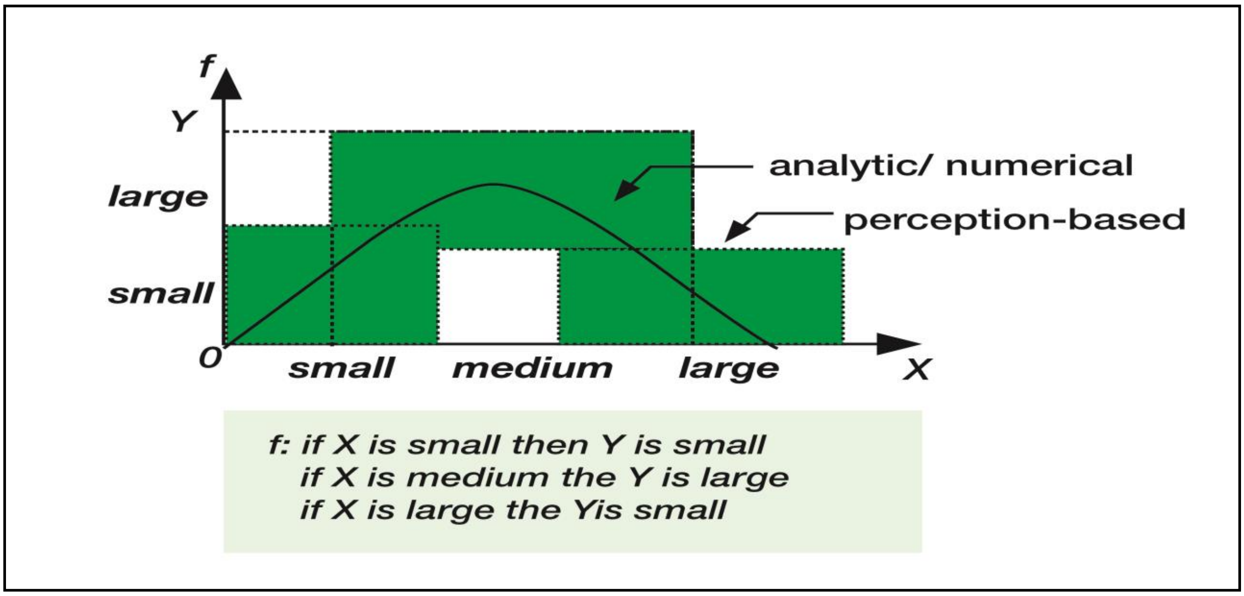


Figure 3.12: Description of a function by a collection of linguistic rules, linguistic representation of perception based probability, adapted from Zadeh (2002).

In essence, a perception-based theory adds value to standard probability theory as a counter traditional capability to convert measurements into perceptions or to deal with perceptions directly (Zadeh, 2002). These described features of perception-based theory and the use of FLM are useful for addressing the HVA in the context of NRBCs with the highlighted characteristics (Section 3.3.2).

3.3.2 The Holistic Vulnerability Assessment (HVA) of Natural Resource-Based Conflicts and the use of Fuzzy Logic Model

Risk has been defined in Section 3.1. Conventionally, the engineering approach usually calculates risk from the probability of an event and the losses it produces. For instance, the risk equation proposed by the United Nations Disaster Relief Coordinator (UNDRO) has been used in natural disaster studies (UNDRO, 1979, Dilley, 2005). Risk is described with three main elements shown in *Equation 3.1*

$$R_{az} = H_{az} * E_{az} * V_{az} \qquad \textit{(Equation 3.1)}$$

where

R	=	*Risk*
H	=	*Hazard*
E	=	*Exposure*
V	=	*Vulnerability*
A	=	*Geographic region*
Z	=	*Type of Hazard*

The above equation can be found in various scholarly works (Blaikie et al., 1994, Bollin et al., 2003, Bollin et al., 2006) with their applications (UNDP, 2004). Vulnerability on the other hands (see Section 3.1.1) reflects the sum of the hazards (defined as a potentially damaging physical/environmental characteristics) to which a society or community is exposed and the mitigating adaptive or coping capacity (the ability to respond effectively to risk) and the available alternative economic opportunities. Vulnerability is defined mathematically as:

$$V = f(E,S) - C \qquad \textit{(Equation 3.2)}$$

where,

E	=	*Exposure*
S	=	*Susceptibility*
C	=	*Capacities*

In this work, vulnerability is defined beyond the conventional interpretation. It is defined as the sum of the perception of the “internal” side and the “external” side ((Bohle, 2001), Section 3.1.1, Section 3.1.2, Figure 3.13). This is because of the vulnerability of people, communities or regions in real-world contexts emanates from different scales—interacting with different thresholds and over uncertain spatial, temporal and multidimensional conditions. These characteristics of vulnerability assessment suggest a holistic approach with the integration of the different dimensions including the human and the natural systems. It is therefore argued in this work that the HVA of NRBCs can be modeled using an adapted FLM rather than a binary logic or a PM. As demonstrated in Section 5, the adapted FLM addresses the NRBCs vulnerabilities at a community level. FLM adds value to the assessment and the solving of real-world problems such as NRBCs. For example, in the collective judgment of vulnerable communities concerning environmental services and resource uses, the assessment could be very imprecise and uncertain as it is based on heuristics. Even though such assessments are very important they are largely unrecognized. But such problems with uncertainties are what FLM can naturally handle.

There are a number of characteristics of HVA of NRBCs which can adequately be addressed using the FLM. These are briefly discussed below:

- Complexity: There is a complex relationship between the drivers and the occurrence of conflicts. This relationship cannot be determined by simply conducting a non-linear statistical analysis between the independent variables and the occurrence of conflicts

(Homer-Dixon, 1996, Schwartz *et al.*, 2000). But, FLM, being a non-linear model can systematically use linguistic terms and **the *"If-then"*** rules (see Section 5).

- Multi-dimensional: A holistic assessment of NRBCs entails different dimensions shown earlier in Section 3.1.2. Similarly, the drivers of NRBCs for sustainable peace could be classified in many dimensions such as environmental, socio-economic and political with their variables having multiple interactions (Homer-Dixon, 1996). Thus the modeling process would require data from different sources and with different metrics, This complicates the modeling process. The implementation of FLM addresses the multi-dimensionality problem of HVA of NRBCs
- Lack of threshold and uncertainty. HVA of NRBCs lacks a clear-cut threshold (Adger, 2006) because it is manifest in specific places, scale and at specific times. NRBCs occur in developing countries of the world with highly heterogeneous characteristics. In addition, the determination of the threshold level is not simply a proportional measure, the same for all sectors of society. Moreso, arriving at decisions is further complicated by uncertainty and difficulties in the measurements. This thereby resorts to heuristics in decision making (Vasvári, 2015). A vulnerability assessment of NRBCs for sustainable peace will thus require adapting fuzzy logic modeling where the views of the actors can be collected and integrated as management strategies and solutions.

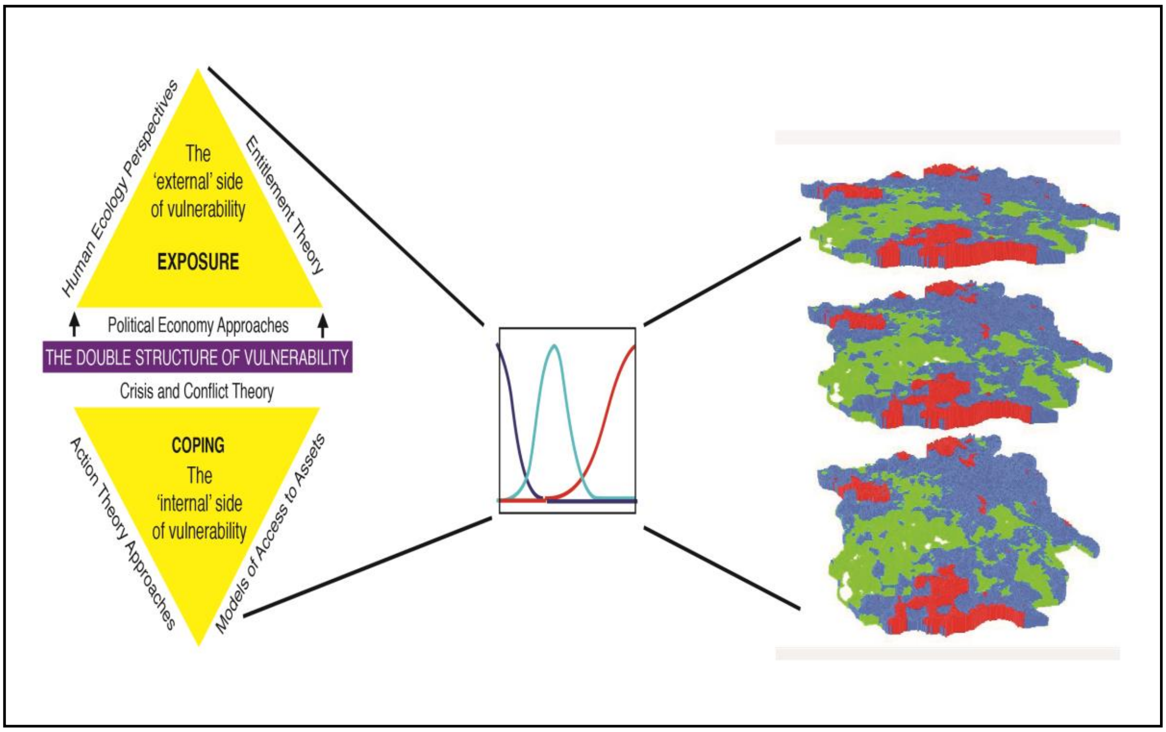


Figure 3.13: Schematic of the simplified theory of fuzzy vulnerability assessment (TFVA) adapted from Zadeh (1965), Bohle (2001) and Kienberger et al. (2013).

As will be shown in Section 5 of this thesis, Spatially Explicit Fuzzy Logic Adapted Modeling for Conflict Management (SEFLAME-CM) is developed and implemented based on the above-discussed concepts. Theoretically, SEFLAME-CM draws on a paradigm shift from the classical bivalent logic or the bivalent-logic-based probability theory (Zadeh, 2008a). It is related to the theoretical proposition of computing with words (CWW) from computing with numbers (CWN (Zadeh, 2008b); perception based computing (PBC) Skowron and Wasilewski (2010), and perceptual computer (PC) (Mendel and Wu, 2010). These have been identified as a new direction in artificial intelligence (AI) in dealing with real-world problems (Zadeh, 2009). A shift from CWN to CWW is what may be called a computational theory of perceptions (CTP) in line with the use of Natural Language (NL). CWW is capable of addressing distance, size, weight, force, color, numbers, and other characteristics of physical and mental objects (Zadeh, 1999, Zadeh, 2001). CWW can also complement CWN (Zadeh, 2008b). The combination of CWW and CWN demonstrate the use of artificial intelligence for a better understanding of the fundamental importance of the remarkable human capacity to perform a wide variety of physical and mental tasks without or with a combination of measurements during computations (Zadeh, 1999).

The process of implementing the model-SEFLAME-CM under a transdisciplinary-based coupled approach begins in this work with a joint problem framing (Section 4).

4 Joint Problem Framing

This section focuses on joint problem framing and structuring in order to operationalize the problem of Natural Resource-Based Conflicts (NRBCs) for modeling and simulation. It integrates problem structuring methodologies (PSMs) such as remote sensing, geographic information system (GIS) and interviews. Firstly, it looks at why NRBCs requires a joint problem framing using PSMs. Secondly, it highlights the problem structuring tools that are useful for framing a "wicked" problem. Thirdly, the results of the joint problem framing are presented. This begins by presenting the assessment of the environmental change in the study area using remote sensing, which is validated with a discourse analysis method. Then a presentation of all the actors' perception of conflicts as their mental maps follows using GIS. Next, a discussion on the comparison of the actors' mental maps is presented. It ends with a presentation of how the conflict drivers/factors generated from the joint problem framing are operationalized in this work for modeling.

4.1 Problem Framing in Vulnerability Assessment to Natural Resource-Based Conflicts

The transdisciplinary approach begins with the joint problem framing and exploration of research questions (Mauser *et al.*, 2013). Problem framing and problem structuring concepts are used interchangeably. With the support of problem structuring methodologies (PSMs) and tools, the actors can frame the resource conflict problem. The PSMs or tools such as geographic information systems (GIS) can be used to visualize discourse analysis results to ascertain for instance, how the actors in the studied communities define the meaning of resource conflicts or how they negotiate the frame through the way they use language in their interactions with each other (Dewulf *et al.*, 2005). The joint problem framing is therefore presented as the first step in the modeling process of SEFLAME-CM. The combination of PSM and discourse analysis is a mixed-method approach. The main goal of the use of PSMs is to support the framing of the problem of Natural Resource-based conflicts (NRBCs) so as to enhance the decision-making domain (i.e. management of NRBCs for sustainable peace) at a community scale.

As discussed in Sections 1 and 3, consensus has been reached on the need to focus on disaggregated assessment of NRBCs, i.e., vulnerability assessment of NRBCs at a local or community scale (Buhaug and Rød, 2006, Lujala *et al.*, 2007). The Local factors responsible for conflict processes are critical to understanding and managing conflicts (Lujala *et al.*, 2007). While the hitherto dominated top-down and Large-N analysis give contradictory results (Gleditsch, 1998), the bottom-up approach at the community-scale is able to leverage on the use of a disaggregated assessment perspective to help link research to policies that support sustainable post-conflict management in resource-rich territories (Rustad and Binningsbø, 2012). In other words, to achieve both sustainability and peace at a local scale, a systematic approach is required to jointly frame the problem of NRBCs involving the actors. See Section 3 for vulnerability and inherent features of a holistic vulnerability assessment (HVA) (e.g. uncertainties and incomplete information).

NRBCs being a "wicked" problem defies straightforward linear planning and fragmented intervention strategies (Martinez-Alier, 2009a, Avcı *et al.*, 2010, Brauch, 2016b). It has been shown that, "natural resources issues are not just out there in the natural world. Different social actors tend to acknowledge and highlight different aspects of reality as problems or opportunities, and thus requiring intervention", (Dewulf *et al.* 2004, 178).

Therefore, the social and cognitive psychologists introduced the concept of framing as an approach to making sense of a complex and "wicked" problem before it is solved (Dewulf *et al.*, 2007). Schon and Rein (1994) proposed several approaches and strategies for frame reflection but offered no clear method or process of frame identification (Kolkman et al., 2007). Discourse analysis is one of such methods that can be used in framing. With a discourse analysis, a common sense can be made out of a confusing or ambiguous situation (Dewulf et al., 2004). When problems are framed, for instance, the elements can be understood in different ways and according to different frames (Dewulf *et al.*, 2007). Dewulf *et al* note how frames can be used in the analysis of NRBCs. This helps in decision-making and negotiation where the individuals and groups can filter their perceptions, interpretations, their understandings of complex situations and experiences. For example, Figure 4.1 depicts the relationships between the mental models of actors with different perspectives. The mental model acts as a "filter" that selects information from the "real world", which is subsequently interpreted from specific perspectives to produce the meaning of the problem situation at hand. Practically, when NRBCs are framed they are clarified and simplified by the parties involved. In this case, the underlying roots of their respective interests of actors are revealed to further mutual understanding and help arrive at a compromise or resolution (Shmueli, 2008). This goes beyond traditional problem-solving approaches in single disciplines. Rather, it enhances the integration between scientific disciplines. When framing is successfully carried out, the results can be used in a further problem-solving cycle (e.g. problem analysis, simulation, and implementation) in the research process. This may be for example, by integrating relevant land use functions, the socio-political process, and the associated stakeholders to arrive at a solution (Mauser *et al.*, 2013).

Similar to framing approaches, PSMs such as GIS can structure and identify complex problems that are inherently "wicked" in nature (Eden, 2004, Mingers and Rosenhead, 2004, Shaw *et al.*, 2006, Jung, 2009). A PSM tool, e.g. GIS can be used to support the framing of NRBCs. In this work, discourse analysis, remote sensing, and GIS are integrated and used for framing and defining the problem of NRBCs. The next section focuses on the need for problem framing, an integration of discourse analysis as a qualitative methodology (QM), into GIS. The results will be used to operationalize the model-SEFLAME-CM.

4.1.1 Natural Resource Conflicts as a "Wicked" Problem: The Need for Problem Framing

It seems clear that the planning problems in NRBCs environments go beyond even what Gorry and Morton (1971) called unstructured problems. Rittel and Webber (1973) refer to this kind of problem as "wicked" and state that the classical rational paradigm of science is not applicable to solving such problems. The problems of NRBCs meet the main elements of a "wicked" problem (Rittel and Webber, 1973, Fischbacher-Smith, 2016). Table 4.1 provides an illustration of the main elements of the "wicked" problems vs. that of the vulnerability of NRBCs.

Table 4.1: Framing natural resource-based conflict as a 'wicked' problem.

Elements of a "Wicked" Problem		Relevant characteristics of Vulnerability to Natural Resource-Based Conflicts
1	No definitive formulation of a wicked problem and wicked problems have no stopping rule.	• It has been and continues to evolve and solving one particular set of issues will not address the problem of socio-environmental conflicts in a holistic way. Changing national demands for national interest against the interest of local groups prevents a generic solution to the problem.
2	The parameters of the problem are not easily identified.	• Due to ideological reasons their link between the natural and human components, the root causes of NRBCs are difficult to deal with. • Several valuation languages are deplored and no one has the sole power to simplify the complexity
3	Solutions to wicked problems are not true-or-false, but good-or-bad. There is no immediate and no ultimate test of a solution to a wicked problem.	• Resource conflicts are diverse and do not allow easy solutions. • They are partly referred to as struggles over the burdens of pollution or over the sacrifices made to extract resources, • They arise from inequalities of income and power and partly due to a shortage of resources and community struggles over cultivable land in the midst of pollution or land grabbing by the multinational investors
4	Every solution to a wicked problem is a 'one-shot operation'; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.	• The solution only applies in the context of the definition and framing of the problem. For instance, the conflicts arise not only from the driving forces of economic growth and the search for profits, and from the different interests and values of the stakeholders involved, but often also from the distribution of scientific and technical uncertainties and related risks.
5	Wicked problems do not have an enumerable(or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.	• No set of permissible operations that may be incorporated into the plan. Potential solutions can be explored but not predicted.
6	Every wicked problem is essentially unique.	• The uniqueness of the location of the problem of NRBCs requires a unique solution. Typology of resource conflicts is diverse.
7	Every wicked problem can be considered to be a symptom of another problem.	• Nested and multi-scalar nature of resource conflicts, operating at different dimensions, spatial (local, regional and global effects), and temporal settings.
8	The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.	• You analyze the part you choose to analyze. There could be an endless list of valuation languages and the more diverse they are the more controversial. • For example, monetary valuation is in itself controversial as it simplifies complex value systems related to environment (such as sacredness, livelihood, territorial rights, beauty, and biodiversity) and it is used by some groups in the society to reach their own interests. In the same vein, "prices" are often in themselves a tool of power through which the capitalist society imposes its own standard of valuation, thereby allowing the tradeoff economic benefits and socio-environmental costs in its own favour.

9	The Stakeholders involved in wicked problems have different perspectives, resulting in discrepancies between policy and practice.	• Stakeholders cut across different sectors and have different perspectives based on their interest. • There are incommensurable values, and it is difficult to explore "compromise" solutions, and the coalitions of social actors that would be behind any hypothetical solutions.
10	The solutions to wicked problems are not easily articulated and framed.	• The complex nature of the problem generates demands for multi-level responses that are difficult to implement. • To effectively address resource-based conflicts that cut across value and livelihood it requires socially intrusive, and innovative knowledge creation and management.

4.1.2 Using Problem Structuring Methodologies (PSMs) to Support Problem Framing

As illustrated in Table 4.1, the vulnerability assessment of NRBCs at the local level is a "wicked" problem (Mingers and Rosenhead, 2004, Shaw *et al.*, 2006) that requires framing with PSMs. PSMs are the tools of collecting and systematizing the stakeholders' views (or their representatives). When "wicked" problems are structured or clarified they aid the modeling process (Mingers and Rosenhead, 2004). Drawing on the Migers and Rosenhead's (2004) work, the two of the important components of the use of a PSMs in modeling a real-world problem include the modeling approach and data requirements.

First, regarding the modeling approach, Franco and Montibeller (2010) identified two model-based approaches in management science for addressing real-world complex problems: the expert modeling and facilitated modeling approach. In the expert modeling case, the experts or consultants define, by themselves, the metrics to be used for evaluating solutions, based on prior categorizations of the problem. The facilitated modeling, on the other hand, is used where competing hypotheses about the scope and depth of the problem is contestable. In the facilitated modeling case, the problem situation always involves subjective elements and a plurality of views. For example, different perceptions exist about the conditions that lead to NRBCs. Thus actors need to collaborate and communicate thereby enabling social learning (Franco and Montibeller, 2010).

Second, the data requirements may be qualitative and quantitative. While qualitative data method is seen to be close to the language of actors and easier to elicit, however, they are also more ambiguous and less amenable to further analysis. Quantitative data, on the other hand, are amenable to further analysis but are more separated from natural human language (Franco and Montibeller, 2010).

In several ways where PSMs are used, both quantitative and qualitative methods may be combined. An example of such methods includes strategic options development and analysis (SODA) (Belton and Stewart, 2002); soft systems methodology (SSM) (Winter, 2006), and robustness analysis (Wong, 2007) and many others. Qualitative and quantitative methods can be integrated as a mixed methods research (MMR) (Fielding and Cisneros-Puebla, 2009). For example, there have been convergent interests in qualitative geography (QG) and qualitative social sciences (QSS) which have been described as emerging, innovative, and inclusive form of

MMR (Fielding and Cisneros-Puebla, 2009). Fielding and Cisneros-Puebla argued that spatially oriented qualitative social science and qualitatively oriented geography are particularly likely to produce "pure mixed" form of MMR. A major impetus toward the affinity of "pure mixed" MMR is the technologies that support QG and QSS (Fielding and Cisneros-Puebla, 2009). The emergence of Computer Assisted Qualitative Data Analysis "CAQDAS" in the 1980s provided new computational resources for qualitative and MMR This paradigm shift in the use of qualitative approaches is informed by the argument that knowledge is socially constructed even in apparently factual representations of space and place, such as the use of maps (Knigge and Cope, 2006). Thus, the integration of QM, CAQDAS, and GIS support the recent development of the need to combine more than one PSMs in problem structuring or problem framing (Mingers and Rosenhead, 2004). With the emergence of QM software such as *Nvivo, MAXQDA, Atlas.ti,* it has become easier to integrate QM into a large quantitative analysis in an interdisciplinary research. When a QM approach (e.g. discourse analysis) and GIS are integrated and such integration helps to ascertain the knowledge of the actors regarding the problem of NRBCs. This is the main focus of this section (Fielding and Cisneros-Puebla, 2009). Section 4.2, therefore presents the implementation of the joint framing of NRBCs using QM and GIS and the analysis results.

4.2 Joint Problem Framing and Analysis

In the integration of QM such as discourse analysis and GIS is possible (Mingers and Rosenhead, 2004), while QM through an interview is used to collect the perception of the actors on the drivers of NRBCs, the GIS is used to store, retrieve, display and modify the knowledge produced (Mingers and Rosenhead, 2004). Figure 4.1 shows the design of the joint problem framing of NRBCs. The arrows indicate the sequence of data production. The numbered arrows indicate the sequence of explanation of the actors' decision preference. The dotted arrows have not been fully investigated. The dashed circles and arrows denote possible future use of the method in action-oriented research. The processes of using PSMs for framing NRBCs are given below. These are therefore the steps used for the implementation of a joint problem framing of NRBCs:

The Steps of Analysis:

(1) Identification of land use changes and potential environmental drivers of NRBCs by using satellite imagery and the use of interviews for validation.

(2) Eliciting and analyzing the framing of actors. Without going into more complex issues of responsibilities and interests of the actors of the NRBCs, the focus here is to derive the languages and the opinions of the actors and how they construct NRBCs in the Niger Delta.

(3) Integration of geo-linked interviews into GIS. The following steps are followed in the integration of geo-linked interviews through MAZQDA software into GIS:

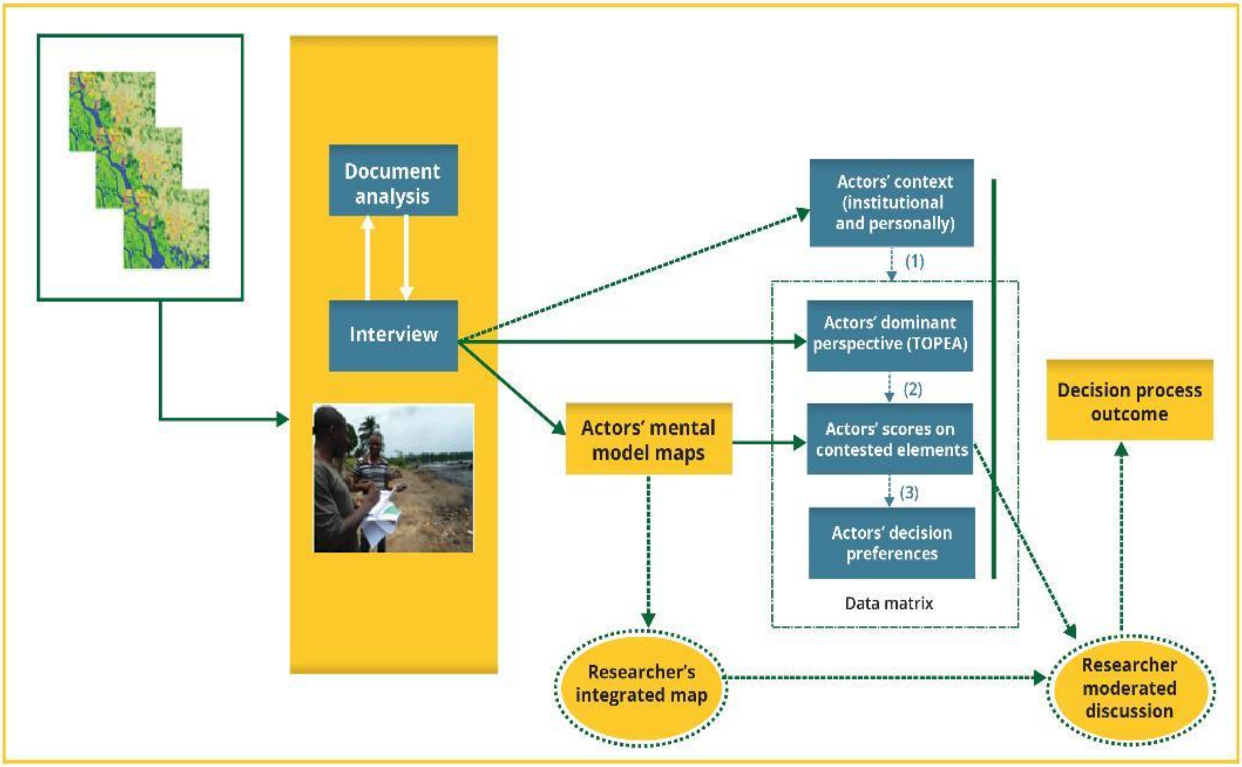


Figure 4.1: Design of problem framing and structuring of natural resource-based conflicts adapted from Kolkman *et al.* (2007).

(i) The first round of coding using one set of field notes generated a codebook with 44 codes under four general themes: environmental drivers, socio-economic drivers, political drivers, legal drivers. Generated codes are drawn from documented interviews and minutes of meetings and workshops with local actors: farmers, youths, NGOs, local politicians, and community leaders. The interviews with case informants had an open character.

(ii) Checking the intercoder agreement. There was an adopted convention for selecting an entire paragraph and applying relevant codes. A coding table for each coder and text were exported from MAXQDA to an excel file in preparation for maps in GIS

(iii) For each text, there was re-inspection of the original data for the discrepancy and consideration of reasons for applying or not applying a particular code

(iv) A focused re-reading of all the passages in field notes and memos

(v) Analyzing geo-referenced spaces and textual data using links to GE- functions in MAXQDA

(vi) Producing conflict maps of actors across conflict vulnerability categories.

4.3 Identification of the Drivers of Natural Resource-Based Conflicts (NRBCs) by the Local Actors

This section presents the results of the joint problem framing.

LULC Results: Figure 4.2 depicts the dynamics of different land cover categories mapped using remote sensing and GIS. Table 4.2 and Figure 4.3 show the land cover classification results and the line graph on the temporal dynamics of the individual classes from 1986-2016. What is clearly evident is a spatially heterogeneous land use and cover changes in the study area under investigation.

Table 4.2: Results of LULC analysis of the study area.

CC(ha)	BU	MF	TF	SF	MF	WB	TC	UC	OT
1986	13,894	51,782	57,428	12,466	85,288	31,817	254,661	1,412	256,073
2000	8,780	75,314	62,871	17,179	58,297	30,549	254,991	1,082	56,073
2016	23,040	26,335	91,649	53,278	34,560	23,517	254,394	1,678	56,073

CC=Cover classes, BU=Built-up, MF=Mangrove Forest, TF=Thick Forest, SE= Secondary Forest, MF=Mixed farmland, WB=Water Body, TC=Total Classified, UC=Unclassified, OT=Overall Total

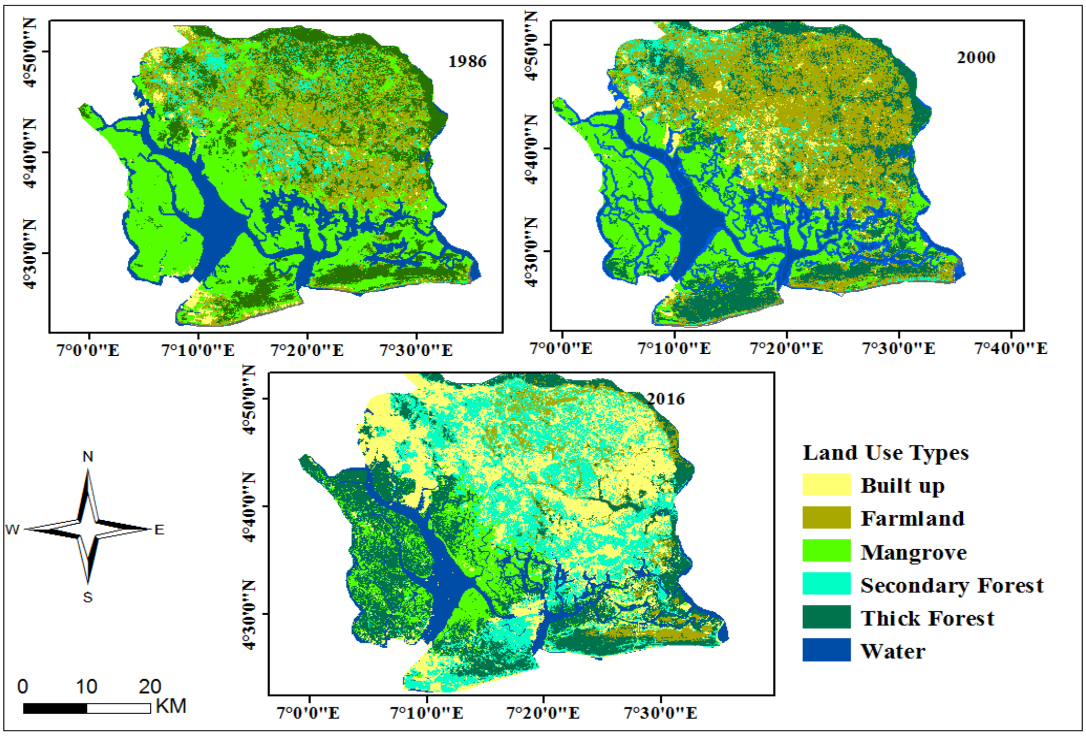


Figure 4.2: Map of various land use types in the study area (1986-2016).

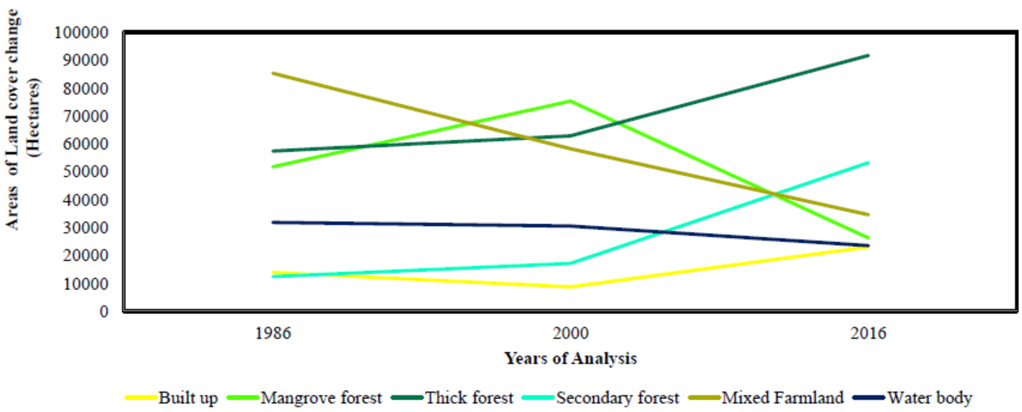


Figure 4.3: Land cover change results for a period of 30 years (1986-2016) in Ogoni and Okrika territories of the Niger Delta

The notable land cover classes that experienced decrease as shown in Figure 4.3 are the mangrove forest and farming related activities. Although the level of education, as can be seen, is not even in all the localities investigated. In 1986-2000, the mangrove increased fairly from 51,782 ha to 75,313 ha, but it reduced to 26,335 ha in 2016. Farmland, on the other hand, reduced consistently from 85,288 ha in 1986 to 58,297 ha in 2000 and went down to 34,560 ha in 2016. In recent times, many of the rural dwellers have shifted their means of livelihood from farming activities to non-agricultural jobs. Many young people now see oil extractive benefits and city life as the order of the day. Many farmers claim that their land no longer produces as before, leading to migration to neighboring communities in search of fertile lands.

The built-up areas decreased from 13,894 ha in 1986 to 8780 hectares in 2000. However, it increased very rapidly in 2016 to 23,040 ha. There are cases of both rural-urban and rural-rural migration i.e. from the villages to the city and from one village to another small village respectively. Built up increase is mainly in localities that are closer to the main city of Port-Harcourt, such as Oyigbo. Furthermore, the reduction of agricultural activities has also led to an increase in secondary forest land cover in the territories investigated. Secondary forest is made up of disturbed land cover by human and extractive activities. Regarding the thick forest, the reason for the increase is due to the introduction of invasive Indo-Pacific palm *(Nypa palm)* believed to be responsible for the replacement of dominant and native mangrove that is a source of livelihoods with high economic value (Udoidiong and Ekwu, 2011). *Nypa palm* trees have taken root in many of the local areas, particularly in Bonny communities. The thick forest increase is also partly due to the fact that the thickly forested areas bear the very similar spectral signature with mangrove forest. Recently, there has been a widespread increase in conservation activities and plantation farms by the government against the will of the villagers which have further led to conflicts between the villagers and government security operatives. Bonny LGA villagers complained that they are no longer allowed to fetch firewood from some of the forests because of government policies. There is no significant increase in the water body. But the mangrove forest decrease is mainly due to rapid dredging activities and land reclamation that has been predominant in Bonny and Andoni communities. This may have reduced the amount of water surface. However, the physical observation and interaction with local people reveal large-scale pollution due to the oil spill in coastal communities.

4.3.1 The Conflicts Drivers Identified by the Actors

Table 4.3 shows the results of in-depth interviews. There is a comparison of all the drivers, the individual drivers/factors and the sum of all factors across the various actors. Figure 4.4 clearly displays an overview of comparison all the drivers of NRBCs under different categories/dimensions, such as environmental drivers (A), socio-economic drivers (B), political drivers (C) and legal drivers (D).

4.3.1.1 Environmental Drivers of Conflicts

As shown in Figure 4.4 the important environmental drivers adduced to NRBCs include loss of fishing (29.0%), oil infrastructure location close to the villages (19.3%), water scarcity (17.8%) and loss of mangrove (11.2%). These seem to be responsible for instigating violence between communities and against the government or oil company representatives. The loss of fisheries correlates with mangrove depletion in the study area. The losses of the non-renewable resources have been greatly adduced to the activities of oil extraction in many villages studied. For instance, a local chief in the Bodo village in the Gokana local community reported:

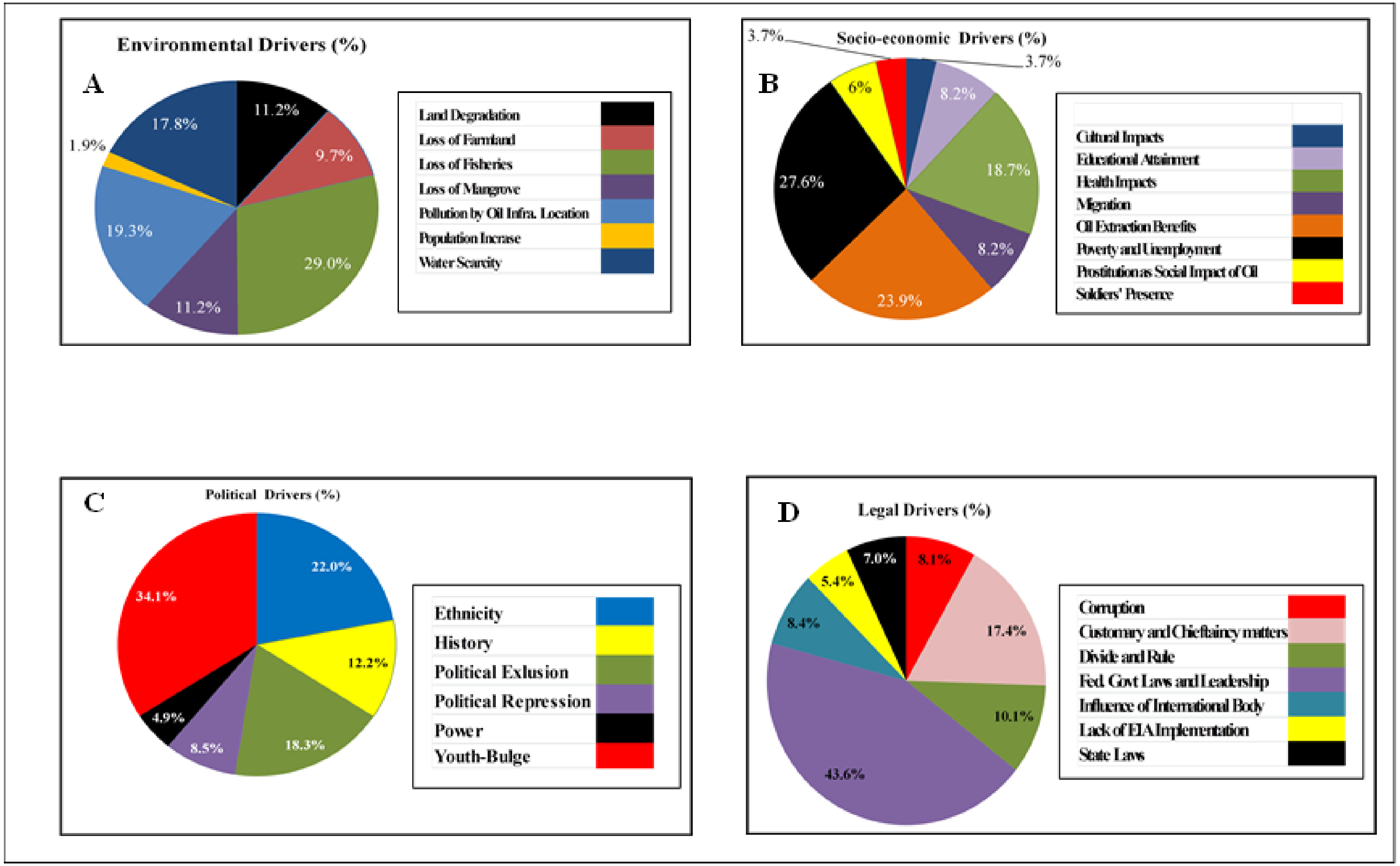


Figure 4.4: Overview of comparisons of all the conflict drivers under the different vulnerability dimensions: environmental drivers (A), socio-economic drivers (B), political drivers (C), legal drivers (D)

> "This community is a naturally blessed community... More than half of Bodo community is surrendered by water. We were used to having spring water, from neighboring villages (Gbe, Kai, Uma, and Jokakrir). We would rush to fetch water when the tide recedes. Then there was no sickness. We were used to drinking spring. Now we always have cholera. We visit hospitals often. Here is a grave (pointing at a grace), we have our suck away pit there and we drink the well water here. If we have to get good water we must travel very far to fetch the clean water. Oil pollution is responsible for this problem." (Community Chief in Bodo).

Thus, as reported in Table 4.3, when compared to other drivers, the environment seems to top the collective drivers of violent resource conflicts. According to a community Chief in Goi village of Gokana community:

> *"More critical issues of conflicts are the environment and socio-economic parts of livelihood. Politics is created by the people. If I am comfortable in my house I will not go out to bother anybody…with land God has given to me, I will not be bothered about politics... We do not have light, but if the environment is in order I will not go to the city to live. I will cultivate the land and live a comfortable life. I can do without politics but I cannot do without the environment. Many people have never been to Port-Harcourt (state capital) in their lifetime. You can politically isolate yourself, but you cannot isolate from the environment. You can be part of politics, but you may not get anything. The main cause of the problem is the environment, not politics. If there was no environmental problem there will be no problem at all… We are predominantly fishermen. ..Our people were living fine. If you are sick, you will receive herbal treatment and be healed." (Community Chief in Goi village of Gokana community).*

Obviously, communities who are predominantly fishers perceive the environment to be a key driver of NRBCs. The environment is their main source of worry that should be addressed before political or socio-economic issues.

4.3.1.2 Socio-economic Drivers of Conflicts

As in Figure 4.4, the socio-economic drivers of NRBCs include poverty (27.6%), oil extraction benefits (23.9%) and health impacts (18.7%). They are also discussed as being linked to the environment. But villagers believe the solution to the NRBCs should be environment first. For instance, polluted villages — due to oil spills, were declared uninhabitable by the government (see Figure 4.5). This made people move to nearby villages.

Figure 4.5: Public notice on villages declared inhabitable due to pollution.

The limited renewable resources, such as forest and farmland often resulted in violent conflicts at the receiving villages. According to one of the local youth leaders interviewed:

> *"We expected them to come and clean the land, but they are not saying anything. If Shell comes now and clean this place and develop it, we will come back to this community. The money they will give to us, we will use it and dig water bore-holes. They should clean the land and give us adequate compensation. The land should not remain like this. The money they will give to us will soon finish. If you continue to spend the money and it does not increase, it will soon finish. The firewood we get from this forest, and the fishes we get from the water, we sell it and pay the school fees for our children. If we leave the land like this and just collect money our children and their children will not forgive us." (Youth Leader, Goi Village).*

As seen in the statement above, the youth's perception of NRBCs is closely related to the views of community leaders. This shows that the consciousness for sustainable resource management has increased over the years in the Niger Delta region.

4.3.1.3 Political Drivers of Conflicts

As clearly shown in Figure 4.4, politically, the main resource conflict drivers mentioned by the actors include youth-bulge (34.1%), ethnicity (22.0%) and political exclusion (18.3%). Some of the local politicians also pointed out that the political problems that instigate conflicts among the communities are also linked to issues of the environment. For instance, an NGO staff and local political activist stated thus:

> *"We do not need to study again. There are many studies that have been carried out but no implementation. There are so many Environmental Impact Assessments (EIAs) but nothing is done about them. The Federal Government is a fraud… Somebody that was nobody is now somebody. If you have connections you get a contract from Nigerian Liquefied Natural Gas Company (NLNG). The rot in the system has been done. The problem with Nigeria is a leadership problem and corruption. There is resistance. The people come out and block the road, preventing people from passing. But the problem is coming from the top. The rules are there. If the rules are well implemented the rural chiefs will comply. The rural chiefs cannot compromise if the Federal government does not compromise". (NGO and Local Activist).*

As seen from the statement, the NRBCs persistence is connected to past management efforts e.g. EIAs were not often implemented, if at all with inadequate consideration of the role of the environment to villagers.

4.3.1.4 Legal Drivers of Conflicts

As shown in Figure 4.4, the key legal drivers of resource conflicts include federal government laws and leadership (43.5%), customary and chieftaincy matters (17.4%), the influence of international organizations (18.7%), and corruption (8.1%). The least important is though the lack of implementation of EIA (5.4%) but the mere mentioning of EIA shows its importance Although the various factors relating to the law show that institutions play a greater role in contributing to conflicts over resources, a comparison of the various dimensions of drivers reveals the order of importance (see Table 4.3).

4.3.1.5 Comparison of Conflict Driver Dimensions (Environment, Socio-economic, Political, and Legal)

This section shows the results of further analysis of the comparison of the actors' perception of the conflict drivers. Table 4.3 clearly shows that under the environmental drivers, the community leaders have the highest perception (28.95%), followed by the farmers (26.64%) and the youths (25.9%), the least was that of politicians (8.88%). The high perception of the community leaders is because the community leaders claim to be supporters of the cause of the people. The low perception of the environment as a driver of NRBCs is not surprising because the politicians often protect the interest of the government. Regarding the socio-economic drivers, the highest percentage by farmers is (30.61%), followed by the youths (23.81%), the NGOs (20.41%), and the lowest given by the community leaders is (10.20%). The community leaders do not seem to attribute NRBCs to socio-economic drivers. However, the farmers attach great importance to the presence of the soldiers, as they complain that this makes them feel insecure. The soldiers sometimes rape their women which often increase anger and instigate violence. On the political drivers, the farmers (0.0%), and NGOs (0.0%) do not seem to attribute NRBCs in any way to political issues. However, farmers still consider history to be an important driver of conflicts.

Table 4.3: Comparison of all actors' perception of drivers of resource conflicts.

	Actors = CL	Actors = F	Actors = N	Actors = P	Actors = Y	SUM (%)
All Environmental Drivers	**64.44**	**4.44**	**2.22**	**17.78**	**11.11**	**100.00**
Water Scarcity	26.09	50.00	10.87	0.00	13.04	100.00
Population Increase	60.00	20.00	0.00	0.00	20.00	100.00
Land Degradation	37.93	13.79	3.45	20.69	24.14	100.00
Loss of Fisheries	17.33	32.00	14.67	0.00	36.00	100.00
Loss of Mangrove	20.69	24.14	17.24	6.90	31.03	100.00
Loss of Farmland	20.00	28.00	8.00	16.00	28.00	100.00
Pollution Due to Oil Infrastructure Location	18.00	26.00	8.00	14.00	34.00	100.00
Sum	**28.95**	**26.64**	**9.54**	**8.88**	**25.99**	**100.00**
	Actors = CL	**Actors = F**	**Actors = N**	**Actors = P**	**Actors = Y**	**SUM (%)**
All Socio-economic Drivers	**61.54**	0.00	0.00	**30.77**	**7.69**	**100.00**
Poverty and Unemployment	2.70	18.92	29.73	24.32	24.32	100.00
Oil Extraction Benefits	3.13	59.38	0.00	28.13	9.38	100.00
Educational attainment	0.00	18.18	18.18	0.00	63.64	100.00
Cultural Impacts	0.00	0.00	100.00	0.00	0.00	100.00
Prostitution as social impacts of oil	0.00	0.00	100.00	0.00	0.00	100.00
Soldiers Presence	0.00	100.00	0.00	0.00	0.00	100.00
Migration	0.00	18.18	36.36	0.00	45.45	100.00
Health-Impacts	20.00	40.00	0.00	0.00	40.00	100.00
Sum	**10.20**	**30.61**	**20.41**	**14.97**	**23.81**	**100.00**

	Actors = CL	Actors = F	Actors = N	Actors = P	Actors = Y	SUM (%)
All Political Drivers	**57.14**	0.00	0.00	**14.29**	**28.57**	**100.00**
Political Exclusion	46.67	6.67	6.67	20.00	20.00	100.00
Power	100.00	0.00	0.00	0.00	0.00	100.00
History	20.00	50.00	0.00	20.00	10.00	100.00
Ethnicity	77.78	0.00	0.00	0.00	22.22	100.00
Political Repression	0.00	0.00	0.00	71.43	28.57	100.00
Youth-Bulge	14.29	7.14	50.00	3.57	25.00	100.00
Sum	**39.33**	**8.99**	**16.85**	**13.48**	**21.35**	**100.00**
	Actors = CL	**Actors = F**	**Actors= N**	**Actors = P**	**Actors = Y**	**SUM (%)**
All Legal Drivers	0.00	0.00	0.00	**100.00**	0.00	**100.00**
Federal Govt. Laws and Leadership	7.69	27.69	4.62	52.31	7.69	100.00
Corruption	41.67	0.00	8.33	50.00	0.00	100.00
Divide and Rule	73.33	6.67	0.00	6.67	13.33	100.00
Influence of International Body	0.00	7.14	0.00	92.86	0.00	100.00
Lack of EIA Implementation	0.00	0.00	0.00	100.00	0.00	100.00
State Laws	0.00	33.33	33.33	33.33	0.00	100.00
Customary and chieftaincy matters	23.08	11.54	19.23	34.62	11.54	100.00
Sum	**18.00**	**17.33**	**8.00**	**50.00**	**6.67**	**100.00**
N (Documents)	**10.00**	**11.00**	**8.00**	**10.00**	**11.00**	0.00

CL=Community Leaders, F=Farmers, N= NGOs, P=Politicians, Y=Youths

4.3.2 The Integration of Qualitative Methods into GIS: Comparison of Actors' Mental Maps

Figures 4.6-4.10 show the mental maps of the actors: Community leaders, Farmers, NGOs, Local politicians, and Youths: The results show that NRBCs are influenced by the cultural perception of nature and are socially molded (Martinez-Alier, 2009b). Assessing the NRBCs in terms of valuation and knowledge of actors enables us to better comprehend the various dimensions for possible specific intervention policies (Martinez-Alier, 2009b). For instance, intervention policies will be better informed if we are able to differentiate between the disagreements that can be controlled and solved via technical measures or bargaining over those to be addressed using monetary compensations (Avcı *et al.*, 2010, Martinez-Alier, 2013, Badera and Kocoń, 2014).

1. The Community Leaders' Mental Map: Figure 4.6 shows that community leaders associate conflict more to the environment than to any other drivers, due to reasons similar to that of the farmer's mental maps. This is because the majority of the community leaders still engage in farming. The community leaders' consciousness for the environment in terms of conflicts is highest in the Khana community area (80%).

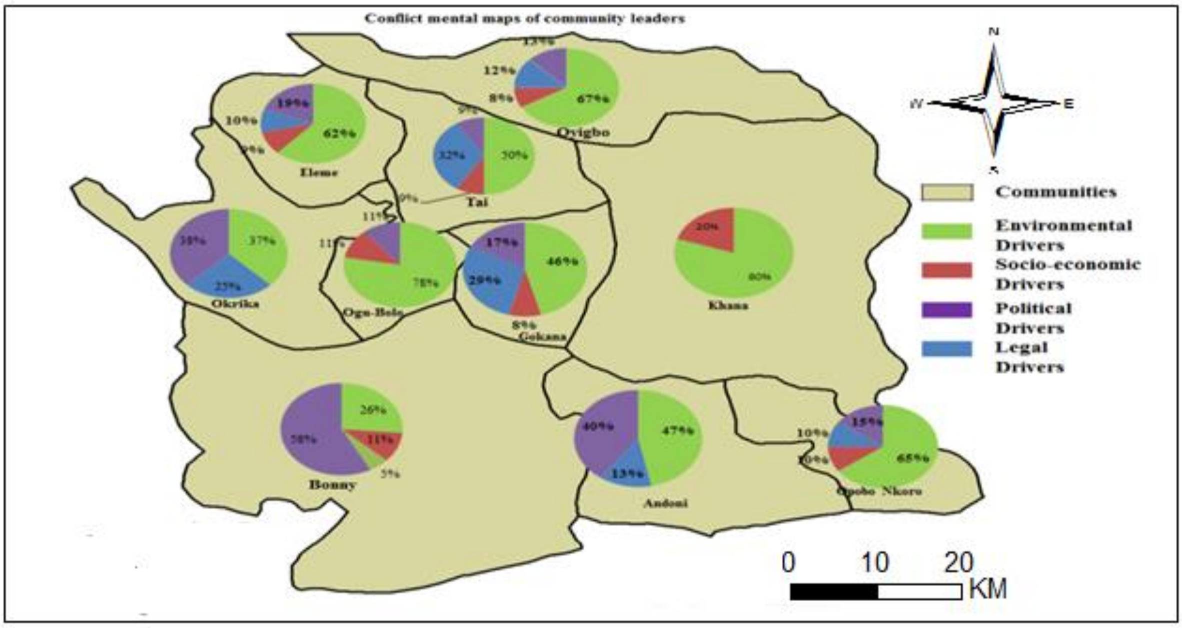


Figure 4.6: Community leaders' mental map of conflicts.

2 The Farmers' Mental Map: Figure 4.7 shows the farmers' mental map of NRBCs. As expected, the farmers perceive conflicts to be more associated with environmental factors. In Ogu-bolo for instance, the entire farmers perceive NRBCs to be mainly associated with environmental drivers. Farmers merely did not link NRBCs to legal and institutional factors, except in Andoni where 84% of the interviewed farmers referred to legal factors as drivers of NRBCs. In other communities where the legal factors were mentioned, is far less than 50%. Farmers in upland communities attribute conflicts more to the environment than the coastal areas. However, spatiotemporal evaluation proved that NRBCs diffuse towards the coastal areas (see Section 6.5.3). Arable crop farming activities have reduced greatly in such communities due to the scarcity of productive lands arising from oil pollution. This clearly shows that the migration seemed to be coastward.

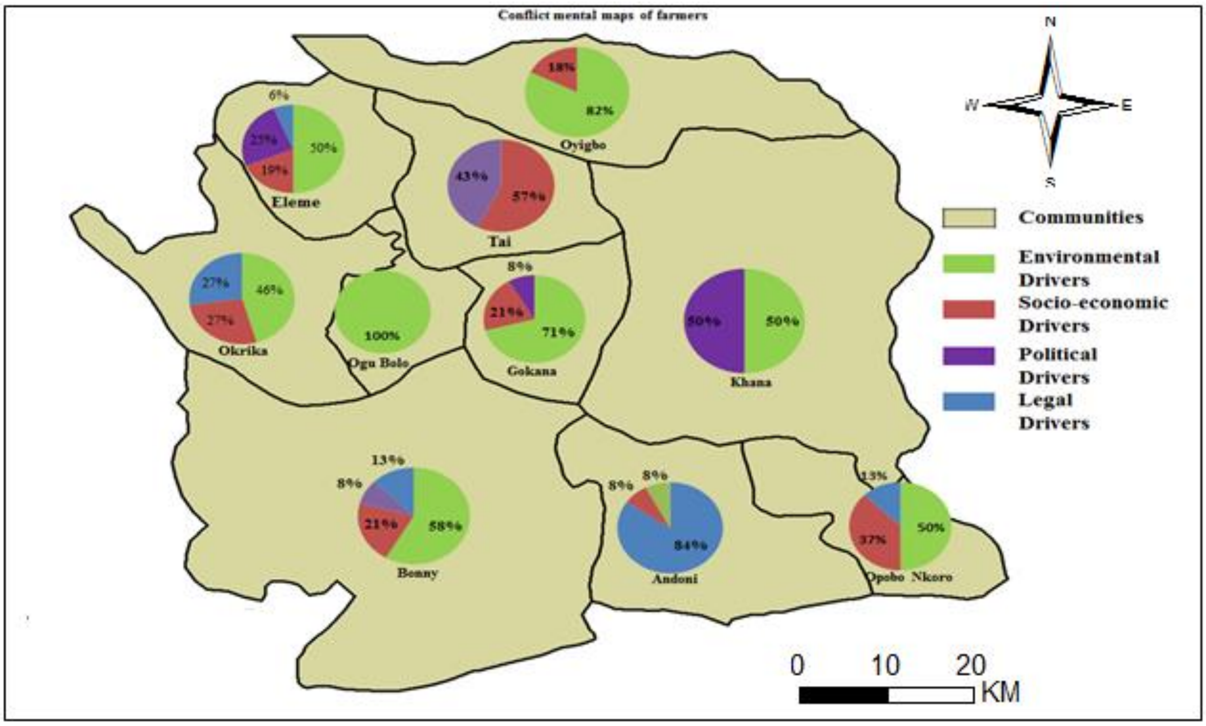


Figure 4.7: Farmers' mental map of conflicts.

3. The NGOs' Mental Map: Figure 4.8 shows that with the exception of Eleme, NGOs do not associate conflicts so much with environmental compared to socio-economic issues such as poverty, low education.

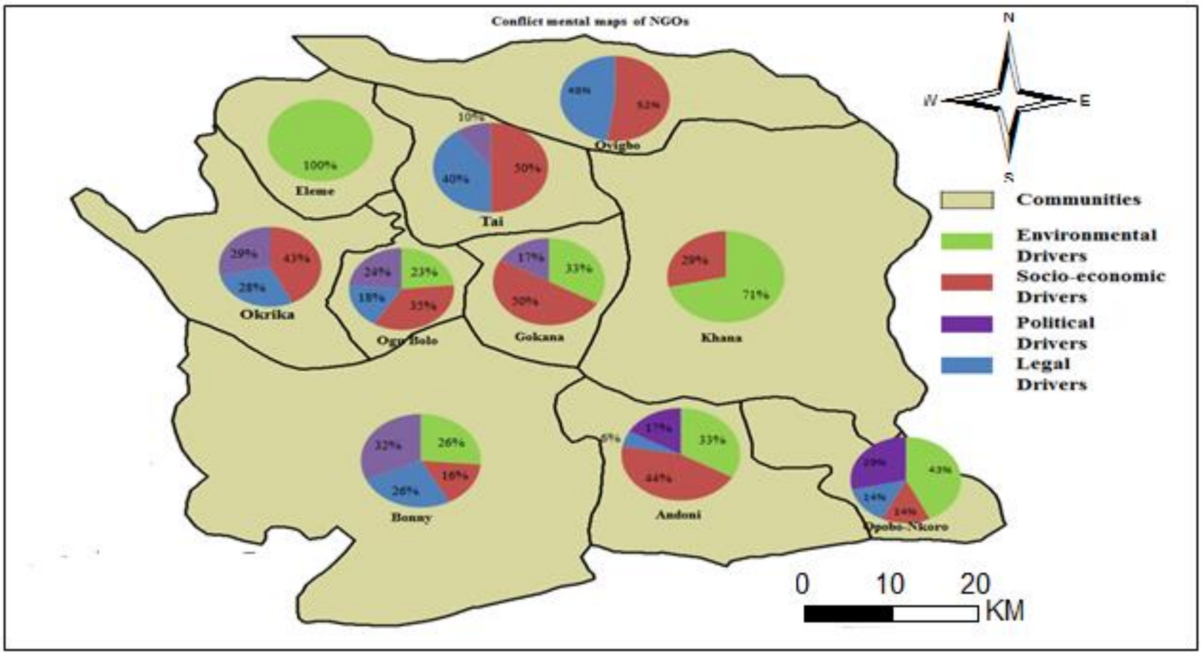


Figure 4.8: NGOs' mental map of conflicts.

4. The Politicians' Mental map: Figure 4.9 shows the local politicians' mental map of conflicts. Politicians do not see environmental issues to be significant drivers to conflict occurrence rather as shown on the map, conflict is seen to be more associated with legal issues such as EIA regulations, Land Use Act etc.

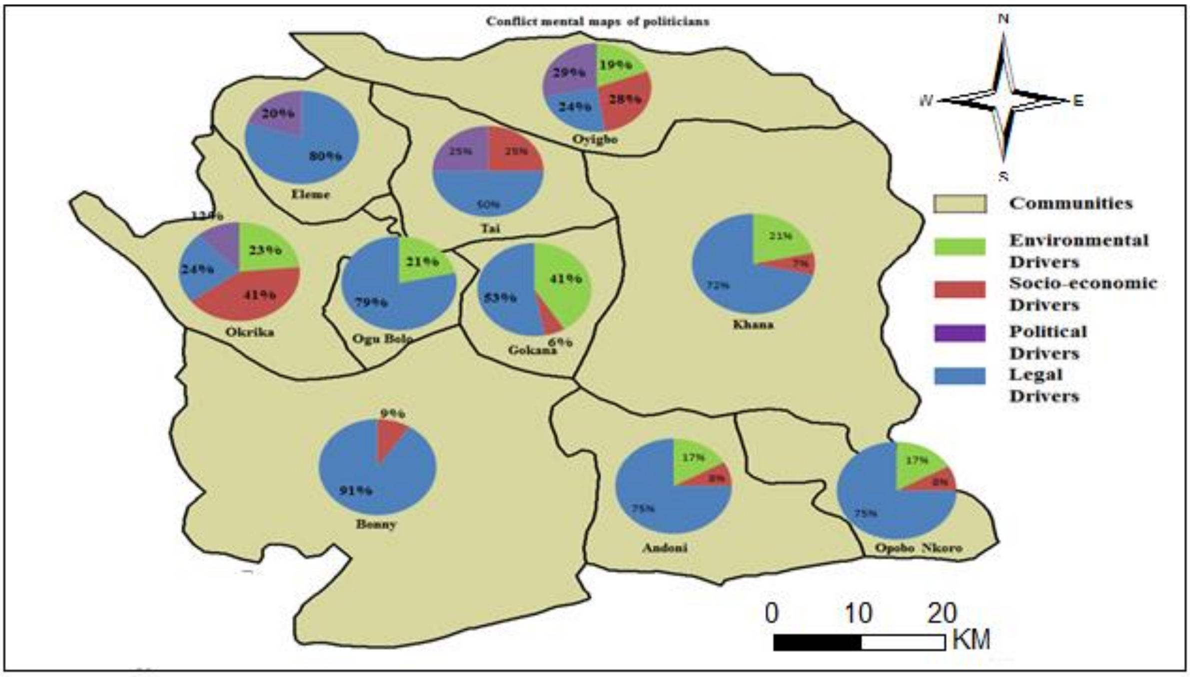


Figure 4.9: Local politician's mental map of conflicts.

5. The Youth's mental map: Figure 4.10 shows a youth's mental map of conflicts. The youths' mental map remarkably shows that more youths around the coastal communities emphasize the environment. For instance, Gokana, Andoni and Bonny, attributed 90%, 74%, 70% to environmental issues respectively. These can be explained with the understanding that though farming is decreasing generally, but youths around the coast are still very much attached to fishing. Although this is now affected by oil pollution and mangrove depletion.

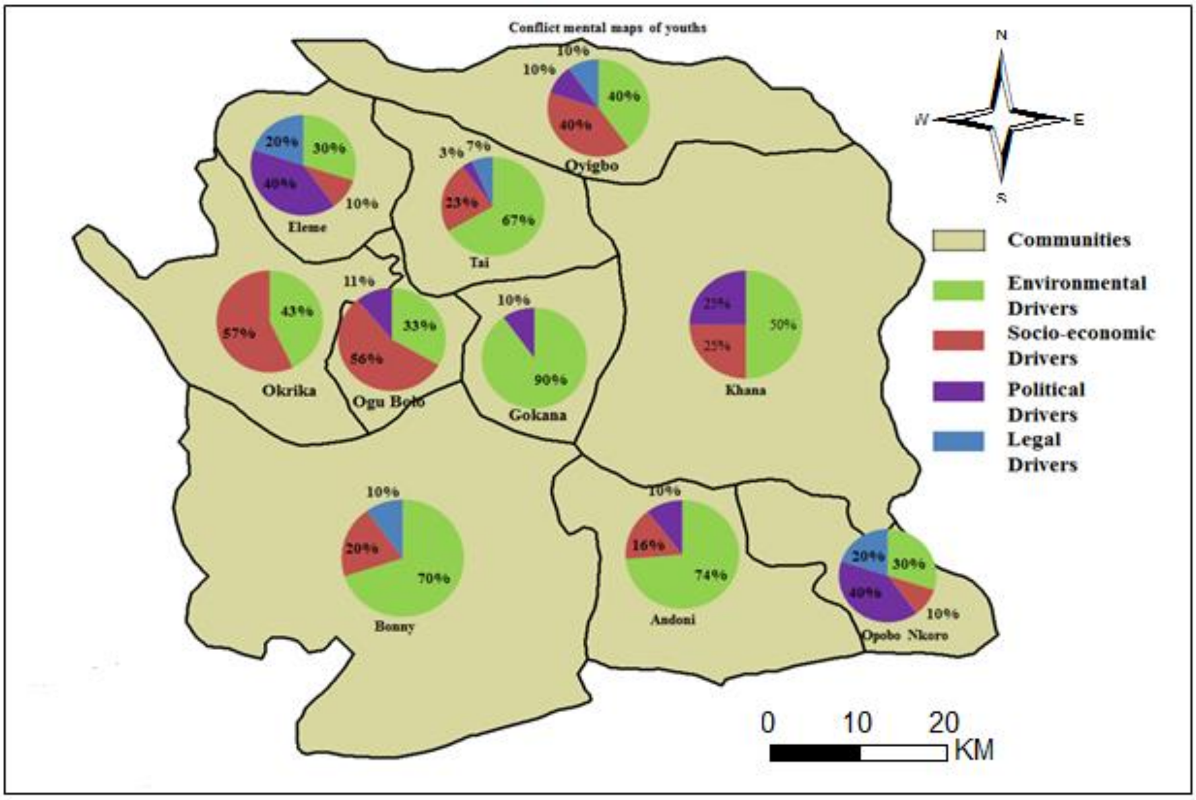
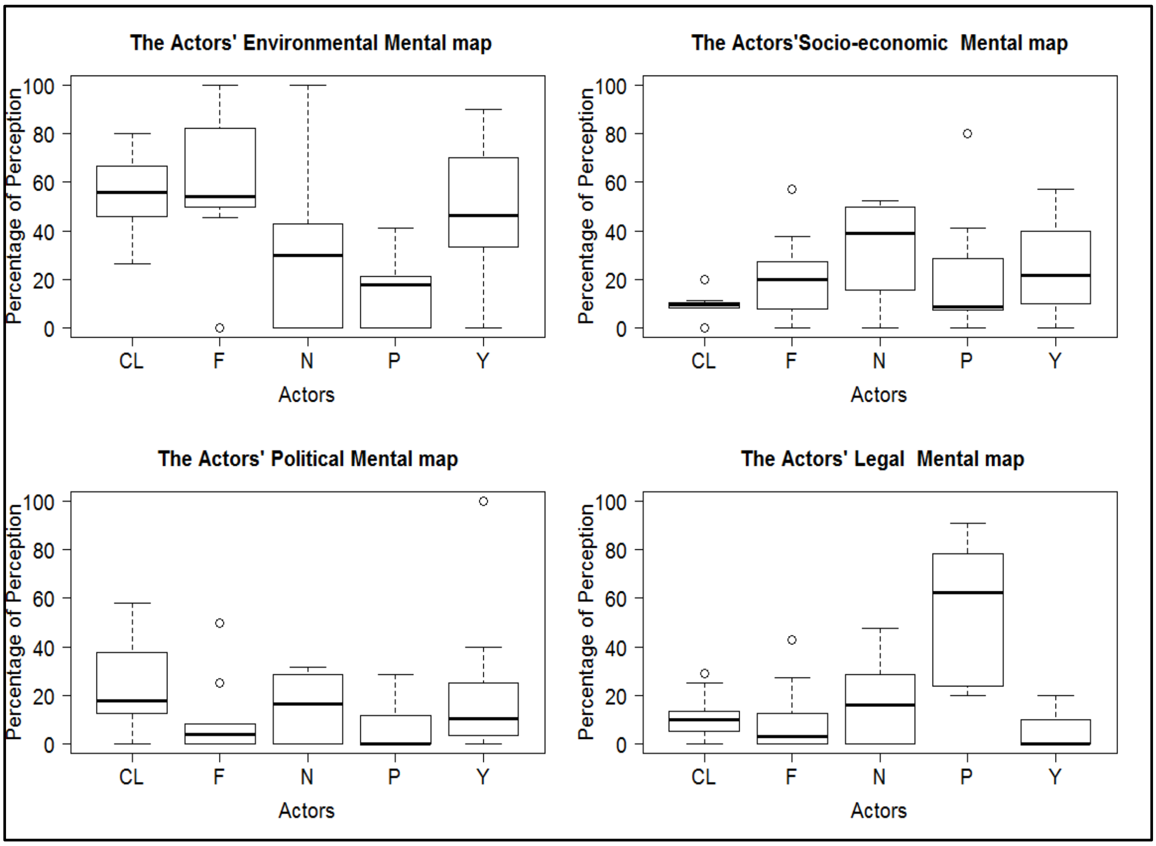


Figure 4.10: Youths' mental map of conflicts.

4.3.3 Differences in Actors' Mental Maps

The differences in the perception of the actors regarding NRBCs in the Niger Delta region suggest the complexity and trade-offs involved in the problem of NRBCs. Boxplots in Figure 4.11 give an idea about the similarity and differences in the perception of the actors in terms of the various drivers of environmental, socio-economic, political and legal drivers of conflicts. As shown in Figure 4. 11, one can identify the similarity among the difference in the mean levels of actors' perception. Although the pattern does not seem to be very distinct, it is obvious that community leaders, farmers, and youths are very close in their knowledge of the events of resource conflicts. As stated in Reed et al. (2009), similarities in the actors or stakeholders are traceable to their interest. Under the environmental drivers, the highest mean is that of farmers followed by the youths. On the socio-economic drivers, the highest mean is that of the NGOs followed by the youths. On the political drivers, the highest mean is that of community leaders followed by the youths. On the legal drivers, the highest mean is that of politicians followed by the NGOs. The youth's aggression in the area is reflected in their responses in almost all the drivers.



Actors: CL=Community Leaders, F=Farmers, N=Non-Governmental Organizations, P=Politicians=Youths.

Figure 4.11: Boxplots on the differences in actors' mental maps for the environmental, the socio-economic, the political and the legal drivers.

4.4 Operationalizing the Vulnerability to Natural Resource-based Conflicts

From the joint problem framing, the model inputs are determined. The model inputs are then selected by considering the available data through the various sources of data collection (see Section 5.2.1). Also considered are the feasibility of operationalizing the variables with less difficulty (e.g. the legal dimension was not included in the model), and the cases where consensus was not reached in previously tested hypotheses. Information from an extensive literature search from international and local research on NRBCs was used to operationalize and parameterize the model input variables (see Table 4.4).

Table 4.4: Operationalizing vulnerability assessment of NRBC.

Conflict Vulnerability Component/	Conflict Drivers / Factors	Operationalization			
		Conflict Indicators (Past Studies)	Source	Resolution	Conflict Indicators (Current Study)
	Mangrove Loss	% of change of forest	Hauge and Ellingsen (1998)	Large-N	Weighted dist. to mangrove forest
Environmental risks-exposure to conflicts		Log (distance.)	Tollefsen and Buhaug (2015	grid cell	
	Farmland loss	Severity of land degradation	Hauge and Ellingsen (1998)	Large-N	Weighted dist. to farmland
	Water	The ratio of (upstream and downstream)	Tollefsen and Buhaug (2015	grid cell	Weighted dist. to less polluted water
		Coding of countries crossed with rivers	Kalbhenn (2012)		
	Oil infrastructure	% of oil and gas location	Lujala *et al.* (2007)	Large-N grid cell	weighted dist. to oil infrastructure
			Buhaug and Rød (2006)		
		Dist. to oil location		grid Cell	
	Poverty	GDP	Collier and Hoeffler (2004)	Large-N	weighted % of multidimensional measure of poverty
Socio-economic Vulnerability to conflicts		Weighted welfare index (Multidimensional poverty)	Hegre *et al.* (2009)	Grid cell	
	Education level	% male educational level	Barakat and Henrik (2008)	Large-N	weighted % of educational level
	Migration level	Qualitative	Homer-Dixon (1994)	Large-N-	weighted

			Black and Sessay (1998)	(selection of cases)	% of migration level
		Perception of push and pull factors	Ezra and Kiros (2001)	National	
	Oil Benefits	% of satisfaction with CSR projects	Idemudia (2009a)	Regional	
		% of acceptance of community reciprocity	Idemudia (2014)	Regional	Weighed % of benefits from oil companies in communities
Political Vulnerability to conflicts	Political Repression	Binary measure of perception of repression over the state	García-Ponce and Pasquale	Large-N	Weighted % of perception of community repression
	Political exclusion	The 5-point scale of ethnic group's level of exclusion	Rustad *et al.* (2011)	National	Weighted % perception of community exclusion
		Binary (years of ethnic group exclusion and otherwise)	Asal *et al.* (2015)	Large-N	
	Ethnic Ethnolinguistic Fractionaliz (ETLF)	Index of ETLF	(Cederman and Girardin, 2C	Large-N	Weighted % of the Perception of ETlF
		Binary (ethnic groups)	Hegre *et al.* (2009)	Grid cell	
	Youth-Bulge	% of males within 15-24 year	Urdal (2001)	Large-N	Weighted % of of the influence males between 15–24-years on conflicts
		15–24-year-olds relative to the total adult pop. (15 years and above).	Urdal (2006)	Large-N	

Fuzzy Conflict Data (FUZZYCONDATA) is developed for the model input variables (see Section 5.2.4). In FUZZYCONDATA, the spatial information is a key attribute. As shown in Section 5, based on the information from vulnerability literature, the selected parameters for modeling the SEFLAME-CM are conveniently grouped under the external (environmental risks) and the internal component of vulnerability, i.e. the socio-economic and the political dimensions. The environmental systems refer to biophysical processes while the social systems are also made up of rules and institutions that mediate human use of resources. In addition, the social systems are made up of the systems of knowledge and ethics that interpret the natural systems from a human perspective (Berkes and Folke, 1998, Berkes *et al.*, 2000). See also Gleditsch (1998), and Bernauer *et al.* (2012) for the analysis of NRBCs as a socio-economic, political and environmental system. See Sections 4.4.1, 4.4.2, and 4.4.3 for discussions on the drivers of NRBCs from the past empirical studies) Appendix A.12.3 shows all the equations for the parameterization of the model inputs.

4.4.1The External Component of the NRBCs: Environmental Dimension

(1). Access to Mangrove Forest Products: Forest and conflicts have been conceived in two main dimensions. The spatial restriction on conflicts/insurgency due to physical inaccessibility of forested areas and dependence of forest as ecosystem service by communities (Le Billon, 2001). In the case of the forest as a physical geographical entity, the forest could be a safe haven for the insurgency. But forests as an ecosystem service are conceived as a useable product and livelihood-dependent ecosystem service. Communities are vulnerable to conflicts due to dependence on resources. In this case, resource-linked armed conflicts are seen as a historical process of dialectic transformation of nature and social group (Le Billon, 2001). For example, indigenous people of the Niger Delta region have a strong historical attachment to the use of renewable resources such as mangrove. Thus, they resist activities that affect the continuous availability. Such resistance can be in the form of conflicts with the neighboring communities or resistance of the multinationals, government representatives.

(2).Surface Water. Water scarcity, environmental degradation are connected to interstate armed conflicts (Hauge and Ellingsen, 1998). Water scarcity including other factors of environmental degradation has direct and positive effects on the incidence of conflicts (Hauge and Ellingsen, 1998). For example, large-scale degradation and pollution of water surface due to negative impacts of resource extractive activities (e.g. oil) may generate tension and encourage resistance by the affected group. But systematic empirical analyses suggest that transboundary waters are associated with low-level conflicts, but not with full-scale “water wars” (Gleditsch *et al.*, 2006). In contrast, Kalbhenn (2012) reports that states tend to cooperate rather than fight over their shared water resources and that most international water conflicts are not full-scale wars, but rather diplomatic tensions. Intrastate empirical studies have shown clearer evidence of water scarcity and conflicts (Raleigh and Urdal, 2007). Recent link between climate change and rainfall significance have revealed that in Africa, countries face freshwater availability problems in connection to the likeliness of civil conflict (Raleigh and Urdal, 2007). Studies inform the need for new approaches. For example, Magnus Theisen (2008) did not find the results of Hauge and Ellingsen (1998) replicable, except that a very high level of land degradation could increase the risk of large-scale NRBCs.

(3). Access to Farmland: Land plays two key roles in the traditional African context: the cultivation of land is a main source of livelihood and there is a strong cultural attachment.

There are problems of shortage of cultivable land due to land degradation, weak land governance structures, and large-scale acquisition of land by foreign investments in Africa (Osabuohien, 2014). Osabuohien's (2014) showed how local institutions are undermined by large-scale foreign investors over land. Therefore the struggle for the available productive lands increases the likeliness of NRBCs. Three typologies of "environmental scarcity": "Supply-induced scarcity", "Demand-induced scarcity" and "Structure-induced scarcity" explain the complex interaction of arable land and conflicts (Homer-Dixon, 1994).

(4). Environmental Impacts of Oil Extraction: Until recently there exists a disagreement on how hydrocarbons affect conflicts. Scholars have ascribed this challenge to the lack of data collection methods and the measurements of oil extraction and conflicts (Lujala *et al.*, 2007). Political ecology and development researchers have relied increasingly on the use of qualitative approaches (Bernauer *et al.*, 2012). There is a proposal in empirical research for new data and approach at a micro scale (Lujala *et al.*, 2007), called PETRODATA. This is a new dataset on hydrocarbon reserves and production that facilitate unraveling how natural resources affect conflicts. Although spatial information was the key feature of PETRODATA, much has not been addressed on the link between the environmental impacts of oil extraction and how it affects the local conflicts. Oil extraction drives degradation e.g. pollution of land, water, and air, and where oil infrastructures are located attract local attention and constitute main sites for protests.

4.4.2 The Internal Components of NRBCs

4.4.2.1 Socio-economic Dimension

(1).Level of Poverty: Empirical studies on conflicts have addressed economic development or poverty as a cardinal factor of armed conflicts. For example, Collier and Hoeffler (2004) compared income levels of different countries and the viability of rebellion movements through opportunity costs for rebels. Fearon (2005) maintained that GDP per capita is a proxy for state capacity, indicating that richer regimes are better able to monitor the population and implement effective counterinsurgency strategies. Collier and Hoeffler (2004) measured poverty by using traditional GDP in Large-N studies and ignored the local conditions where conflicts actually occur. Since conflicts are local, hence GDP does not account for income differences or different dimensions of well-being in a country or region. In less developed countries such as Nigeria, where many people are part of the informal sectors; assets could capture variations in welfare than GDP per capita (Filmer and Pritchett, 2001). Further, poverty has been described as naturally multidimensional and dynamic in space by reputable studies (Alkire and Foster, 2011). Other factors related to poverty include child mortality, nutrition, electricity, sanitation, household drinking water, floor type, cooking fuels and assets which can be generated through the citizens' perception of poverty. The emphasis on multidimensionality and disaggregation has led to the use of geographically referenced data from the Demographic and Health Survey (DHS) and national censuses (Hegre et al., 2009). Poverty is therefore conceptualized as a multidimensional parameter of armed resource conflicts in this work.

(2).Level of Education Attainment. The role of educational factors in explaining conflict likeliness in post-conflict management and prevention has engaged the attention of academics and policymakers (World Bank, 2009, Oyefusi, 2010). According to Barakat and Henrik (2008), higher secondary education reduces conflict risk in the context of large cohorts of young males. The renewed interest in the relationship between educational variables and conflict has shown

that there have been contradictory views of the authors. Oyefusi (2010)'s study in the Niger Delta showed that individual and community-level factors would influence the disposition to engage in violent conflicts. In addition, the combination of other factors and the type of violence involved: whether community-based land-related conflicts or youth disturbance over resources will determine the potency of education as a conflict factor. For example, the individuals with higher educational attainments or higher earnings from legitimate work are likely to be less willing to participate in militarized struggle or low-level violence and oil-related crime, because of the high opportunity cost of participation (Lochner, 2004). In addition, while low education in communities with high youth-bulge may increase conflicts, this may not be the case in those communities with low education but have very few youths who lack the population strength to organize protests against resource extraction externalities.

(3).Level of Resource-Induced Migration: It is generally agreed that internal and international migration is a frequently observed coping response to environmental pressures such as environmental degradation/scarcity (Tamondong-Helin and Helin, 1991, Suhrke, 2004, Bardsley and Hugo, 2010, Laczko, 2010). But how this result to conflicts has not received any consensus. Individuals decide to migrate if the net benefit (total benefit minus total cost) from migrating is higher than that from not migrating (Reuveny, 2007). It is suggested that environmentally induced migration can lead to conflict in receiving areas because of competition for scarce resources, economic opportunities and exacerbation of socio-economic "fault lines" (Raleigh *et al.*, 2008). But this is also dependent on other challenges, such as the degree of degradation, environmental pressure and other determining factors that mediate between migration and conflicts. Also the type of conflicts taking place in both the source and receiving region. And the different causes of migration and the challenge of isolating them from one another. Nordås and Gleditsch (2007) argue that the case of environmental scarcity, migration, and conflict is unique that there is no systematic evidence yet for a general link between migration and conflict. Thus, migration-receiving villages with high population and youth-bulge are likely to experience higher conflicts than those migration-receiving villages with low population and low youth-bulge.

(4).Level of Oil Extractive Benefits: Industrial and extractive activities such as oil extraction have an increasing impact on the local economic development of the host communities. Firms have the strategic responsibilities of setting up development projects in communities where they operate. This is generally referred to as Corporate Social Responsibility (CSR) in development literature. Because of community expectations from firms, a company that ignores community expectations does so at its own peril (Burke, 1999). From the model of CSR, the quality of improved livelihood is based on the judgment of the communities, but not based on the number of projects executed or started in a certain community. The level of perception of the wellness of a community largely determines the level of the disposition of communities to violent activities (Idemudia, 2009a). Communities can be poorly perceived on the benefits of CSR projects even though the CSR projects still exist.

4.4.2.2 Political Dimension

(1).Level Political Repression: Political repression is the persecution of individuals in a group for political reasons, particularly for the purpose of restricting or preventing their ability to restrict the political freedom of a society (García-Ponce and Pasquale, 2015) An example could be the "…brutal murder of the late mouthpiece and activist of the Ogoni ethnic evolutional or social

movement activities, Ken Saro-wiwa in the Niger Delta" (Brittain, 2015). Political repression is capable of generating violent conflicts when the ethnic group involved in the majority among other ethnic groups.

(2).Level of Political Exclusion: Political exclusion is the domination of groups against the interest of the other groups. Exclusion of communities is capable of generating grievance which can trigger conflicts (Collier and Hoeffler, 2004). However, the occurrence of conflicts as a result of exclusion is still dependent on other political and socio-economic variables such as youth-bulge and the level of ethnolinguistic fractionalization. Douma (2006) remarked that inter-group violence in Sub-Saharan Africa is likely to be the outcome of a political process whereby some local groups take on other groups living in the same region, mostly as a proxy war for conflicts resulting from the uneven impact of state policies concerning resource exploitation. Political exclusion, particularly at microscale is therefore connected to the socio-economic benefits of resources extracted from communities.

*(3).Ethnic Linguistic Fractionalization (*ETLF)*:* Large-N studies show that Ethnic fractionalization matters in political instability and NRBCs (Alesina. et al., 2003). Alesina. et al. (2003) reported that in more ethnically fragmented communities, the provision of public goods is less efficient, the participation in social activities and trust is lower, while the economic success, measured by growth of city size is inferior. Some approaches can be used to measure the ETLF. There is the index of fractionalization approach and the measure of polarization approach. But I followed the former because of its simplicity. The measure of ethnic fractionalization is given by the logic that the probability that two randomly drawn individuals from the population belong to two different groups. The ETLF is based on the Herfindahl concentration formula as stated below (Alesina. *et al.*, 2003, Hegre and Sambanis, 2006, Cederman and Girardin, 2007).

$$\text{ETLF} = 1 - \sum_{i=1}^{n} s_i^2 \qquad \textit{(Equation 4.1)}$$

where

S_i	=	The share of group i
n	=	Total of n groups

Theoretically, a maximum ETLF index is reached (at the value of 1) when each person belongs to a different group. Hegre et al., (2009) constructed a disaggregated (regional) version of the widely used ETLF index as a measure of ethnic diversity using GIS functionalities, and concluded that in order to calculate the ETLF index, one requires data on the location of each ethnic group as well as population counts. ETLF was therefore combined with the weight assigned by the actors during fieldwork before the GIS input was generated. See Appendix A.12.10 for the equation for deriving ETLF in combination with Equation 4.1 above. The procedure for combining the rating and the generated data is illustrated in Section 5.2.3.

(4).Youth Bulge: The effects of population growth and density on environmental degradation are commonly used but we have to look beyond these crude population measures (Urdal, 2001).

Youth-bulge is referred to as the large cohorts of young people. This can make societies more conflict-prone (MacCulloch, 2003, Urdal, 2006). However, what is not agreed is how youth-bulge is measured and the relationship between youth-bulge and degree of conflicts. MacCulloch (2003) revealed that the likeliness of supporting revolt are higher with younger, lower income distribution or with the unemployed youths who have strong differences across ideological lines. The study by Oyefusi (2010) on the Niger Delta, for instance, showed how high youth-bulge, educational attainment, and income, increase willingness to participate in the armed struggle.

Having all the information from the various literature on parameterizing the model inputs presented, next to the joint problem framing results is the description of the model-SEFLAME-CM. Section 5, therefore, presents details of the model, the drivers and how the parameters are quantified for implementation.

5 The Coupling Process of SEFLAME- CM: A Spatially Explicit Fuzzy Logic Adapted Model for Conflict Management

Implementation of the theoretical considerations described in Section 3 is presented. There the complexity of the issue of Natural Resource-based Conflicts (NRBCs), the importance of the concepts of risk, vulnerability, resilience, a description of the holistic vulnerability assessment (HVA) and the value of fuzzy logic and the spatially explicit considerations of NRBCs were recognized and the existing sources fully reviewed and discussed. Also, the problem domain of NRBCs was analyzed and framed in Section 4. In order to show, in the selected test sites, the full power of the transdisciplinary-based coupled approach, which combines the findings of Section 3, and that of Section 4, I implemented an algorithmic model called the Spatially Explicit Fuzzy Logic Adapted Modelling for Conflict Management (SEFLAME-CM). This Section, therefore, explains this model in detail. It begins with the overall methodology of this thesis. It describes the methodological procedures of the research which is an integration of methods from the natural sciences such as (remote sensing and GIS) and the social sciences such as (human geography, political science, and social psychology), and the local knowledge integration. The second part deals with the implementation of the steps of SEFLAME-CM and how NRBCs drivers and parameters are integrated into the model to derive the validated results in Section 6.

5.1 The Spatially Explicit Fuzzy Logic Adapted Modelling for Conflict management (SEFLAME-CM)

The model-SEFLAME-CM (A Spatially Explicit Fuzzy Logic Adapted Modeling for Conflict Management) simulates the drivers of natural resource-based conflicts (NRBCs). The conflicts in this context include both the non-violent conflicts and the violent conflicts associated with natural resources (see Section 2 for details on the studied conflicts in the selected test sites). The goal of SEFLAME-CM is to develop a tool for sustainable conflict management (CM) that is holistic and that integrates knowledge from disciplines and from the society (the community actors as representatives). SEFLAME-CM uses both qualitative and quantitative data sets and consists of six specific steps, developed based on the three broader phases of transdisciplinary approach by Mauser *et al.* (2013) (see Section1.4):
Phase 1: co-design (see step 1 in Figure 5.2),
Phase 2: co-production (see steps 2, 3, 4, and 5 in Figure 5.2) and
Phase 3: co-creation of the scenario and co-dissemination of co-produced knowledge of CM (see step 6 in Figure 5.2).

As described in Section. 4.4, the selected NRBCs drivers for modeling are grouped under three vulnerability categories/dimensions. These are the environmental, the socio-economic and the political drivers of conflicts. Among these categories, the environment is referred to as the external dimension of vulnerability while the socio-economic and political dimensions are referred to as internal vulnerability dimensions. The different dimensions constitute what is referred to in the literature as the holistic Vulnerability Assessment (HVA) otherwise called the "Vulnerability Cube". These three main dimensions of conflict drivers are coupled by developing algorithms (see Section 5.2.3) to quantify and simulate the specific parameters of the NRBCs drivers. Thus, the NRBCs drivers are derived from the fuzzy parameters. The fuzzy parameters are quantified with the help of the information and the weights (Figure 5.18) from the community actors during fieldwork exercises. While this section (Section 5.1) only gives an overview of the SEFLAME-CM, the detailed implementation steps and the FLAME-CM algorithms are presented in Section 5.2. Then Section 6 presents the model validation strategies and the research findings. For details on how the different layers of analysis are derived, see Figure 5.18. For the measurement of the environmental parameters, the distance parameters used and how they were derived from a land use and land cover model (LULC) using satellite imageries (see Section 5.2.1.1). For the socio-economic and political parameters, the social science tools used include interviews and workshops. Data from secondary sources are also used (see Section 5.2). All the model inputs are derived and simulated to give outputs as Conflict Vulnerability Likeliness (CVL) Index. The CVL Index explains the areas/communities that are vulnerable to conflicts and those that are resilient to conflicts (i.e. the areas that are more likely to experience peace) (see Section 5.2.3.8.2 for detail discussion on the CVL Index).

5.2 The Implementation Process of SEFLAME-CM under A Transdisciplinary based Coupled Approach

The model-SEFLAME-CM is implemented using the fuzzy logic model (FLM) toolbox of MATLAB and run on Simulink in MATLAB. The SEFLAME-CM requires both spatially and non-spatially explicit input data. The former is in the form of a gridded based GIS data (Figure 5.1). It combines two main components of vulnerability assessment.

- The external components (environmental/biophysical processes of natural resource based conflicts) and
- The internal components (socio-economic and political processes of nature resource based conflicts).

The SEFLAME-CM is implemented in this work under a transdisciplinary approach referred to as a transdisciplinary-based coupled approach because of the coupling processes involved. The approach and the model draw on the findings of the reconceptualized NRBCs. These concepts were extensively discussed in Section 3. As shown in Figures 5.1 and 5.2, the transdisciplinary approach follows a recursive process. It integrates the actors' perception into the vulnerability assessment of NRBCs by coupling the relevant biophysical data sources with socio-spatial datasets. The approach draws on the widely held view in the literature that the local people are known to have local experiences about hazards associated with resource extraction (renewable and non-renewable resources), in this case, the environmental and socio-dynamics in the anthropogenic era (see Section 3.2.1 for discussions). In this context, the expert acts as the facilitator while the actors are seen as the "experts" who have the first-hand information about the problem of NRBCs (see Section 4). The combination of scientific and citizens' information required the integration of the "hard and soft sciences" perspectives. This co-created knowledge process enhances anticipatory or social learning. ((Hospes *et al.*, 2017), Section 1). The local actor's involvement allows the researcher (or other external actors) to acquire a deep understanding of the problem of NRBCs.

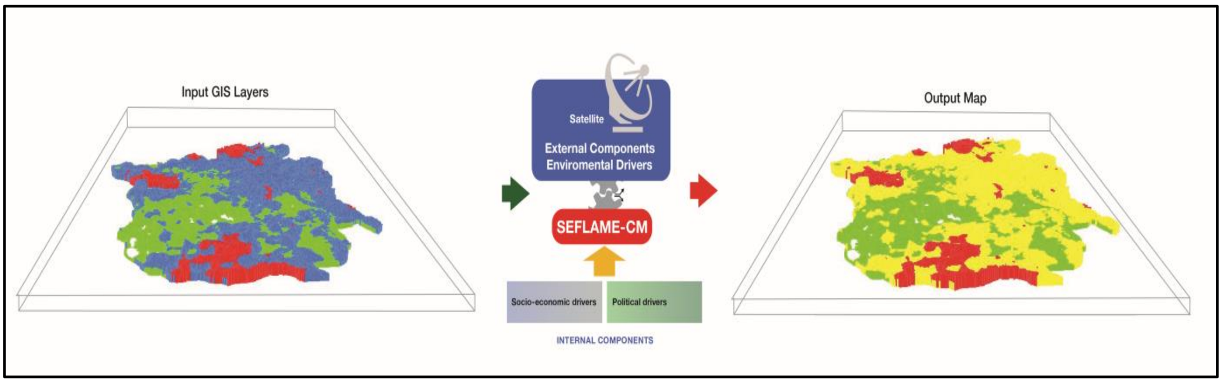


Figure 5.1: Integration of the external and internal components of a vulnerability assessment (space, time and dimensions of vulnerability assessment in the context of natural resource-based conflicts), adapted with modification from Hank (2008).

In the research test sites the tools and the models (including simulation tools and GIS) were used by the researcher to unravel the collective hidden knowledge about conflicts, through the existing oral descriptions, narratives, and memories. The tools also helped to transform the collected knowledge into a spatial and non-spatial representation of the people's views thereby facilitating modeling and simulation. According to Barakat *et al.* (2002), such a composite design method in conflict management (CM) provides regional authorities with the decision support tools that can enhance future CM policy measures and schemes in the face of much uncertainty. For example, a new natural resource governance framework and spatial economic interventions of conflict-prone territories could be created in order to enhance sustainable peace in sustainable transitions. The six steps of the transdisciplinary-based coupled approach therefore include:

1. Joint Problem Framing by the local actors and the scientist(see Section 4 for details)
2. Model Simulation
3. Spatialization of Information using GI tools
4. Integration of all the dimensions of the model
5. Model validation and results
6. Scenario Construction with the actors

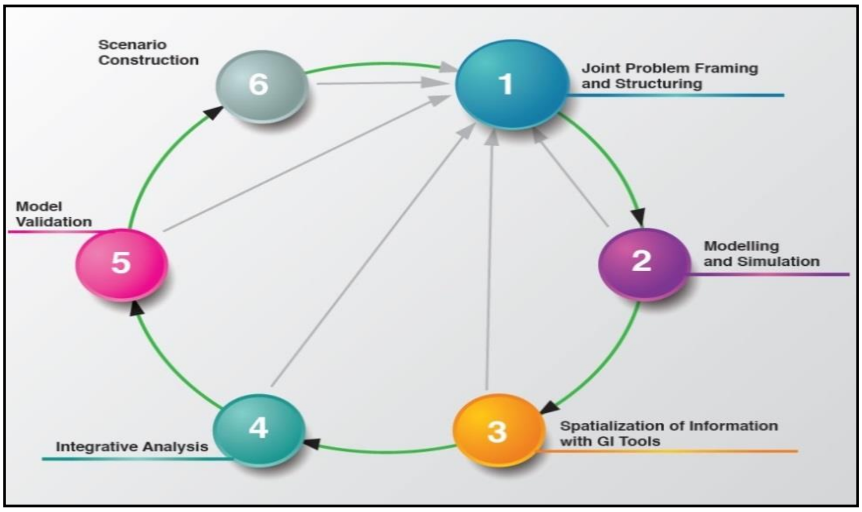


Figure 5.2: The transdisciplinary-based coupled approach for vulnerability assessment of natural resource-based conflicts.

These steps are briefly described below and elaborated in the specific sections of the thesis:

(1). Joint Problem Framing: As presented in Section 4, the problem framing is aimed at identifying and structuring the NRBCs in the selected test sites. This is carried out in this work by integrating the scientific and local knowledge of the actors on the drivers of NRBCs. The process also involves the use of remote using, GIS and interviews (see Section 4 for details on joint problem framing). The joint problem framing specifically involves the various tasks such as.

- *Exploratory visit*. This is constituted of an extensive field campaign made up of meetings with local actors, modeling workshops, and a collection of secondary data. For example, the socio-economic datasets include demographic characteristics; educational characteristics, poverty, and oil infrastructure (e.g. oil wells location, oil pipelines, and oil spill data sets) (see Appendix A.12.4 for a picture taken on the way to the research site by the research team). The exploratory visit supported the determination of the main categories of NRBCs drivers in the study area. The period before the 1990s used as a benchmark in this work (see Section 2 and 5.2.1.1 for justification). Open interviews were directed to farmers/fishers, local politicians, NGOs, community leaders, and youths. The selection of the actors in this work was based on a local literature review on the problems of environmental degradation and NRBCs in the Niger Delta. The questions were addressed to ascertain for instance the actors' perceptions of the role of renewable natural resources and agricultural landscapes e.g. mangrove, water, and farmland and oil extraction in conflict with vulnerable and resilient communities. Other questions include how the actors perceive the drivers of NRBCs and the effect of changes over time. The open interview responses were analyzed using MAXQDA with particular attention to the joint framing of the problem (see details of results in Section 4). The results helped in the further research processes such as the derivation of parameters, operationalizing the model parameters and determining the fuzzy logic rules for model setup.
- *The Measurement of biophysical components (environmental risk parameters of conflicts) using remote sensing*. Satellite datasets were used with Global Positioning System (GPS) in the field research trips. This involved the use of community mapping exercises such as transects walks including Focused Group Discussions (FGDs). In the questionnaire survey, information on the languages used by the actors to frame the conflicts problem is critical in this work. The information on the weighting of the conflict drivers by the actors was also derived. Thus, with the fuzzy logic model, what is referred to as computing with words (CWW) and the numeric rating of parameters can be integrated into the modeling process (Zadeh, 1999). GPS was used to verify the observed conflict data sets with the assistance of the local people. Specifically, the aim of satellite data in this work is two folds:
  - To model land use and land cover change (LULC) and measure distance parameters from village to location of natural resources, e.g. mangrove loss, farmland loss, surface water pollution, oil location.
  - Using remote sensing data collected to validate the SEFLAME-CM.

(2) Modeling and simulation: Model simulation set up used the fuzzy logic based algorithm (see Figure 5.18 for the simplified hierarchical structure of model input data layers). A questionnaire survey in combination with expert knowledge generated the fuzzy rules for the fuzzy logic modeling. See Section 5.2.3 for the algorithm steps, the model inputs, and output processes.

(3) Spatialization of information with GIS tools: GIS is used to prepare the spatial and attribute data sets at the various point of the research. The GIS software tool (ArcGIS) is used with satellite image processing software (ERDAS imagine). See Section 5.2.4 for the spatial data attributes.

(4) Integrative Analysis: The integrative analysis involves the integration of the remotely sensed data into GIS as well as the coupling of the environmental and social data types, GIS is very specifically useful for visualizing, spatial modeling, and spatial validation of the model (see Section 5.2.2 for data integration).

(5) Model Validation: The details of the model validation process are presented in Section 6. The model validation is carried in this work based on two main strategies:

- The temporal and vulnerability dimension validation: This focused on the time scale across all the dimensions of conflict drivers. Qualitative and quantitative comparisons of the model are carried out using the observed conflict data within the reference periods of 1986-2000 and 2000-2016 (see Section 6.5.1) for details.
- The spatially explicit validation (see Section 6.5.3 for details). This involved
  - Model validation by the comparison of SEFLAME-CM vs. the Spatial Multi-Criteria Evaluation for Conflict Management (SMCE-CM), and
  - Model validation of SEFLAME-CM using environmental data from remote sensing.

(6) Co-creating Scenarios: This is the concluding phase of the work. It proposed co-created scenarios for future CM and sustainable peace. See Section 7 for details on the scenarios. The scenario construction strategies are proposed for the future management of NRBCs. The proposed period is until 2060 (see Section 7.3 for justification of time scale).

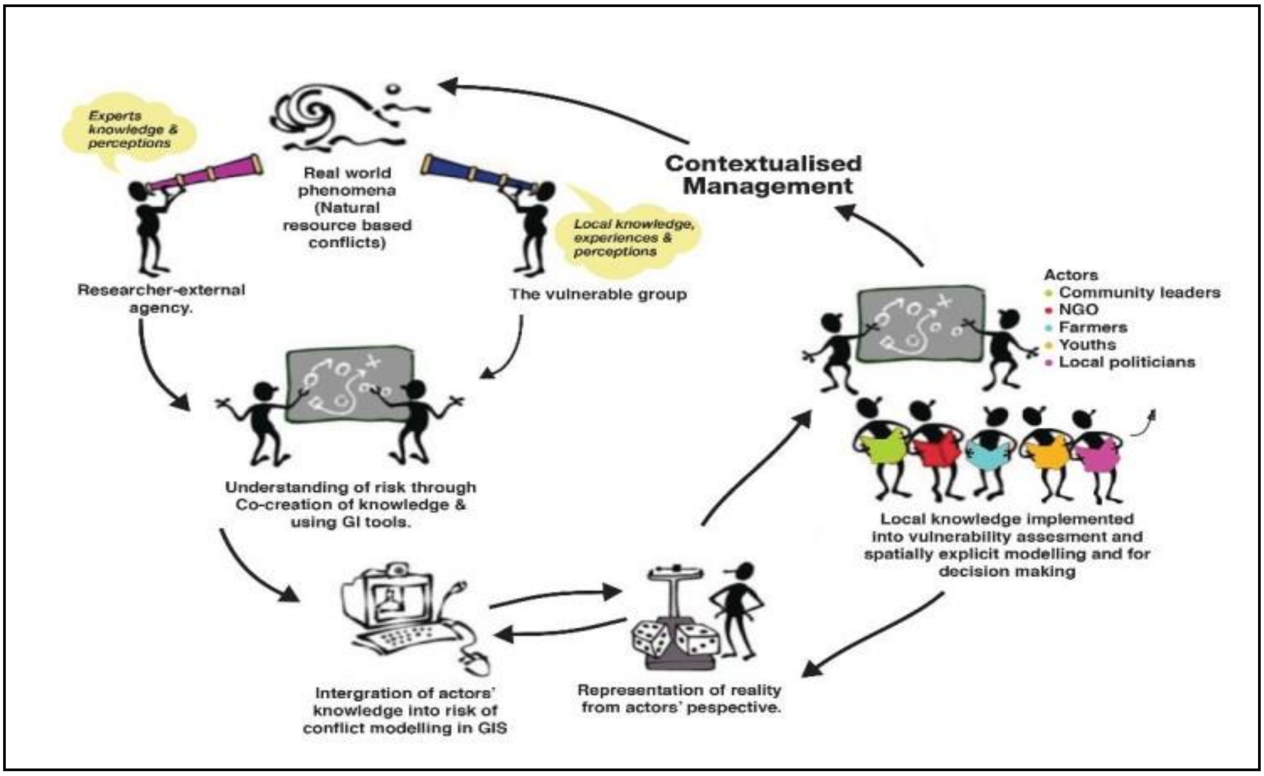


Figure 5.3: Schematic overview of the integration of hard and soft systems in a transdisciplinary process of the research.

5.2.1 Data and Methods of Collection

Data sets were collected between 2013 and 2015. The first fieldwork was conducted in 2013 (February–April) while the second fieldwork was conducted in 2015 (February–May). The first fieldwork involved an open interview and field campaign mainly for the collection of the ground truth used for the satellite data validation. During the second fieldwork, modeling workshops were organized and the conflict data verified for model validation.

In general, three main data sources are used: (1) the remote sensing data (see Section 5.2.1.1). (2) the secondary data sources (see Section 5.2.1.2), and (3) the fieldwork data, such as actors' workshops, open interviews and questionnaire surveys (see Section 5.2.1.3). See Table 5.1 for a list of data types and sources. Figure 5.4 shows the steps and techniques used for data collection. The various sources of data are used to develop the Fuzzy Conflict Data (FUZZYCONDATA). FUZZYCONDATA is used for model development and validation (see spatial data attributes in Section 5.2.4) and (see model validation in Section 6). The validation data are the conflict datasets available for free download from the Uppsala Conflict Data Programme Geo-referenced Event Dataset (UCDP-GED) (http://ucdp.uu.se/downloads/) and Armed Conflict Location Event Data (ACLED) (https://www.acleddata.com/data/) and the remote sensing data-sets (see Table 5.2).

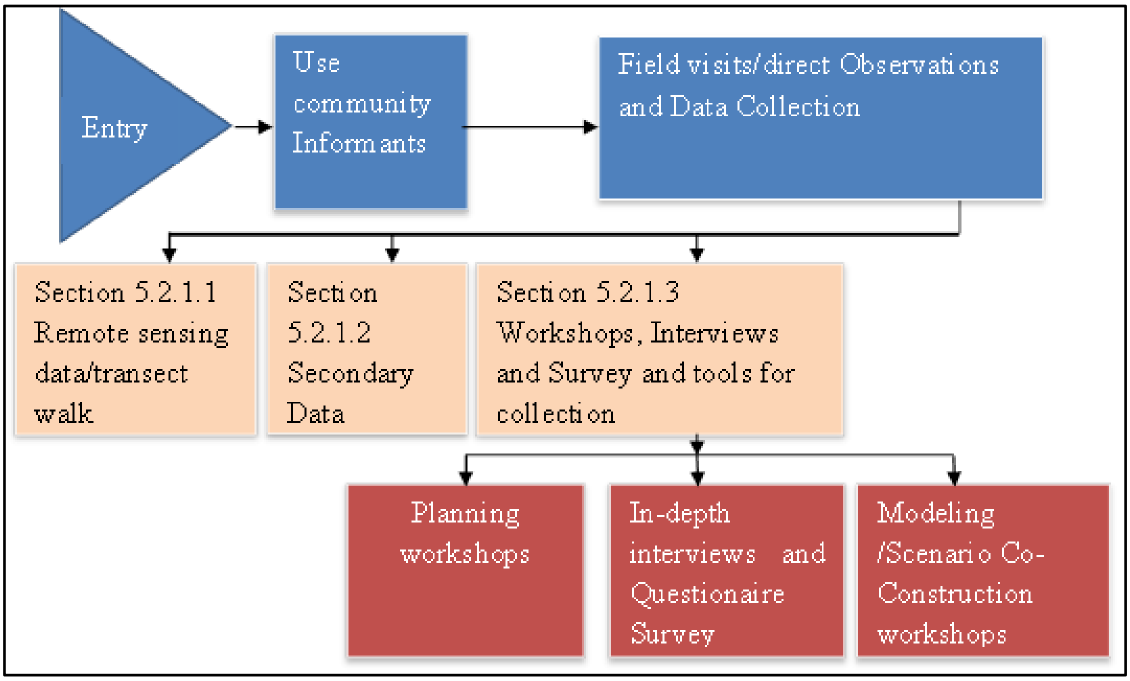


Figure 5.4: Fieldwork steps and tools for setting up a joint research and data collection at the local level.

Table 5.1: List of datasets and sources in vulnerability assessment of natural resource-based conflicts.

Conflict drivers and vulnerability Dimensions	Sources
Environmental dimension (external component)	
Mangrove loss	Remote Sensing

Water pollution	Remote Sensing
Farmland loss	Remote Sensing
Oil infrastructure, e.g. pipeline, oil well,	Petroleum Corporations n Nigeria
Socio-economic dimension (internal component)	
Poverty level (Wealth index)	National Population Commission
Education Level	National Population Commission
Oil Migration	National Population Commission
Oil Benefits	National Population Commission
Political dimension (internal component)	
Political Repression	Fieldwork
Political Exclusion	Fieldwork
Ethnic Linguistic Fractionalization	Census Data from National Population Commission/ Fieldwork
Youth-Bulge	Census Data from National Population Commission/ Fieldwork
Observed Conflicts	UCDP-GED and ACLED

5.2.1.1 The Use of Remote Sensing for Community Mapping of Natural Resource-Based Conflicts

The type of remote sensing data sets used is the optical sensors from different sources (see Table 5.2). The time scale of the satellite data considered the availability of data sets. Besides this, there was also a particular consideration of the available data before the 1990s and after. Importantly, the period before the 1990s was used as a benchmark because the intense conflict in the Niger Delta began around the late 1980s and early 1990s after the Ogoni crises (Oyefusi, 2008).

The remote sensing data sets were pre-processed and taken to the field. This temporal quality of the data specifically offers the advantage of problem framing, and of course the temporal and spatial vulnerability assessment. The methodology of using satellite data sets in vulnerability assessments that relates to socio-ecological systems (SESs) and conflict management is still in its infancy (Hall, 2010, Sulik and Edwards, 2010, Yan and Xu, 2010, Witmer, 2015). Hence, to address the social aspects of the problem NRBCs, the use of satellite data was supported with transects walk sessions in collaboration with the mobilized representatives of local people in the study area (Okrika and Ogoni territories). Their involvement also helped to obtain the local knowledge of NRBCs in the villages (see Section 4.3 and Table 5.6 for information on the actors). The information was used for developing the model, validation of both the LULC models and the SEFLAME-CM.

Table 5.2: Characteristics of satellite images used.

Time scale	Data	Date	Resolution	Source
Before 1986	**Landsat** TM	1986-12-19	30 m	USGS
1987-2000	Landsat ETM	2000-12-17	30 m	USGS
2001-Present	**KOMPSAT** 2	2012-02-11	4m	ESA
	Nig Sat 2	2013-02-11	22m	NSRDA
	Landsat 8	2016-01-03	30m	USGS

5.2.1.1.1 Land Use Land Cover (LULC) Analysis

The remote sensing techniques based on optical sensors have shown their value in mapping, environmental change in rural territories. Image processing, image classification, change detection and feature extraction of land-use types were carried out. Changes can be detected on the basis of land-cover categories as well as in the use of continuous variables based on reflectance values measured by a satellite sensor (Lambin, 1997). The results of image analysis for the three year period: 1986, 2000 and 2016 were derived from the satellite remote sensing data. Change detection was carried out by post-classification comparisons and the creation of contingency tables for the time intervals: 1986-2000 and 2000-2016. The land use classes of interest include mangrove, farmland, water, built-up, secondary forest, and thick forest. The LULC classification scheme was amenable to the research question of where the changes are most intense and based on previous classification schemes (Anderson, 1976, Mengistu and Salami, 2007). See Table 5.3 for the classification schemes used in the study. Appendix A.12.5 shows pictures of some land uses mapped with a satellite image. See Appendix A.12.6 and Appendix A.12.7 for some pictures of an abandoned oil well and that of polluted water surfaces respectively.

Table 5.3: The LULC classification scheme used in this study.

Level I (Main Cover category)	Code*	Level II (category Description)
Built-up	BU	Single-family Units, Multi-family, Group Quarters, Other Residential or industrial infrastructures
Farmland	FL	Cropland, Mixed farmland, plantations, and others
Water Pollution	WP	Streams, canals, lakes, bays, and estuaries
Mangrove Loss	ML	Mangrove swamp forest, different mangrove trees, and shrubs, mangrove trenches
Secondary Forest	SF	Disturbed thick forest, abandoned farmlands
Thick forest	TF	Undisturbed forests such as nypa palm

*BU= Built-up, FL=Farmland, WT=Water, MG=Mangrove, SF=Secondary Forest, TF=Thick forest. Source: Anderson (1976), Mengistu and Salami (2007).

5.2.1.1.2 Intensity Analysis

Intensity Analysis focused on land use and land cover changes at three levels: time interval, category, and the spatial transition of the cover classes (Aldwaik and Pontius, 2012). The time interval level examined the rate of change varies across time (see Figure 5.5). For any particular category, the transition level examined how the size and intensity of the category's transitions vary across the other categories that are available for that transition (Aldwaik and Pontius, 2012). For instance, images of “t1”, “t2”, “t3” were used to derive the Persistence, Gain, Loss and other land uses (PGLOLU) categories of intensity transitions. To derive the first time dimension changes, the time dimension was derived thus: “t2” minus “t1”. The second time dimension was based on “t3” minus “t2”. The resulting maps of each of the PGLOLU intensity transition parameters for the categories (mangrove, farmland, water) are used for spatial validation (Section 6.5.3.2.4). From the maps, distance parameters are derived (fuzzy set parameters) and used as model input variables (see Section 5.2.4). Table 4.4 shows the structure of the LULC intensity transitions.

Table 5.4: The description of LULC intensity transitions.

Time	PGLOLU	BU	FL	WT	MG	SF	TF
T3-T2 T2-T1	Persistence	✓	✓	✓	✓	✓	✓
T3-T2 T2-T1	Gain	✓	✓	✓	✓	✓	✓
T3-T2 T2-T1	Loss	✓	✓	✓	✓	✓	✓
T3-T2 T2-T1	Other Land use	✓	✓	✓	✓	✓	✓

P-Persistence, G-Gain, L-Loss, OLU-Other land use, ✓ -Measured parameters

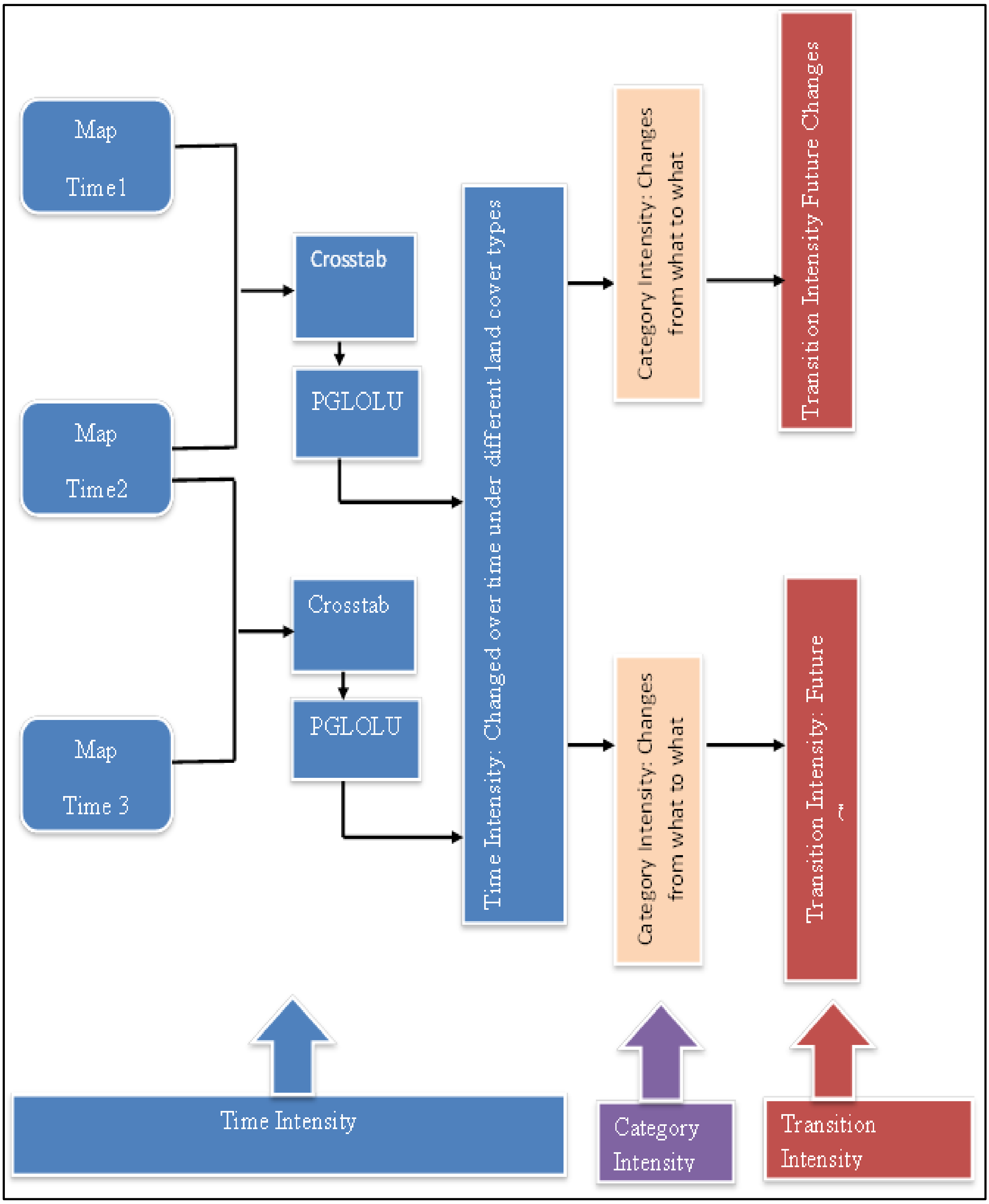


Figure 5.5: Methodological flow among the three levels of land change analysis, adapted from Aldwaik and Pontius (2012).

5.2.1.1.3 Distance Measurements

Two types of distances are developed and used in this study: the Non-spatially Explicit Distance Parameters (NSEDP) and Spatially Distance Parameters (SEDP). The first set of distance parameters are used to test the model at the village scale using the Fuzzy Logic Adapted Modelling for Conflicts Management (FLAME-CM). These distances are derived measured from village points to mangrove, water, farmland, and oil infrastructure. The FLAME-CM model is transferred from the village level of measurement to derive a spatially explicit validation using a grid cell as the unit of analysis. However, the same fuzzy rules and weights were used for both the FLAME-CM and the Spatially Explicit Fuzzy Logic Adapted Modelling for Conflicts Management SEFLAME-CM.

5.2.1.1.3.1 The Non-Spatially Explicit Distance Parameters (NSEDPs)

The NSEDPs are used in the context of NRBCs at a local scale. The context and area of influence of a type of resource determine its accessibility to villagers. The accessibility of natural resources is important to villagers. For example, the access to resources such as the drawing of firewood, fetching of water from streams or cultivation of arable crops within a village are all important to villagers. Therefore villagers would want to minimize the distances they travel to access the maximum amount of natural resources. As they would prefer to travel less to access these resources and whoever that takes it farther away would be resisted. Regarding distance parameters, traditionally, the Euclidean distance measurement stipulates that an object, “O” is totally determined by its perceived spatial boundaries, irrespective of the actual location of “O” and its surrounding environment (Brennan and Martin, 2012). The weighted distance was thus used to derive the distance from a village to the location of a natural resource. In the case of distances to oil infrastructure, it is assumed that oil infrastructure distances are about double of the distance villagers travel to mangrove forest for firewood or to farmland. This is because oil infrastructures are further apart from the people than the resources that they depend on for their livelihood. The closer a village is to an oil infrastructure, the more likeliness of conflicts in that village (Lujala, 2010). In oil production, the mere presence of hydrocarbon reserves or oil infrastructure is sufficient to attract resource-related conflicts in the conflict region (Lujala, 2010). The distances (see Figure 5.6 and Table 5.5) were measured and weighted so as to determine the access to mangrove, the access to water and the access to farmland, and the nearness of oil infrastructure. See *Equations 5.1 and 5.2* on how distances were calculated using the model input parameters. The results were integrated into the fuzzy logic model using GIS. The following steps guided the deriving of NSEDP:

- Feature extraction of natural resources, e.g. mangroves from remote sensing using, multiple buffer distances such as 5 km, 10 km, 15km and 20km,
- Calculation of area of mangrove land use (in hectares) around a village,
- Derivation of the percentage of hectares within a village,
- Derivation of weighted distance by dividing the distance by buffer area (%).

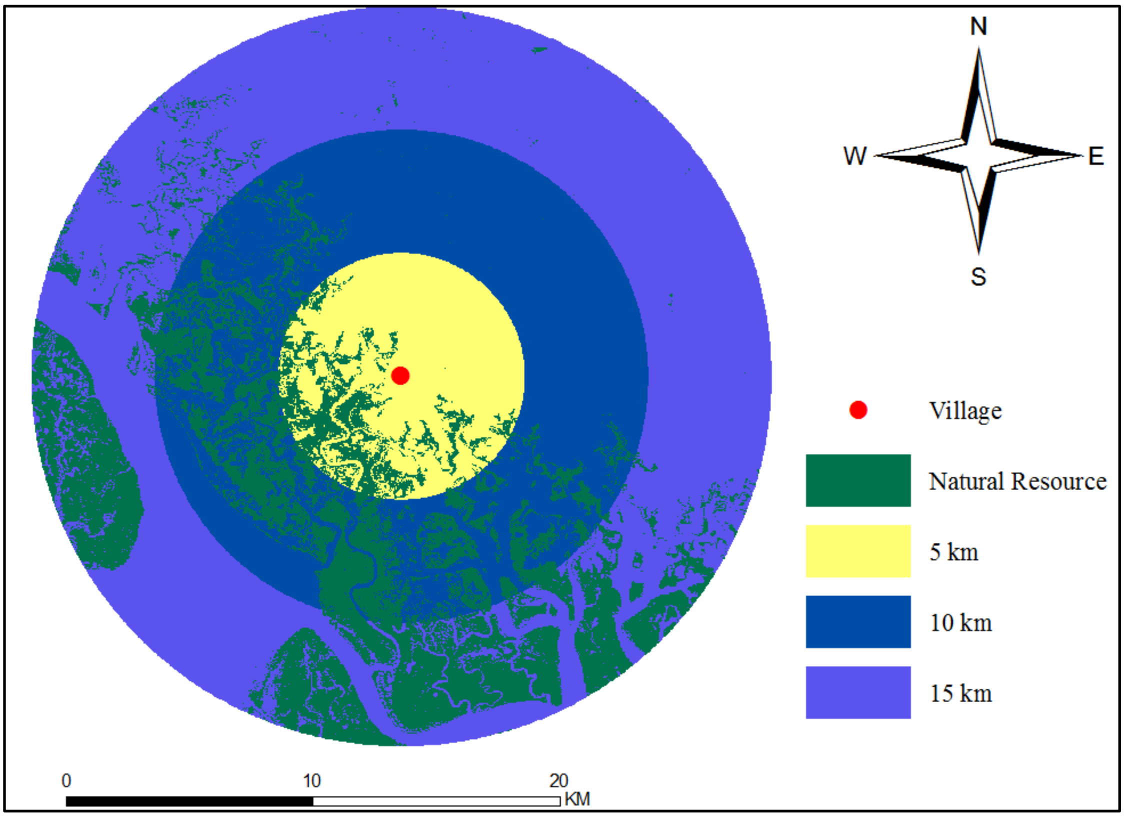


Figure 5.6: Measurement of distances from village center.

Table 5.5: Measurement of distance in GIS.

Distance	Mangrove (ha)	Farmland(ha)	Water (ha)
Very Near	0-5km	0-5km	0-5km
Near	5-10km	5-10km	5-10km
Far	10-15km	10-15km	10-15km

5.2.1.1.3.2 The Spatially Explicit Distance Parameters (SEDPs)

For the SEDPs, 200 by 200-meter square cell grids are artificially constructed, with the consideration mainly based on the resolution of the available data and the area of study. For the SEDPs, the Euclidean algorithm was followed. A distance is calculated using each of the grid cells as a unit of analysis (see Section 6.5.3 and Figure 6.26). Normally, Euclidean distance gives the distance from each cell closest to the source (ESRI 2014). Theoretically, for each cell, a distance to each resource is determined by calculating the hypotenuse to other two legs of the triangle: “x_max” and “y_max” Therefore, “x_max” and “y_max” represent the maximum distance measurements on vertical and horizontal sides as the other two legs of the triangle respectively (Figure 5.7). The shortest distance to a source is determined. But theoretically, if the distance is less than the specified maximum distance, the value is assigned to the cell location of the output raster (ESRI 2014). It is important to note that this description is only a conceptual depiction of how distance values were derived (Figure 5.7). A distance was measured from the cell location of a village to the natural resources. The maps of the village access to mangrove, access to water, access to farmland, and the nearness of oil infrastructure are used as model inputs (see Section 5.2.4).

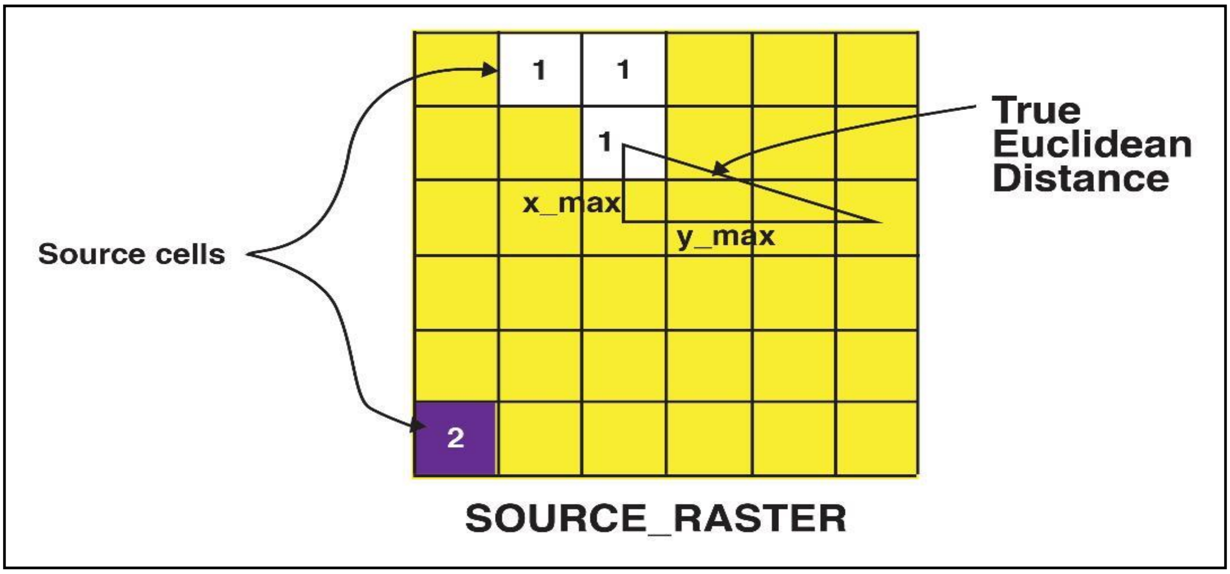


Figure 5.7: Design of spatially explicit distance measurement, according to ESRI (2014).

5.2.1.2 Secondary Data Sources

During the initial field campaign in the study area, a considerable time was spent on the collection and compilation of secondary datasets. Both the non-spatial and spatially explicit data sets were collected during the field campaigns. The information and data collected include among others:

- Statistical profile (1986-2016) of the study area, including several socio-economic indicators such as:
  - Population
  - Age structure
  - Income
  - Marital status
  - Poverty indicators
  - Environmental quality

Some of the spatial data sets obtained which were used as the spatially explicit vulnerability assessment include:

- Topographic Data (land use, soil types, land cover)
- Administrative maps(political, ethnicity map, conflict map)
- Oil infrastructure, including:
  - Oil pipeline
  - Oil well
  - Oil spill Data
- Socio-economic data (e.g census, poverty, public social services etc.)
- Natural features. These include rivers and creeks.

Some challenges were encountered during the course of secondary data collection. For example it was challenging to obtain high-resolution imagery from the development authorities and Federal Ministries in Nigeria. An effort was also made to access the high-resolution satellite imageries from the European Space Agency (ESA). After a successful proposal to ESA, KOMPSAT 2 high-resolution data set was granted. Unfortunately, this was only available for a limited spatial coverage, but not did not cover the entire study area. Eventually, the Landsat TM, ETM imageries for 1986, 2000, and Landsat8 2016 were used.These were however supplemented with other data sets such as Nigeria satellite image (Nig sat) (see Table 5.2).

5.2.1.3 Workshops, Surveys, and tools for collecting Actors' Local Knowledge on Perception of Conflicts

As earlier mentioned in Section 5.2, under the discussion on the transdisciplinary process, the workshops, interviews, and survey were undertaken at the joint problem framing and the exploratory stage of the research process. This helped to depict the environmental, socio-economic, political, and institutional dimensions of NRBCs in the test communities. Thus the various tools used during the problem framing phase are discussed below:

(A) Planning Workshop. There was a general awareness workshop organized in collaboration with NGOs in the study area. Before the first workshop, the research team (the Ph.D. researcher, two staff of the University of Port-Harcourt and two Masters Students) visited agencies and parastatals that were designated with the responsibilities of oil exploration, exploitation and the development of the Niger Delta region. We first visited the headquarter of the Niger Delta Development Commission (NDDC) in Port-Harcourt, Nigeria; then the Department of Petroleum Resources (DPR) in Lagos, Nigeria; and the National Oil Spill Detection and Response Agency (NOSDRA). We also visited LGA/community administrative officers in charge of the local government in the various local communities (see Appendix A.12.8 for sample introductory letters from LMU and from DPR to the Multinational Oil Corporations (MNOCs)). These initial visits and the reports collected helped to take a decision on the villages that would be studied in detail (test sites within the Okrika and Ogoni territories.

(B) Interviews and Questionnaire Survey: The actors such as farmers/fishers, community leaders, youths, politicians, and NGOs were interviewed (see Appendix A.12.9 for sample design of research questionnaire). It was however very challenging to have access to the representatives of the MNOCs for interviews. Several calls and visits were made to the offices of these companies such as Shell, for an interview. But this did not yield any positive result. Some of the questionnaires were administered during interviews while others were used during the workshop sessions (see "C" in Section 5.2.1.3 below). A total of 40 semi-structured questionnaires were administered to the different actors in each community/LGA, with two villages' selected based on the purposive sampling method. The number of actors chosen (see Table 5.6) was considered as a representation of each of the villages sampled as the test sites. Among the actors used for the study, a consideration was given to certain age brackets: the old people (70 years and above), the average aged (40-69 years) and the youth (20-39 years). We retrieved an average of 200 field questionnaire in each of the age brackets in all the villages sampled (Table 5.6). Research assistants were helpful in completing the questionnaire. Due to the scientific information required for fuzzy modeling, a training session was organized for the field assistants.

Table 5.6: Distribution of structured questionnaire.

Age	Farmers	Youths	NGOs	Politicians	Community Leaders
70years and above	40	40	40	40	40

40-69 years	40	40	40	40	40
20- 39years	40	40	40	40	40

(C) Modeling Workshops and Scenario Construction: Besides the planning workshop, subsequent workshops were held and complemented with the FGDs (Table 5.7). See Appendix A.12.10 for some workshop pictures taken with the actors. The workshops lasted for two days on the average in each village. The goal was mainly to weight the conflicts parameters that were inputted into the model. About 5 experts of conflict management were invited from the University of Port-Harcourt, Nigeria and the representatives of the actors in each of the 20 sampled villages. From the semi-structured questionnaire, the ratings of the input variables were derived to determine the input weights and the fuzzy rules weightings. It is to be noted that the interviews and the subsequent questionnaire survey conducted are different from the approaches used in (Oyefusi, 2008, Oyefusi, 2010). This author mainly investigated the willingness of the local people to participate in resource-related violence. But the focus of the fieldwork in this thesis was not to assess the willingness of people to participate in violence rather on assessing the drivers of NRBCs and how an integrated method can be developed through the co-creation of knowledge for conflict management.

Table 5.7: List of workshops/FGDs conducted in the research with dates and periods.

Workshop /FGDs	Communities /Scale	Participants	Date	Period
Ist	Andoni	NGOs, Local University Students, community Leaders, Local politicians, Farmers, Youth leaders	Feb 2014	1
2nd	Bonny	NGOs, Community Leaders, Local politicians, Farmers, Youth leaders	Feb 2014	2
3rd	Ogun-Bolo	FGD with Women leaders, Farmers/ Fishers, Youth leaders	May 2014	1
4th	Okirka	NGOs, Community Leaders, Local politicians, Farmers/Fishers, Youth leaders	May 2014	2
5th	Opobo-Nkoro	NGOs, Local University Students, Community Leaders, Local politicians, Farmers/Fishers, Youth leaders	May 2014	2
6th	Eleme	NGOs, Local University Students, Community Leaders, Local politicians, Farmers/Fishers, Youth leaders	June 2014	2
7th	Gokana	NGOs, Local University Students, community Leaders, Local politicians, Farmers/Fishers, Youth leaders	Feb 2015	2
8th	Khana	NGOs, Local University Students, community Leaders, Local politicians, Farmers/Fishers, Youth leaders	Feb 2015	2
9th	Oyibo	NGOs, Local University Students, community	Feb 2015	1

		Leaders, Local politicians, Farmers/Fishers, Youth leaders		
10th	Tai	NGOs, Local University Students, community Leaders, Local politicians, Farmers/Fishers, Youth leaders	Feb 2015	1

5.2.2 Field Data from Actors and Secondary Data

The responses from the interviews are derived and translated for further quantitative modeling. The results in the qualitative and quantitative format are presented while the drivers derived are operationalized for quantitative modeling (see Section 4.4). As stated in Section 3.3.2, qualitative data can be used for modeling in form of CWW. The CWW can perform a wide variety of physical and mental tasks without measurements or by combining measurements. The language and statements from the actors can be linked to quantitative modeling (Liu and Mendel, 2008). The process of linking qualitative and quantitative modeling in fuzzy logic is based on three components: encoder, integration, and decoder (see Figure 5.8).

Figure 5.8: A Perceptual computer for making subjective judgments according to Liu and Mendel (2008).

(1). Encoding of linguistic statements: Encoding involved the generation of natural language and crisp values from interviews, questionnaire surveys. The questionnaire survey was designed for example to ascertain the perception of actors on issues relating to the occurrence of NRBCs. This assessed how respondents perceive the likeliness of NRBCs based on the situation in their villages. Different cultural reasons and knowledge exists about the problem of resource conflicts using different linguistic terms. Such languages can lead to multi-granular linguistic information in decision making (see Figure 5.9).

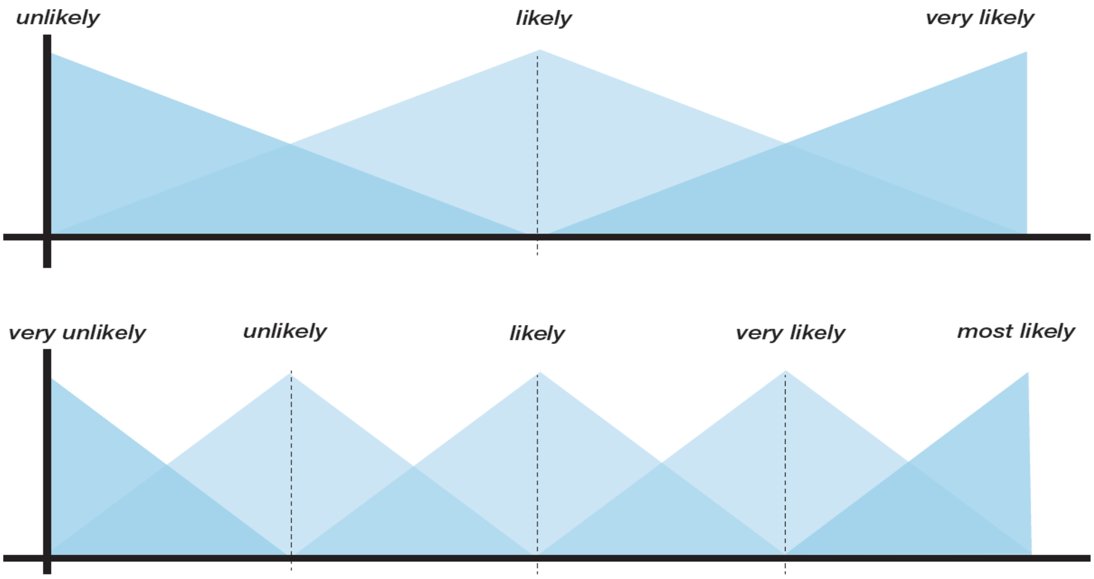


Figure 5.9: Linguistic hierarchy of three and five labels.

For example, in a grading system, a decision maker (DM1) or an actor could choose to use a linguistic term set:

DM1: (unlikely, likely, very likely),

But another decision maker (DM2) or an actor could prefer a linguistic term set with higher granularity such as:

DM2: very unlikely, unlikely, likely, very likely, most likely)

Thus, information can be presented in different degrees as seen in (Figure 5.9 and Figure 5.10). Regarding modeling from the survey responses, two code-books were used: one to derive respondents view during FGDs and another for the weights derived from the respondents during the surveys. The code-books derived two basic information that served as inputs into the model simulation run. These are: (a) words and (b) crisp numbers. Most of the questions asked during interviews required both qualitative and quantitative responses, the latter was in the form of ratings or weight that the respondents attached to the drivers of NRBCs. Examples of both qualitative and quantitative questions asked include:

Sample Question 1 (Qualitative):

how do you rate the effect of poverty as a driver of natural resource-based conflicts, particularly relating to oil extraction in your village?.

The options included: *(unlikely, likely, very likely, most likely etc.).* These were made available for selection by respondents.

The respondents were further asked:

Sample question 2 (quantitative using *a scale of 0—10*):

how do you further specify the rating of the options given (Unlikely, Likely, Very Likely, Most Likely)?

The options included: *[Unlikely: 0 1 2], [Likely: 3 4 5;], [Very likely: 6 7 8], [Most likely: 9 10].*

In the case where quantitative answers were required all the factors of conflicts (input variables) were weighted with a scale range [1—10].

The idea of modeling with qualitative and quantitative responses is based on the recommendation by Slovic (1992). He stated that risk perception-based paradigms assume that with appropriate design of survey instruments risk factors can be quantified.

(2) Integration (CWW and CWN): CWW can be integrated with CWN. This is a situation where, for instance, representation of linguistic statements i.e. CWW is translated and integrated into CWN. This is achieved in this thesis in the context of vulnerability assessment of NRBCs in two steps:

- First, the input variables (numeric values) such as the distance parameters were derived. For example, in the case of environmental drivers, the data sets were derived from remote sensing data, but the socio-economic and the political factors were derived from the secondary data sources and from the surveys.
- Second, weighting by the actors. The weights (see *Equations 5.1 and 5.2)* were derived from a questionnaire survey and integrated into the measured distances to resources from a village center (see Section 5.2.1.1.3.1 for details on distances).

Regarding this weighting process, two processes are involved: Conflict drivers are firstly rated using a value range (0—10) (see *Equation 5.1* for a rating of mangrove distance, for example). Secondly, the results of the rating are integrated into the collected data (see *Equation 5.2).* As examples, *Equations 5.1 and 5.2* are applicable to deriving the inputs of mangrove loss in distance.

$$Rating_{Verynear} = \frac{\sum_{i=1}^{N} r(Verynear, Acrtor_i)}{N} \quad \textit{(Equation 5.1)}$$
$$Rating_{Near} = \frac{\sum_{i=1}^{N} r(Near, Acrtor_i)}{N}$$
$$Rating_{Far} = \frac{\sum_{i=1}^{N} r(Far, Acrtor_i)}{N}$$

$$Weight_{MLdist} = r\big(Rating_{Very\ near}, MLdist1\%\big) + r(Rating_{Near}, MLdist2\%) + r(Rating_{Far}, MLdist3\ \%) \quad \textit{(Equation 5.2)}$$

where

R	=	*Range[0 10]*
N	=	*Number of actors giving the weight among the actors in a village)*
MLdist1		*Mangrove loss distance (fuzzy parameter category 1)*
MLdist2		*Mangrove loss distance (fuzzy parameter category 2)*
MLdist3	=	*Mangrove loss distance (fuzzy parameter category 3)*

For other equations used for deriving the inputs of other environmental drivers see the list of equations in Appendix A.12.3. The results of the derived parameters are then aggregated at a village level as a unit for all the conflict drivers.

(3).Decoding: Deriving of crisp or words or both. The decoding is the last step after the integration. This was based on the use of defuzzification algorithm (see Section 5.2.3). In this case, the weighted crisp input variables and the rules are combined. In Figure 5.10, we can see an example of the linguistic variable for "Conflict", whose corresponding linguistic term set could be either of *[Unlikely, Likely; Very Likely; Most Likely]*. A semantic rule associates each of the different linguistic terms. The critical aspect that determines the validity of a CWW approach is the choice of correct membership functions of the linguistic terms used.

As further shown in Figure 5.11, at the down-upward part, a typical linguistic decision-making environment is first provided with a set of linguistic terms. At the upward part of Figure 5.11, clearly seen are the different alternative structure of linguistic preferences that could be chosen in a situation of conflict by an actor or by an expert. For example, as mentioned in the during the description on encoding above, one actor may say “conflict is unlikely”, another may choose “conflict is likely”. Interestingly, in fuzzy logic, the algorithm rules can equally be used to connect these different alternatives (Herrera *et al.*, 2009). The next section, therefore, presents the description of the steps followed in the implementation of the fuzzy logic adapted algorithm.

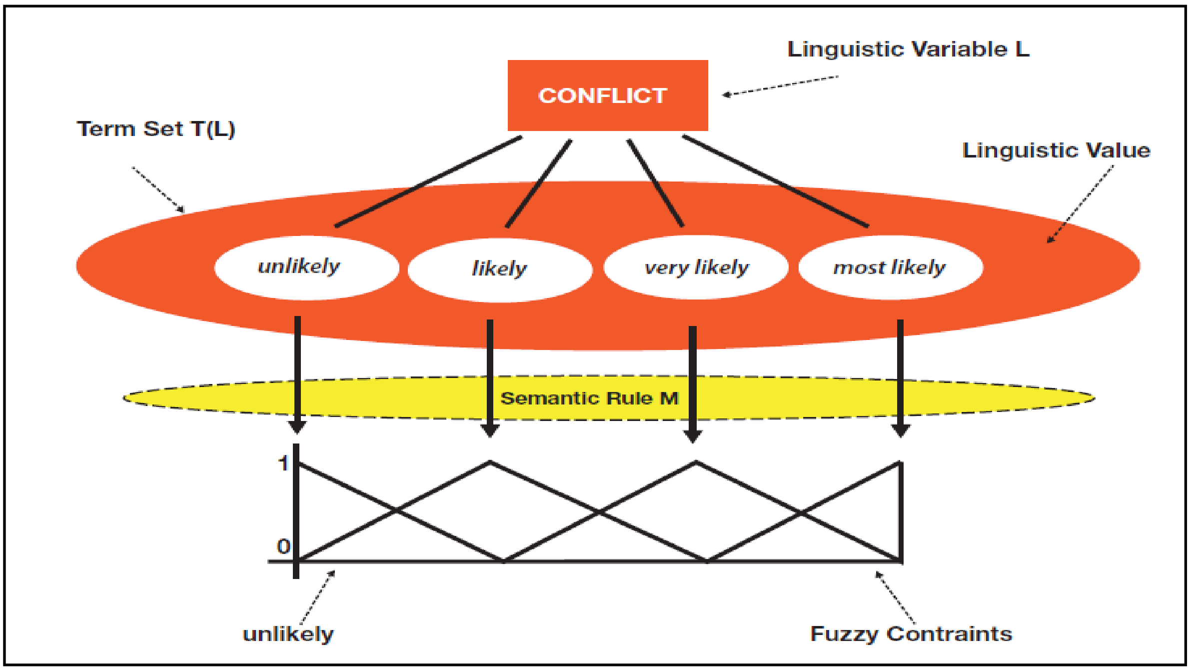


Figure 5.10: Example of the linguistic variables of conflict, adapted from Herrera *et al.* (2009).

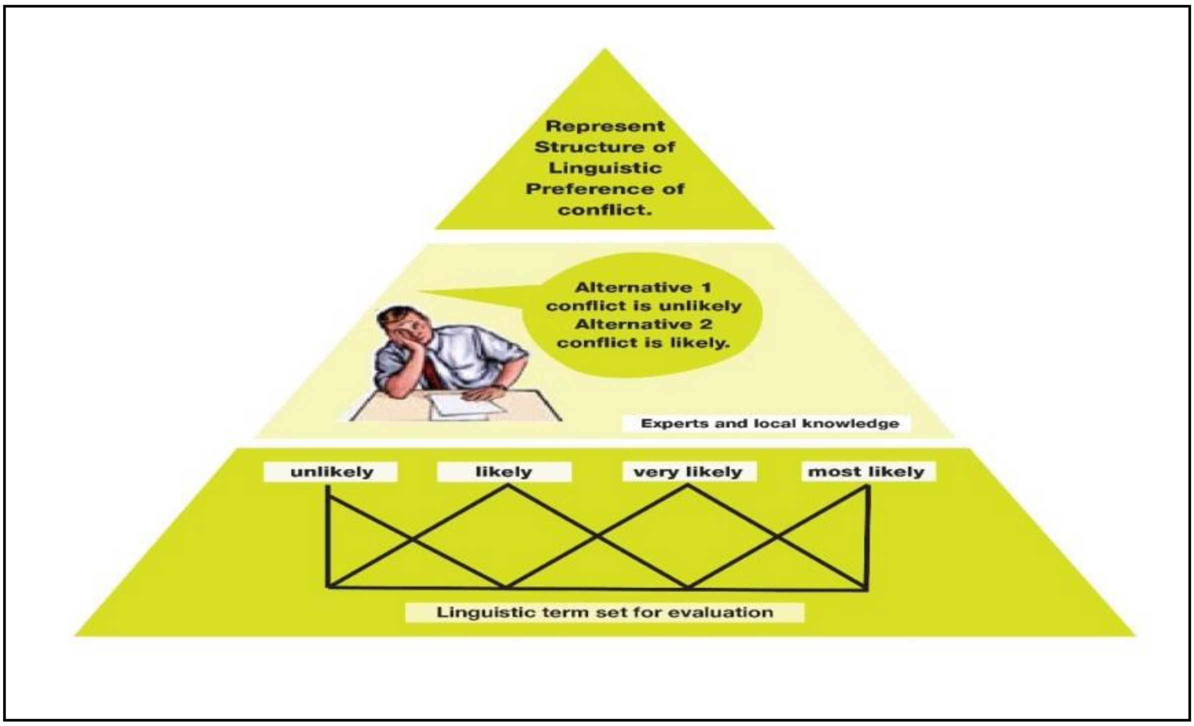


Figure 5.11: Linguistic decision making adapted by Herrera *et al.* (2009).

5.2.3 Description of Steps for Data Inputs and Outputs in FLAME-CM and SEFLAME-CM

This section presents the steps followed in the model inputs and the output processes for the adapted fuzzy logic model (see Figure 5.12 for a representation of the entire steps).

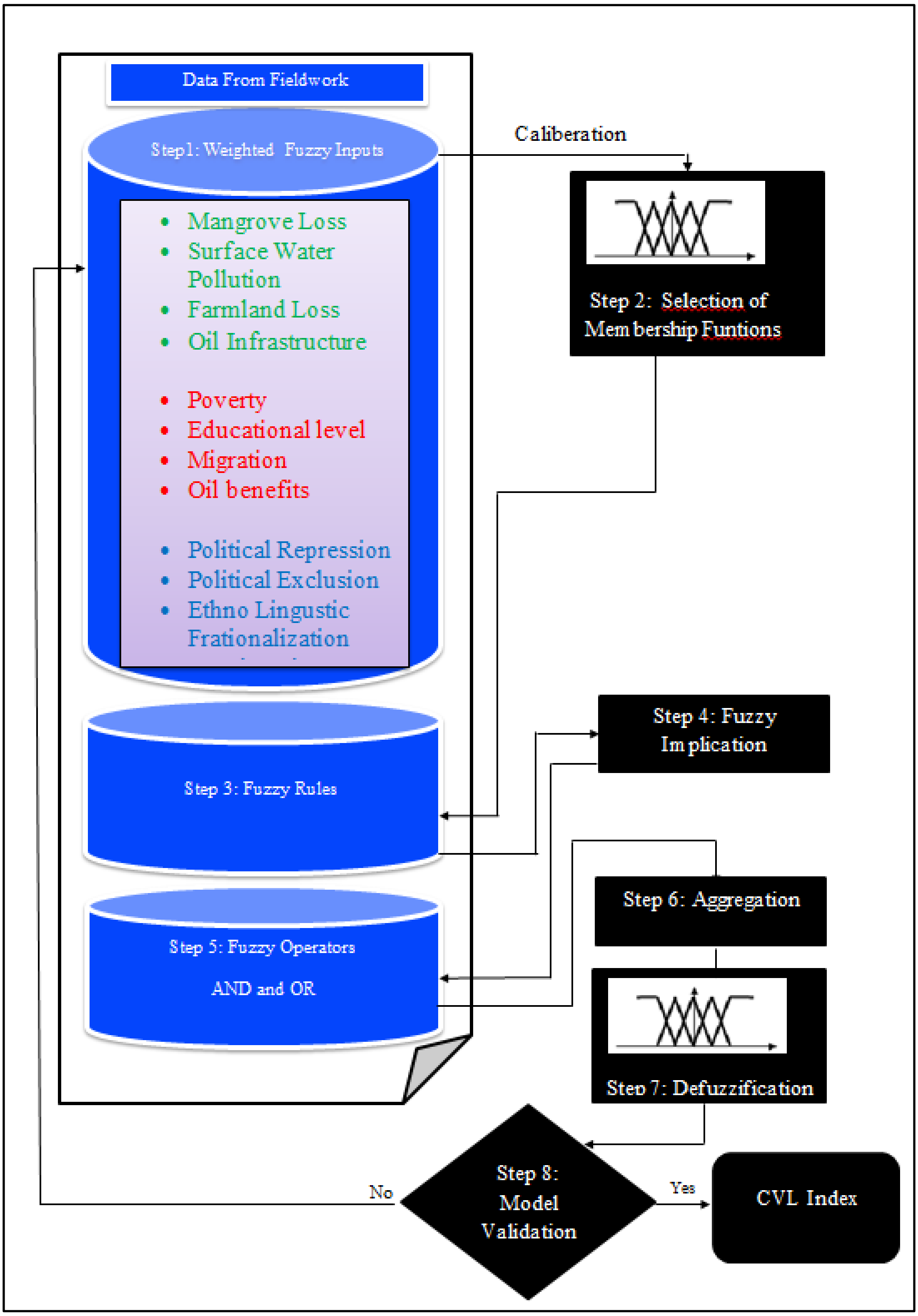


Figure 5.12: Architecture of the integration of field data into the SEFLAME-CM design steps

5.2.3.1 Inputting the Fuzzy Variables

In order to normalize the data for adequate comparison and validation all the model inputs were weighted (*Equations 5.1 and 5.2).* While the FLAME-CM is based on the NSEDPs the SEFLAME-CM used the SEDPs (see Sections 5.2.1.1.3.1 and 5.2.1.1.3.2 respectively.

5.2.3.2 Membership Functions (MFs) Evaluation

The type of membership functions (MFs) used is very important in fuzzy logic models. MFs can have different shapes. The most commonly used shapes are triangular, trapezoidal, gaussian and bell-shaped membership functions (Zhao and Bose, 2002). In this work, the MFs were evaluated by considering the MF types such as triangular, trapezoidal and Gaussian MFs (see Figure 5.13). The evaluation of MFs was used to calibrate the FLAME-CM setup (see Section 6.5).

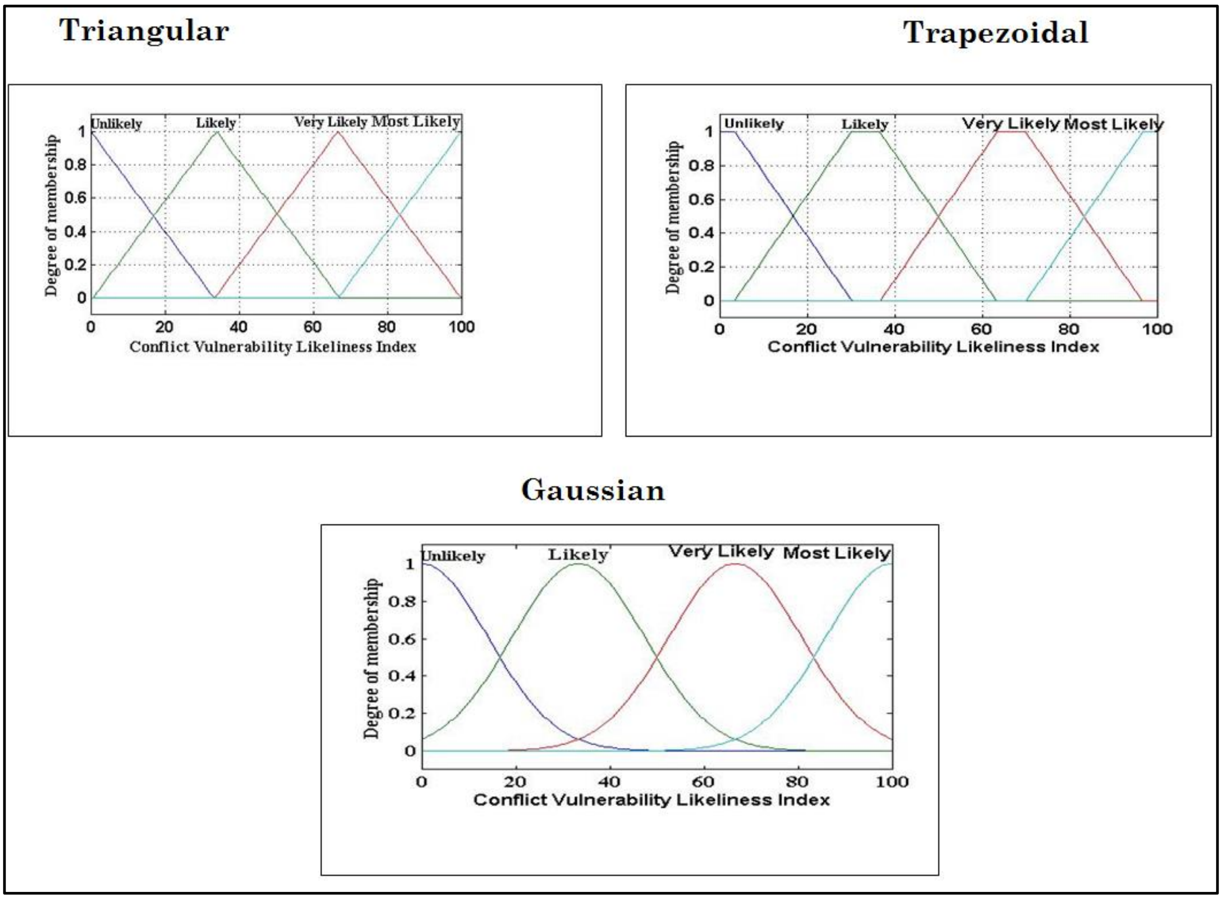


Figure 5.13: Types of membership functions (triangular, trapezoidal and gaussian MF).

5.2.3.3 Generation of Fuzzy Rules (Translation of Linguistic Statements from Interviews in Combination with Expert Knowledge)

The fuzzy rules, *if…then* statements are used to formulate conditional statements for the model. Rule generation in this study is based on a combination of linguistic statements and expert knowledge (Zadeh, 1999, Zadeh, 2001). This procedure involved the implementation of different rules. The fuzzy rules are sequentially combined through the fuzzy set operators. Usually, no general guidelines exist for designing a logical inference procedure except that as much as possible, it should simulate the knowledge base of the problem being investigated and the human decision-making process (Sicat *et al.*, 2005). The heuristic rules in the use of the fuzzy logic model in vulnerability assessment to NRBCs allow the inclusion of the intrinsic factors of conflicts into the model inputs.

Normally, the fuzzy inputs trigger the pre-defined rules that relate the different input linguistic categories to vulnerability to conflicts. There are four linguistically designed input parameters with three membership functions curves each (see Section 5.2.4.for the parameters. The choice of the number of curves is naturally determined by the definition of the parameters (MATLAB, 2015). A total of 81 rules are generated based on each of the out variables (the conflict vulnerability dimensions). The number of rules is based on the number of input variables and the number of MFs. There are four input variables in each conflict driver dimension and three MFs for each fuzzy parameter. To derive the rules, therefore, (x) raise to the number of input variables (y) i.e. x^y, is 3^4. This gave a total of 81 rules. The *if part* of the rules is called the antecedent or premise, while the *then-part* of the rules called the *consequent or conclusion* (Figure 5.14). See Appendix A.12.11, A.12 12, and A.12.13 for the sample of rules used under the environmental, socio-economic and political dimensions of conflict drivers respectively. Figure 5.15 shows a screen-shot of sample rule viewer of SEFLAME-CM as implemented in the Simulink of MATLAB (MATLAB, 2015).

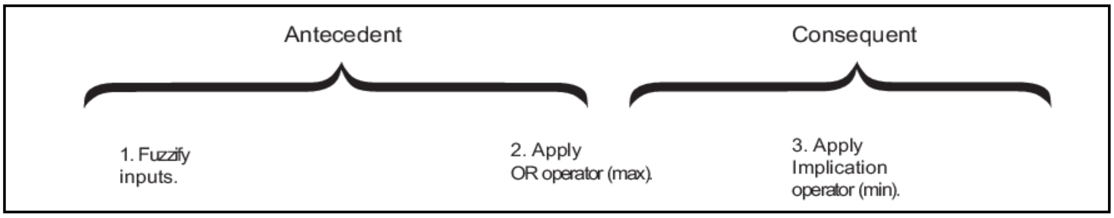


Figure 5.14: Antecedent and the consequent part of a rule.

5.2.3.4 Fuzzy Implication Rules

After setting out the rules, the next step is the fuzzy implication of the rules. Fuzzy implication describes a relationship between inputs and outputs. Before applying the implication method, the rule's weight was determined. Every rule has a weight (a number between 0 and 1), which is applied to the number given by the antecedents. If the weight is 1 there will be no effect at all on the implication process. But one rule is weighted relative to the others by using weight value other than 1. Weights were assigned to each rule through the questionnaires which were administered to the actors (see Section 5.2.2). The fuzzy rule weightings are aggregated *(Equation 5.3).* Similar equations to *Equation 5.3* are used for all the layers in the model simulation set up.

To complete the process of the implication rule, the *consequent* side which is represented by a MFs and the linguistic characteristics that are attributed to it, is reshaped using a function associated with the *antecedent* (a single number). The *implication* is then implemented for each rule.

$$TWARA_{ev} = \frac{\sum_{i=1}^{N} r(ev, Acrtor_i)}{N} \qquad \textit{(Equation 5.3)}$$

$$TRW_{ev} = r(TWARA_{ev}) * \frac{1}{TNPW}$$

where

$TWARA_{ev}$		*The total weight assigned to a rule by actors (TWARA) on environmental drivers dimension (ev)*
TRW_{ev}	=	*Total rule weight used for environmental drivers dimension (ev)*
TNPW	=	*Total number of possible weights of a rule in ev*
R	=	*Range [0 10]*
N	=	*Number of actors assigning a weight*

5.2.3.5 Fuzzy Operator: OR and or AND

While implication links the antecedent and the consequent part of the rule, fuzzy operator links the segments of the antecedent. As shown in Figure 5.15, each of the lines represents a rule and they form an inference engine (integrative component) in fuzzy modeling (MATLAB, 2015). Fuzzy operators are very relevant to determine the degree of fulfillment of the output variables.

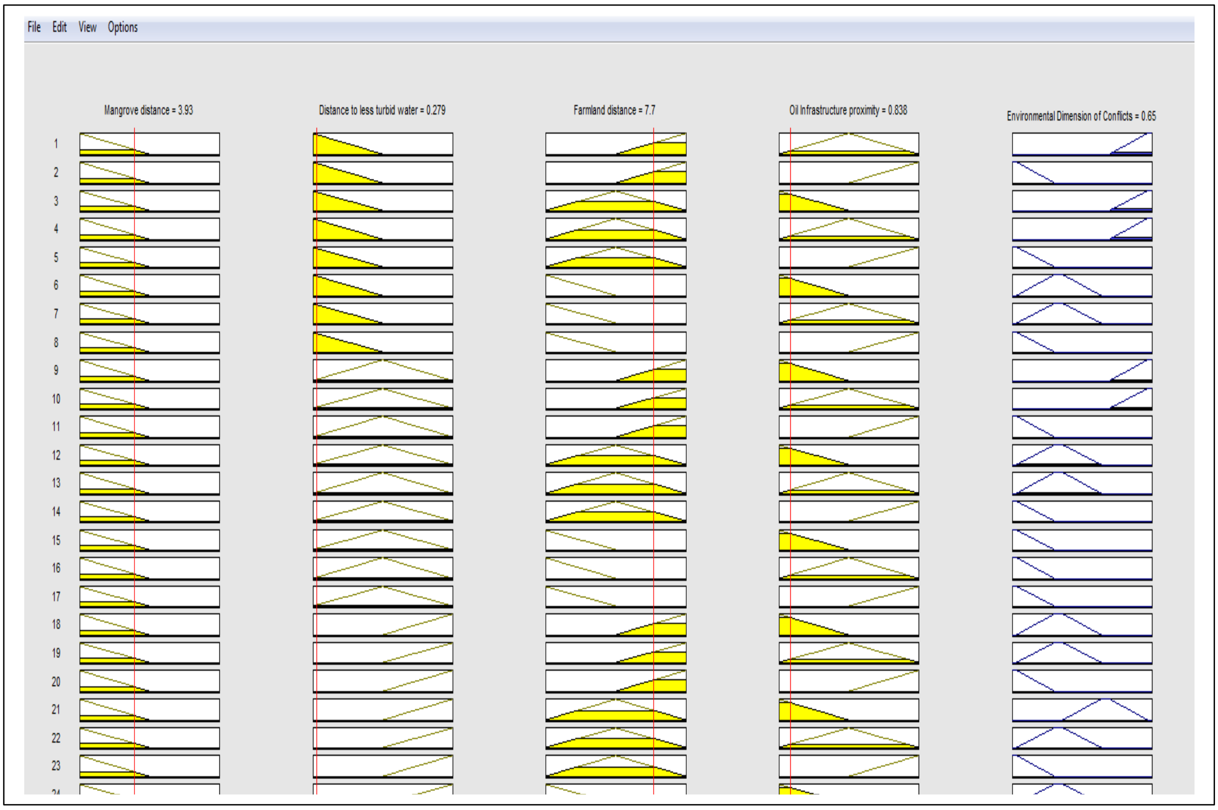


Figure 5.15: Sample rule viewer of SEFLAME-CM.

Thus with the applications of the fuzzy operators, rules are combined. The fuzzy operators are also used to generate fuzzy parameter maps (Sicat et al., 2005). A number of other fuzzy operators exists (Bonham-Carter, 1994, Zimmermann, 2011), e.g., fuzzy algebraic product, fuzzy algebraic sum, and fuzzy gamma operator. According to Sicat et al. (2005), suppose input fuzzy maps A, B and C with $\mu_{A,}$, $\mu_{B,}$ and $\mu_{C,}$, respectively, are membership values in each of their attributes and with W_A, W_B and W_C, as map weights, the FA operator and output fuzzy values, µcombination are obtained as:

$$FA\mu_{combination} = MIN\left(W_A\mu_{A,}W_B\mu_{B,}W_c\mu_{C,} \dots\right),$$ *(Equation 5.4)*

where

FA	=	*Fuzzy AND*
MIN	=	*minimum operator*

The *MIN* operator takes as output the minimum fuzzy value at each point (or pixel) in an input map. This is equivalent, but not equal to a Boolean *AND* operator. Using the *FO operator*, the output integrated fuzzy values $\mu_{combination}$ are obtained as:

$$FO\mu_{combination} = MAX\left(W_A\mu_{A,}W_B\mu_{B,}W_c\mu_{C,} \dots\right),$$ *(Equation 5.5)*

where

FO	=	*FuzzyOR*
MAX	=	*The maximum operator*

The *MAX* operator looks for and takes as output the maximum value at each point (or pixel) in an input map. The *MAX* is equivalent, but not equal to a Boolean *OR operator*. The words *AND* and *OR* to the actors may not strictly mean the same as *FA and FO* respectively. This suggests the need to apply and evaluate the results of the application of other fuzzy operators vis-a-vis the respondents' perceptions of conflict likeliness. The other fuzzy operator normally used is the fuzzy algebraic sum (FuAS), by which output integrated fuzzy values $\mu combination$ is obtained as:

$$FuAS\ \mu_{combination} = 1 - \prod_{j=I}^{n}(1 - W_i\mu_i),$$ *(Equation 5.6)*

where

FuAS	=	*The fuzzy algebraic sum*
W_i	=	*The weight in the input fuzzy factor map i*
μ_i	=	*The fuzzy values in the input fuzzy factor map I, and I = 1, 2, …, n input fuzzy factor maps to be combined*

The output of FuAS for each point is always larger than, or equal to, the maximum fuzzy value at the same point in any input map (i.e., it has 'maximizing' effect).

Two types of fuzzy operators are inbuilt in the fuzzy logic model in MATLAB. These are OR and AND. In the model, there is an indication of 2 for OR and 1 for AND. In applying the fuzzy operators in the context of NRBCs, the two fuzzy operators are used for combining the fuzzy membership functions. Questions were asked to derive the knowledge of the actors on the importance of the rules used.

In the actual interpretation of the operators, OR means that any of the inputs of the antecedents is a significant contributor to conflicts. Conversely AND means that all the antecedents significantly contribute to conflicts. Multiple parts of the antecedent are resolved with the fuzzy operator to assign a single number between 0 and 1, which is the degree of support for the rule. In the translation of the rule in fuzzy logic, OR represents the maximum and AND represents a minimum. For example, in a rule: *If (mangrove distance is far, Water Distance is far, Farmland is far, oil infrastructure is near) conflict is very likely,* with the fuzzy membership values: [0.0 0.2 0.9 1] respectively. The fuzzy OR operator simply selects the maximum of the three values, 1, and the fuzzy operation of the rule is completed. If the AND operator is chosen, the minimum value will be taken and the rest will be discarded. Figure 5.16 (A, B and C) shows the SEFLAME-CM interface for environmental, socio-economic and political vulnerability assessments.

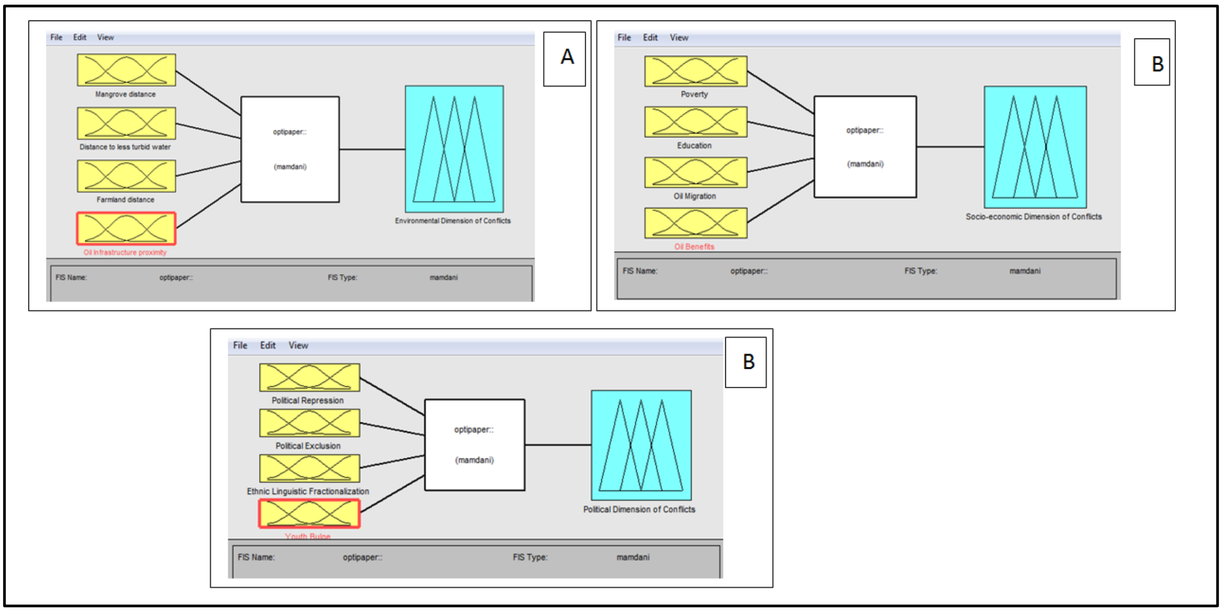


Figure 5.16: SEFLAME-CM interface.

5.2.3.6 Aggregation of Outputs

Since decisions are based on the testing of all of the rules in a fuzzy logic model, the rules must be combined in order to make a decision (MATLAB, 2015). Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to defuzzification (see Section 5.2.3.7). The input of the aggregation process is the list of truncated output functions returned by the implication process (see Section 5.2.3.4). The output of the aggregation process is one fuzzy set for each output variable. The various aggregation types include MAX (maximum), prob. (probabilistic OR) or sum (simply the sum of each rule's output set) (MATLAB, 2015). See Figure 5.17 for simplified schematics on how all three rules in each line are combined /aggregated into a single fuzzy set. This followed the steps such as *fuzzy inputs, fuzzy rules, fuzzy implication rules, and fuzzy operator* as described earlier**.** At the point of aggregation, the membership function assigns a weighting for every output, i.e. the value of weights for the vulnerability to natural resource-based conflicts.

5.2.3.7 Defuzzification (Centroid Defuzzification Algorithm) and Decision Making

Defuzzification is a very important part of fuzzy logic modeling. It involves the transformation of a synthesized fuzzy set back to a crisp set, which expresses the result of modeling. Defuzzification can make use of a subjectively or objectively defined threshold of fuzzy value (Sicat *et al.*, 2005). Hellendoorn and Thomas (1993) described a number of criteria that an ideal defuzzification procedure should satisfy. Many types of defuzzification exist, but in this study, the centroid defuzzification algorithm, called the center of gravity (COG) is used because of its simplicity and adaptability to new problems (Hellendoorn and Thomas, 1995, MATLAB, 2015, Kumar, 2017). COG produces results sensitive to all rules. This is defined mathematically in *Equation 4.7* according to (Ross, 1995) cited in (Pappis and Siettos, 2005) (:432).

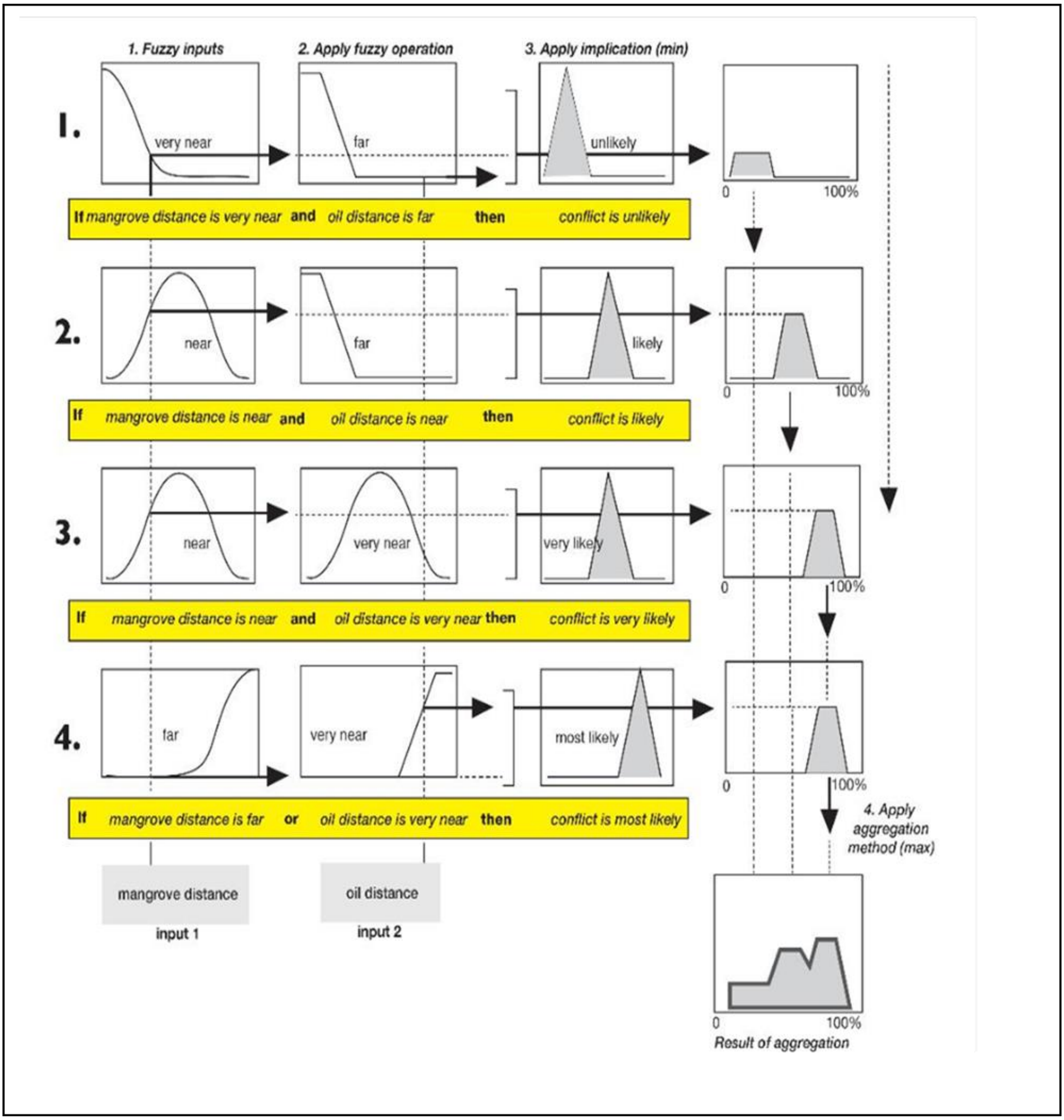


Figure 5.17: Overview of schematics of how all three rules in each line are combined/aggregated into a single fuzzy set adapted from MATLAB (2015).

$$Y = \frac{\sum_{i=1}^{n} A_i(M_i)}{\sum_{i=1}^{n} A_i} \qquad \textit{(Equation 5.7)}$$

where

Y	=	*Output crisp value*
M_i	=	*The value of the membership function of the output fuzzy set of rule i*
I	=	*Representation of rule i*
A_i	=	*The crisp value of the corresponding membership area, indicating the the degree to which that the rule i is fired*

The COG Equations are applied to the different data layers (see Figure 5.18). Therefore the COG defuzzification method is the basis of the algorithm used to develop the Conflict Vulnerability Likeliness (CVL) Index (see Section 5.2.3.8 for details). *Equations 5.8 to 5.16* are used to implement the various data layers of SEFLAME-CM outlined in Figure 4.18. As clearly shown in Figure 4.18, layer 1 contains the input parameters of the drivers of NRBCs, layer 2 includes the three dimensions of conflict drivers considered, layer 3 includes the two typologies of conflicts, while layer 4 is made up of the CVL Indices (the non-spatially and spatially explicit model).

To derive layer 2 (the conflicts drivers under the three dimensions). The *Equations 5.8, 5.9 and 5.10) are* used as shown below:

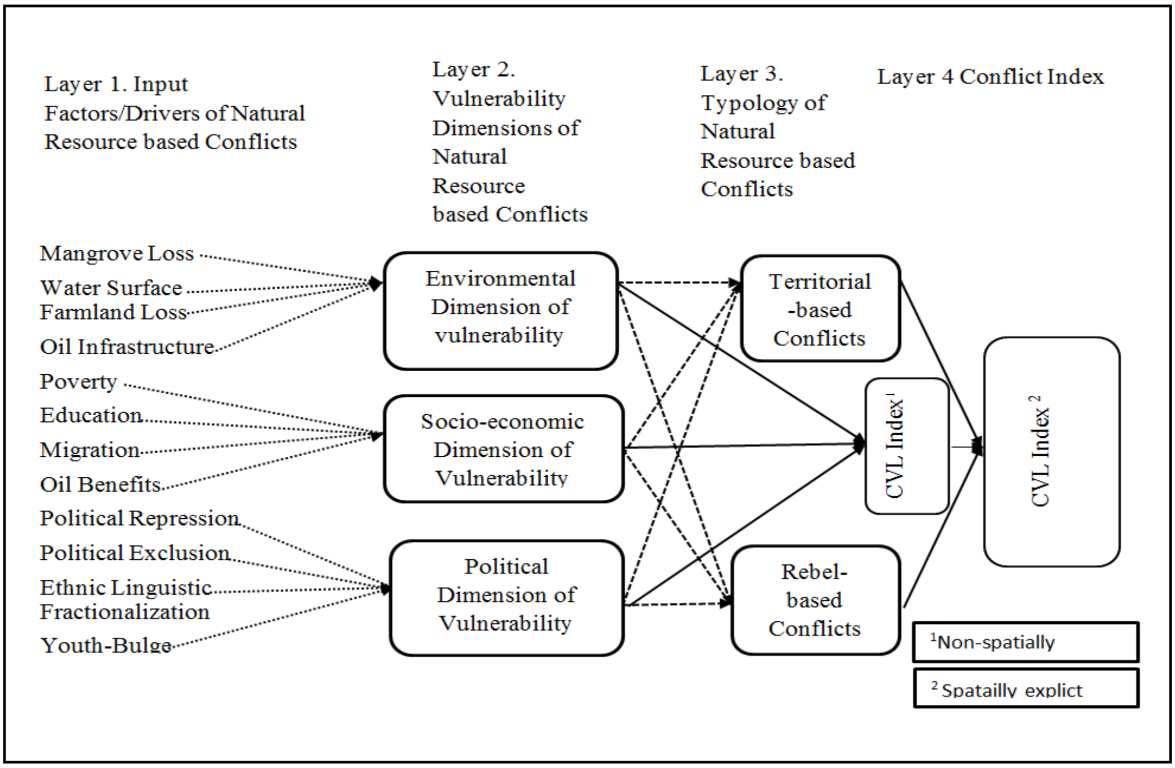


Figure 5.18: Simplified hierarchical structure of model input data layers in vulnerability assessment of natural resource-based conflicts.

- To derive the CVL Index for environmental drivers (Iev), *Equation 5.8* below is used:

$$Y_{Iev} = \frac{\sum_{i=1}^{n} A_i(ev_i)}{\sum_{i=1}^{n} A_i} \qquad \text{(Equation 5.8)}$$

where

Y_{Iev}	=	*Conflicts index value for environment (ev)*
Ev	=	*Environmental drivers of conflicts*
ev_i	=	*Value of the membership function of the output fuzzy set, ev in rule i*
I	=	*Representing rule I of the ev inputs*
	=	*Value of the corresponding membership area, indicating the degree to which rule i is fired*

- To derive the CVL Index for socio-economic drivers (Ise), *Equation 5.9* is applied.

$$Y_{Ise} = \frac{\sum_{i=1}^{n} A_i(se_i)}{\sum_{i=1}^{n} A_i} \qquad \text{(Equation 5.9)}$$

where

Y_{Ise}	=	*Conflicts index value for socio-economic (see) drivers*
se	=	*Socioeconomic drivers of conflicts*
se_i	=	*Value of the membership function of the output fuzzy set, se in rule i*
i	=	*Representing rule i of the ev inputs*
A_i	=	*Value of the corresponding membership area, indicating the degree to which rule i is fired*

- To derive the CVL Index for political drivers (Ipo), *Equation 5.10* below is applied:

$$Y_{Ipo} = \frac{\sum_{i=1}^{n} A_i(po_i)}{\sum_{i=1}^{n} A_i} \qquad \text{(Equation 5.10)}$$

where

Y_{Ipo}	=	*Conflicts index for political (po) drivers of conflicts*
po	=	*Political drivers of conflicts*
po_i	=	*The value of the membership function of the output fuzzy set, po of rule i*
i	=	*Representing rule i of the po inputs*
A_i	=	*Value of the corresponding membership area, indicating the degree to which rule i is fired*

- To derive layer 3 (the conflicts typologies under the three dimensions of environmental, socio-economic and political drivers), *Equations 5.11 to 5.14* are used as shown below:

- CVL Index-environmental drivers of conflicts vs. rebel-based conflicts (IevRBC)

$$Y_{IevRBC} = \frac{\sum_{i=1}^{n} A_i(evRBC_i)}{\sum_{i=1}^{n} A_i} \qquad \textit{(Equation 5.11)}$$

where

Y_{IevRBC}	=	*Conflicts index for environmental drivers of conflicts vs. rebel-based conflicts*
evRBC	=	*Environmental rivers vs. rebel-based conflicts*
$evRBC_i$	=	*The value of the membership function of the output fuzzy set, evRBC of rule i*
I	=	*Representing rule i of the evRBC inputs*
A_i	=	*Value of the corresponding membership area, indicating the degree to which rule i is fired*

Equation 5.11 is shown as an example. Similar models are set up for the socio-economic drivers vs. rebel-based conflicts (YIseRBC) and for the political drivers vs. rebel-based conflicts (YIpoRBC).

The final index for the rebel-based conflicts typology for all the drivers is derived as an average of the YIevRBC, YIseRBC, and YIpoRBC using *Equation 5.12* below. See Section 6.5.3.2.1 for the results of the implementation.

- CVL Index for all rebel-based conflict typology

$$Y_{IRBC} = \frac{(Y_{IevRBC}[\%] + Y_{IseRBC}[\%] + Y_{IpoRBC}[\%])}{n} \qquad \textit{(Equation 5.12)}$$

where,

Y_{IRBC}	=	*Rebel-based conflicts index*
Y_{IevRBC}	=	*Conflicts index for environment risks drivers vs.RBC*
Y_{IseRBC}	=	*Conflicts Index for socio-economic drivers vs.RBC*
Y_{IpoRBC}	=	*Conflicts Index for political drivers vs.RBC*
N	=	*Number of conflict driver dimensions*

- CVL Index- environmental drivers of conflicts vs. territorial-based conflicts (IevTBC)

$$Y_{IevTBC} = \frac{\sum_{i=1}^{n} A_i(evTBC_i)}{\sum_{i=1}^{n} A_i} \qquad \textit{(Equation 5.13)}$$

where

Y_{IevTBC}	=	*Conflicts index for environmental drivers of conflicts vs. territorial-based conflicts*
evTBC	=	*Environmental divers vs. territorial-based conflicts*
$evTBC_i$	=	*The value of the membership function of the output fuzzy set, evTBC of rule i*
I	=	*Representing rule i of the evTBC inputs*
A_i	=	*Value of the corresponding membership area, indicating the degree to which rule i is fired*

While *Equation 5.13* is shown as an example, similar models are set up for the socio-economic drivers vs. territorial-based conflicts *(YIseTBC)* and for the political drivers vs. rebel-based conflicts *(YIpoTBC)*. The final index for the territorial-based conflicts typology for all the drivers is derived as an average of the *YIevTBC*, *YIseTBC*, and *YIpoTBC* using *Equation 5.14* below. See Section 6.5.3.2.1 for the findings of the investigation.

$$Y_{IRBC} = \frac{(Y_{IevTBC}[\%]+Y_{IseTBC}[\%]+Y_{IpoTBC}[\%])}{n} \qquad \text{(Equation 5.14)}$$

where

Y_{ITBC}	=	*Territorial-based conflicts index*
Y_{IevTBC}	=	*Conflicts index for environment risks drivers vs.TBC*
Y_{IseTBC}	=	*Conflict Index for socio-economic drivers vs.TBC*
Y_{IpoTBC}	=	*Conflict Index for political drivers vs.TBC*
N	=	*Number of conflict driver dimensions*

To derive layer 4 (the final non-spatially explicit and the spatially explicit CVL Index), *Equations 5.15 and 5.16* are used as shown below:

- The final CVL Index based on FLAME-CM (non-spatially explicit). This is the non-spatially explicit conflicts index. It is the average of the output of *Equations 5.8, 5.9, and 5.10.* This is then derived using *Equation 5.15* as shown below:

$$CVL\ Index\ 1 = \frac{Y_{Iev} + Y_{Isv} + Y_{Ipo}}{n} \qquad \text{(Equation 5.15)}$$

where

CVL Index 1	=	*Conflicts vulnerability Likeliness Index-non-spatially explicit [0 1]*
Y_{Iev}	=	*Conflicts index for environment risks drivers*

Y_{Ise}	=	*Conflicts Index for socio-economic drivers*
Y_{Ipo}	=	*Conflicts Index for political drivers*
n	=	*Number of conflicts driver dimensions*

- The Final CVL Index used SEFLAME-CM (spatially explicit). This is the spatially explicit conflict index. It is the average of the output of *Equations 5.12, and 5.14.* This was derived using *Equation 5.16* below:

(Equation 5.16)

$$CVL\ Index\ 2 = \frac{Y_{IRBC}+Y_{ITBC}}{n}$$

where

CVL Index2	=	*Conflicts Vulnerability Likeliness Index -spatially explicit [0 1]*
Y_{IRBC}	=	*Conflicts index for rebel based conflicts*
Y_{ITBC}	=	*Conflicts Index for territorial based conflicts*
n	=	*Number of conflict typologies*

5.2.3.8 Model Validation of Fuzzy Composite Index: Conflict Vulnerability Likeliness (CVL) Index

The Model-SEFLAME-CM is the spatially explicit context of FLAME-CM. Both FLAME-CM and SEFLAME-CM are used to derive the CVL Indices as composite indices, by combining multiple and complex drivers of NRBCs into one measure (Fritzsch, 2011) (see Figure 5.18 and Table 5.8). The pros and cons of composite indices have been widely discussed (Nardo, 2005, Rahman, 2007). See also Section 3.4 and (Sivanandam *et al.*, 2007, Acosta-Michlik *et al.*, 2008, Fritzsch, 2011) for details on the fuzzy-based composite index. The fuzzy-logic based index is beyond that proposed in OECD (OECD, 2004). See Figure 5.18 for the structure of the nested multi-method model with the integration of the multiple conflict drivers. The data types contained in the model design are explained below:

Conflict Typologies: These are the two main typologies of NRBCs. They are the rebel and territorial-based conflict typologies (Raleigh, 2011)

Vulnerability Dimensions: These are the vulnerability dimensions/components of NRBCs. They are the main forces that drive resource conflicts. They include environmental, socio-economic, political dimensions (Bohle, 2001).

Drivers/Factors: These are the conflict drivers and conditions identified from the field surveys through a series of interviews. They are intrinsic conditions that make people and places vulnerable to NRBCs.

Parameters: The parameters are the key quantifiable measures of NRBCs. They are the measurable model input variables. Parameters are fuzzy measurements of the NRBCs (see Section 5.2.4 for details).

Indicators: Indicators are used in development studies and in the social sciences. Vulnerability indicators were developed from the identified drivers/factors and from the conditions of NRBCs in the data collection process using literature review of the past local and international scientific studies on NRBCs (see Table 5.8 for example). Indicators are constituents of the main factors and as such, they determine the degree of influence of the factors for each of the driver components in the overall vulnerability to NRBCs.

5.2.3.8.1 The FLAME-CM vs. the SEFLAME-CM

In this thesis FLAME-CM is used as a test model while SEFLAME-CM is the target model. FLAME-CM generates the CVL Index and transferred it into SEFLAME-CM. The final CVL Index is generated using SEFLAME-CM. The two typologies of conflicts are introduced into SEFLAME-CM (see Figure 5.18 for the data layers and Figure 5.19 for the implementation of the SEFLAME-CM in MATLAB). The final CVL index is validated using the SMCE-CM.

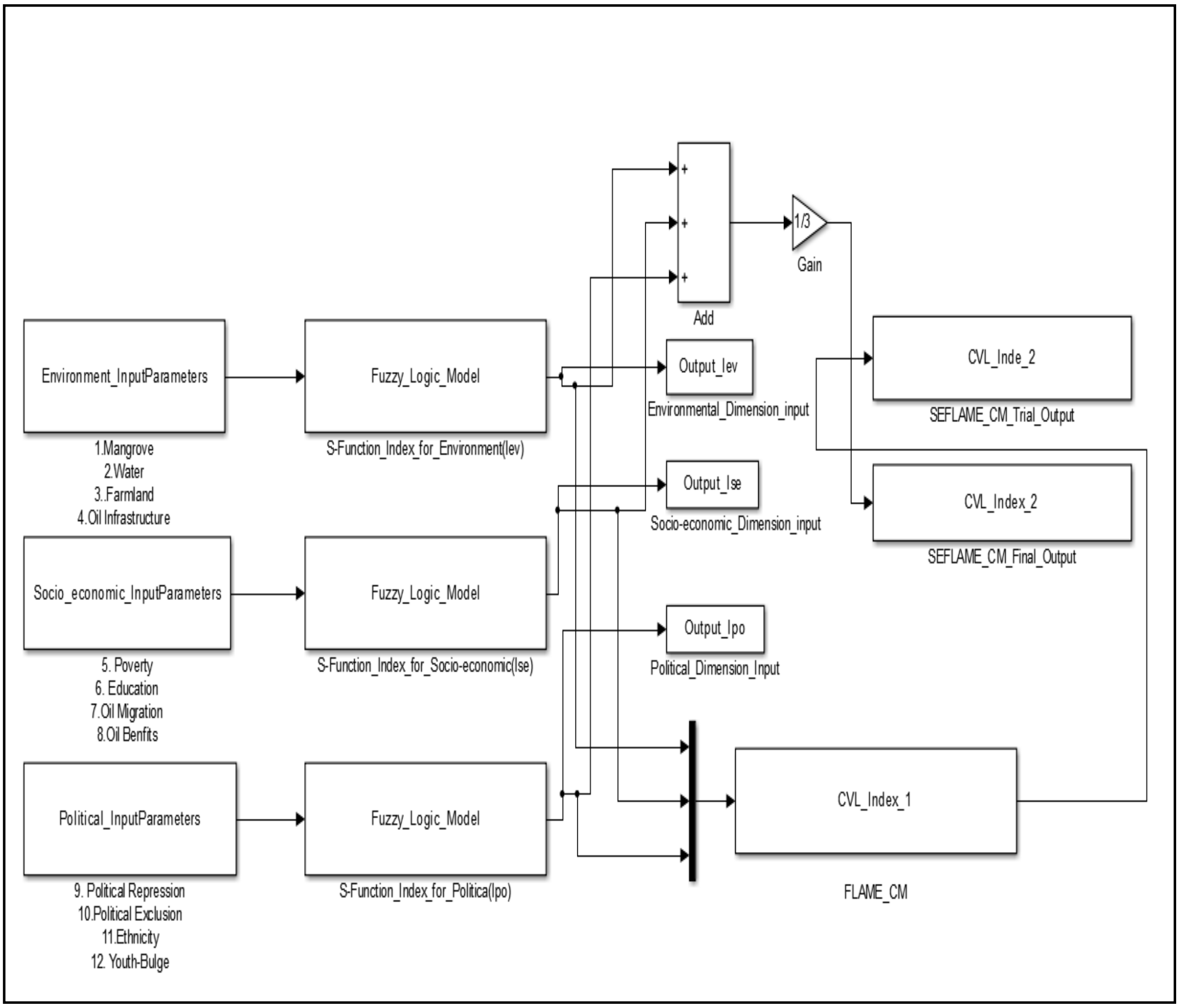


Figure 5.19: Overview of implementation strategy of SEFAME-CM in MATLAB for deriving the CVL Index.

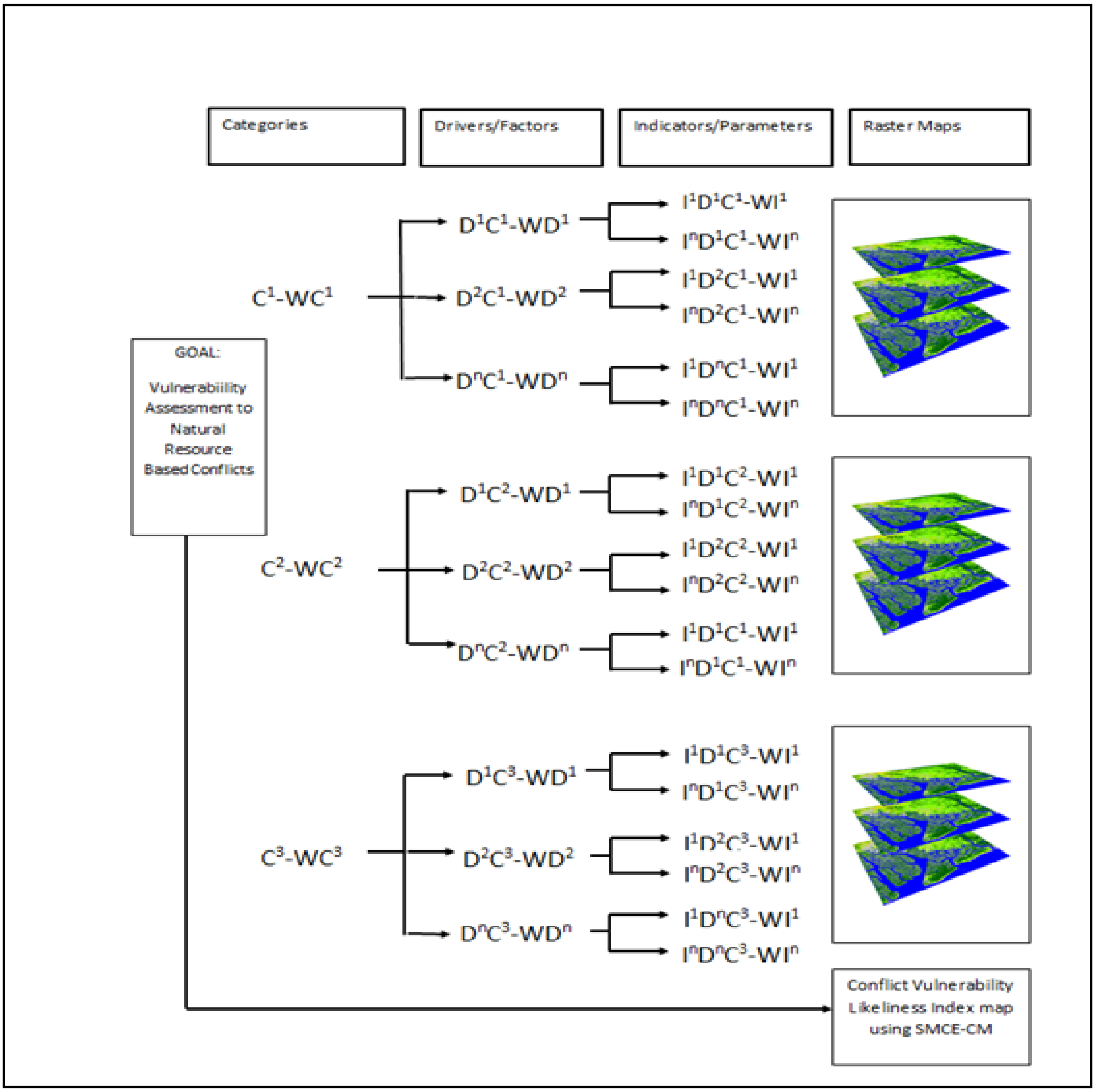
Table 5.8: Explanation of model data formats in vulnerability assessment of natural resource-based conflicts.

Conflict Typology	Vulnerability Dimensions/ Categories	Conflict Drivers/ Factors	Indicators	Fuzzy Measured Parameters	CVL Index
Territorial based conflicts	Environment	Mangrove Loss	Distance to Mangrove	Very near-near-far	Unlikely (0-0.25)
		Water Pollution	Distance to Less Turbid Water Surface	Very near-near-far	
		Farmland Loss	Distance to Farmland	Very near-near-far	
		Oil Infrastructure	Distance to Oil-well Distance to Oil Flow station	Very near-near-far	Likely (0.25-0.50)
	Socio-economic	Poverty	Water supply Household size Sanitation (type of toilet) Access to TV Access to Phone Hosing materials Cooking Energy	High-Medium-Low	Very Likely (0.50-0.75)
Rebel based conflicts c	Political				Most Likely (0.75-1.00)
		Education	Number of Enrollment	Primary-Secondary-	

		Tertiary
Migration	% Migration from LGA/Community	High-Medium-Low
Oil Benefits	Ranking of CSR Oil Company projects	Low-Medium-High
Political Repression	Rating	High-Medium-Low
Political Exclusion	Rating	High-Medium-Low
Ethnolinguistic Fractionalization (ETLF)	Number of ethnic groups	High-Medium-Low
Youth-Bulge	% Population (Age15-24)	High-Medium-Low

5.2.3.8.2 Creating Spatial Multi-criteria Evaluation for Vulnerability Assessment of Natural Resource-Based Conflicts

To validate SEFLAME-CM, Spatial Multi-criteria Evaluation for Conflict Management (SMCE-CM) is developed and implemented. Like SEFLAME-CM, the development of the SMCE-CM is based on the combination of the different data layer as described earlier (see Figure 5.18). Therefore the SEFLAME-CM and the SMCE-CM are based on the same data types (see Section 5.2.4 for details on FUZZYCONDATA). See Figure 5.20 for the schematic procedure of the SMCE-CM based on the Analytical Hierarchical Process (AHP). Figure 5.20 shows how the various data layers are combined by using the SMCE-CM to produce the final conflict map.



Key: C-Category, D-Drivers, W-Weight, Indicators, WC-Weighted Category,
WD, Weighted Drivers, WI-Weighted Indicators

Figure 5.20: Schematic procedure for the SMCE-CM based on AHP, adapted from Van Westen (2007).

The theoretical background of the multi-criteria evaluation is based on AHP. AHP is developed by Saaty (1987). It has been extensively applied to complex decision-making problems, in vulnerability assessment and suitability mapping (Saaty and Vargas 2001). From a decision-making perspective, multi-criteria evaluation (MCE) can be expressed in a matrix (Triantaphyllou, 2000) (see Table 5.9). The spatial processes of implementing the SMCE-CM include a semi-quantitative model in the MCE module of ILWIS-GIS. ILWIS-GIS is an SMCE application guide for users of MCE in a spatial context (ITC, 2005). The inputs are a set of maps that are the spatial representation of the criteria while the outputs are one or more conflict composite index map(s).

Table 5.9: Multi-criteria decision matrix.

Matrix A	C_1 (W_1 W_2, W_3 …W_e)	C_2	C_3	• • •	Cn
A_1	a_{11}	a_{12}	a_{13}	• • •	a_{1n}
A_2	a_{21}	a_{22}	a_{23}	• • •	a_{2n}
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
A_m	a_m1	a_m2	a_m3	• • •	a_{mn}

The implementation undergoes three main processes. First, defining the criteria tree and grouping of factors and/or constraints for conflict vulnerability mapping. Second, standardization of criteria. The third step includes weighting of the criteria. These steps are further described below:

Step 1: Defining the criteria tree and grouping of the factors. An important component of the SMCE is the criteria. This is referred to as the conflict drivers. These criteria are the factors and constraints for determining the communities that are vulnerable to NRBCs. The grouping of criteria means classifying of the drivers of conflicts into sub-goals called categories or dimensions of conflict vulnerability (see Figure 5.20). The indicators are derived from the drivers/factors. They are generated based on the knowledge of the literature using data sets from various sources described earlier. The indicators are further subdivided into the parameters which form the input raster maps. A criteria tree is critical to the SMCE setup. The criteria tree is the structure that holds the different layers of data. Every conflict driver forms a criterion (Cj) which further determined the raster layers of conflict parameters. Every pixel (or set of pixels) of the final composite index map eventually becomes an alternative Aj (Malczewski, 1996, Malczewski, 2004, Thill, 1999). The alternative in this regard is the likeliness levels of conflicts vulnerability. For example, as shown in Table 5.9, matrix A contains the criteria in one axis (C1 to Cn), and a list of possible alternatives (vulnerability likeliness of conflicts), from which a decision has to be taken on the other axis (A1 to An). Each cell in the matrix (aij) indicates the performance of a particular alternative in terms of a particular criterion. The value of each cell in the matrix is composed of the multiplication of the standardized value (between 0 and 1) of the criterion for the particular alternative and the weight (W1 to Wn) related to the criterion. Once the matrix is filled, the final value can be obtained by adding up all cell values of the different criteria for the particular alternative (e.g. a11 to a1n for alternative A1), see Van Westen (2007).

Step 2: Standardization**.** The second step includes converting the parameters into values with increasing vulnerability between 0 and 1 from their original values, based on the subjective measurement. This is in order to make spatial multi-criteria analysis possible. Importantly the indicators could have different measurement scales (nominal, ordinal, interval and ratio) and their cartographic representations could also be different (natural and administrative polygons and pixel-based raster maps). Various standardized methods are provided in the SMCE module of ILWIS (ITC, 2005). The standardization process is different if the indicator is a 'value' map with numerical and measurable values (interval and ratio scales) or a 'class' map with categories or classes (nominal and ordinal scales). In standardization, the value is converted to the actual map values to a range between 0 and 1. The class maps use an associated table for standardization where a column must be filled with values between 0 and 1.

An important component of standardization is decided for each indicator, whether it is favorable or unfavorable in relation to the intermediate or overall objective. For example, for the intermediate objective of vulnerability, the conflict driver maps with values show an increase in the overall vulnerability. The overall vulnerability is considered favorable (benefit), when the distance between a village and a resource such as oil infrastructure is very near. For example the closer the distance to oil infrastructure the higher the CVL Index. Otherwise, the overall vulnerability is considered unfavorable (cost) when it constrains the occurrence of conflicts. In this case, a close distance of mangrove will reduce conflicts likeliness. In this study, all parameters are organized to have both a positive contribution (being favorable), and negative contribution (unfavorable) to the CVL Index. Figure 4.21 shows an example of both benefit (left) and cost standardization (right).

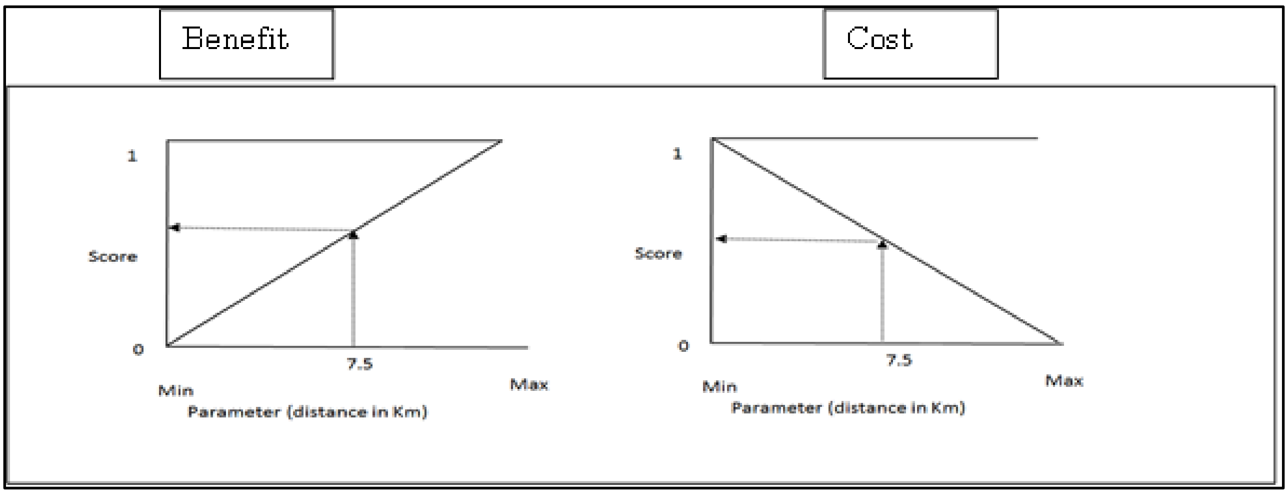


Figure 5.21: Examples of standardization.

Another important aspect of the model design is the use of constraint indicators. Constraint indicators are those that mask out areas and assign particular values to the resulting map, irrespective of the other parameters (Van Westen, 2007). No driver was used as a constraint parameter. After selecting the appropriate indicators, defining their standardization and the hierarchical structure, the weights are assigned to each criterion and the intermediate result.

Step 3: Weighting process of criteria. This is meant to assign the relative importance of conflict drivers in the entire criteria (see Figure 5.22). The weight was performed from the indicators, drivers and finally the categories or the sub-goals of the criteria. In the SMCE module, the process of weighting within a group and among the groups is normally facilitated using methods such as the 'direct weight method', 'rank order methods' and 'pairwise comparison' methods (ITC, 2005). The implementation of the weighting process in SMCE-CM was based on 'pairwise comparison' (ITC, 2005). The weights assigned to each driver/factor were therefore obtained via the pairwise comparison matrix. In the analysis, the literature reviewed and the opinion of the experts involved in the NRBCs in the implementation of SEFLAME-CM are considered very critical. The implementation of the SMCE-CM used the ILWIS-GIS environment (ITC, 2005) (see Figure 5.22).

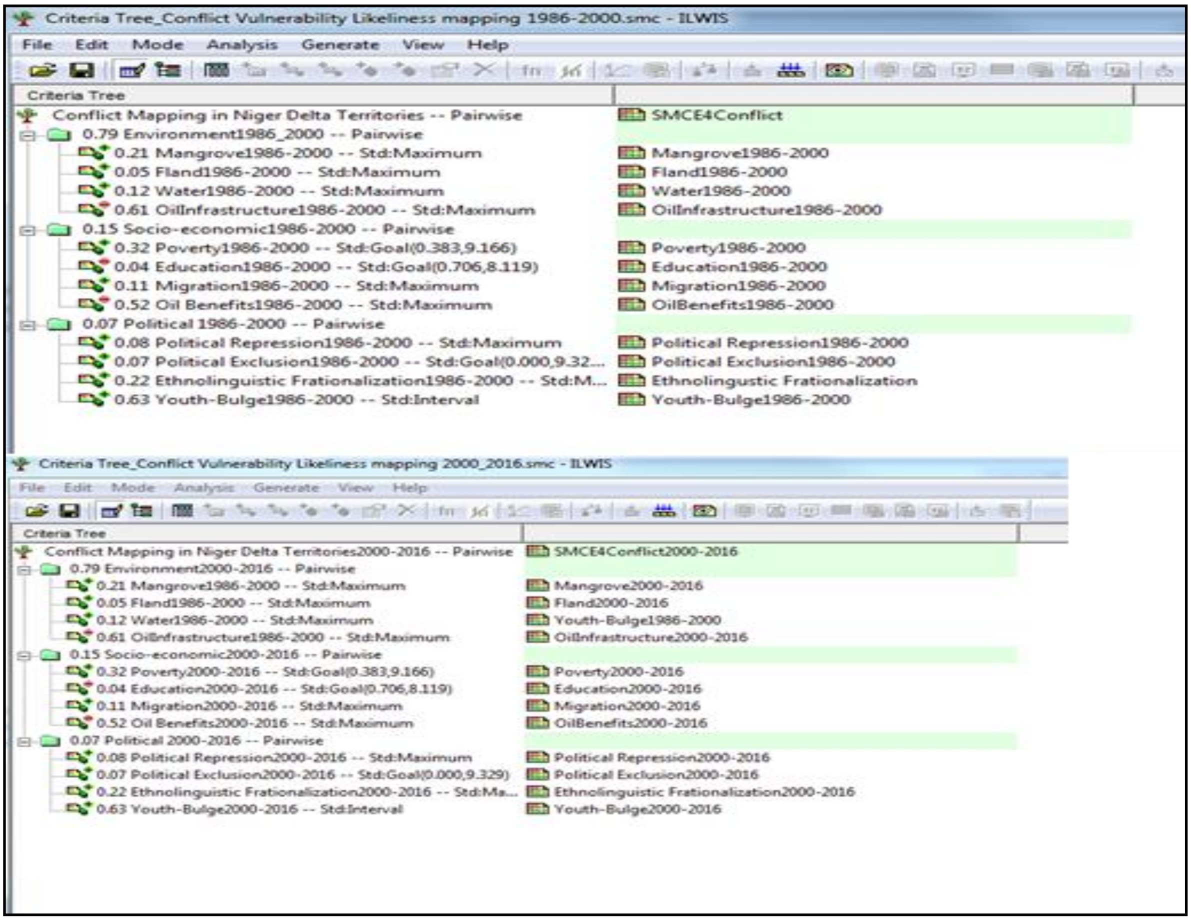


Figure 5.22: SMCE-CM screen-shot: criteria tree.

The results of SEFLAME-CM and SMCE-CM are compared using spatial statistics (see Section 6.5.3.1). Section 5.2.4 describes the FUZZYCONDATA and the spatial attributes of the data sets.

5.2.4 Spatial Attributes and the Description of Fuzzy Conflict Data (FUZZYCONDATA)

FUZZYCONDATA contains the training and the validation data sets which were derived from the various data sources. Table 5.10 and Table 5.11 show a list of input variables with fuzzy set parameters and the output variables respectively.

Table 5.10: Fuzzy input variables.

Input Variables	Fuzzy set Parameter (Categories)
Mangrove Distance	Verynear (1) -Near (2) -Far (3)
Distance to Less Turbid water	Verynear (2) -Near (2)-Far (3)
Distance to Farmland	Verynear (1) -Near (2) -Far (3)
Oil Infrastructure Distance	Verynear (1) -Near (2) -Far (3)
Poverty	High (1) -Medium (2) - Low (3)
Education	High (1) -Medium (2) - Low (3)
Oil Migration	High (1) -Medium (2) - Low (3)
Oil Benefits	High (1) -Medium (2) - Low (3)
Political Repression	High (1) -Medium (2) - Low (3)
Political Exclusion	High (1) -Medium (2) - Low (3)
Ethnic Linguistic Fractionalization	High (1) -Medium (2) - Low (3)
Youth-Bulge	High (1) -Medium (2) - Low (3)

The outputs are expressed as four linguistic categories referring to the level of the intrinsic vulnerability to conflict: *Unlikely, Likely, Very likely, and Most likely* (Table5. 11).

Table 5.11: Fuzzy Output variables.

Output	Fuzzy Set of Conflict Likeliness
Environmental risk Vulnerability	Unlikely-Likely-Very Likely-Most Likely
Socio-economic Vulnerability	Unlikely-Likely-Very Likely-Most Likely
Political Vulnerability	Unlikely-Likely-Very Likely-Most Likely
CVL Index	Unlikely-Likely-Very Likely-Most Likely

The model description has been presented in Section 5.1, while the model implementation steps and the algorithm were presented in Section 5.2.3. Therefore all the model input parameters under the environmental, socio-economic and political data categories make up the FUZZYCONDATA. These input parameters as shown in Section 5.1 are based on the fuzzy rules, fuzzy ratings, and fuzzy weights. They are processed and disaggregated to the grid size unit (see Section 6.5.3) for the FLAME-CM. The averages of the input parameters are calculated for each of the communities being investigated and visualized. These served as inputs parameters for the SEFLAME-CM. The interpolation of the data is not deemed necessary at this point because of the use of social data sets which are continuous variables. See Appendix A.12.14 to Appendix A.12.19 for examples of spatial input parameters under the environmental, socio-economic and political vulnerability dimensions for the reference periods 1986-2000 and 2000-2016.

The model validation and the findings in this work are presented in Section 6.

6 Model Validation

The modeling of Natural Resource-Based Conflicts (NRBCs) as a "wicked" problem in the Niger Delta territories requires a validation in order to test the model credibility. In this work, a multi-stage validation process (MSVP) is seen as a useful strategy. The highest emphasis is placed on evaluating the relationship between the target model-SEFLAME-CM, developed based on the actors' knowledge of conflicts (violent or non-violent conflicts) in their communities and the observed conflict data sets as the real-world context. The model quality and accuracy are monitored by comparing the model results with the real-world data sets on conflicts. The main assumption is that an accurate qualitative and quantitative modeling approach based on the weighting of the drivers of conflicts by the actors will lead to credible (robust) model results. The validation strategies include firstly, temporal and dimensional validation. This is carried out by using the villages as test sites and the observed conflict data sets as the validation data with the reference years (1986-2000) and (2000-2016). Secondly, a cross-validation strategy is applied to improve the model results. This involved performing the model's robustness and uncertainty check with a new validation set generated through the exponent of the logarithm of the observed conflict data (ELOBCONDATA). Thirdly, the performance of the model is tested in the Niger Delta selected communities and evaluated in a spatially explicit context. This part involved three sub-steps. The first sub-step used descriptive statistics to evaluate the model using the two conflict typologies studied. In the second sub-step, the SEFLAME-CM is validated with the Spatial Multicriteria Evaluation for Conflict Management (SMCE-CM). Here the results of the SEFLAME-CM and SMCE-CM are compared with the use of spatial statistics. In the third and the final sub-step, the SEFLAME-CM results are validated with satellite data on the study area using all the datasets for the period of 1986 to 2016.

6.1 Validating Natural Resources-Based Conflict Model in a Transdisciplinary Research

Detailed observed data sets are required for the model validation processes of the NRBCs under the transdisciplinary-based coupled approach. Due to the fact that many international research agencies have shown research interests in the Niger Delta, conflict data sets are available in the public domain. These observed conflict datasets are recently archived in disaggregated format ((Raleigh et al., 2010, Raleigh, 2011), Section 5.2.1). These conflict data sets and the satellite datasets are used for the model validation (see Figure 6.2 for example). The results of the validation of the FLAME-CM and the SEFLAME-CM (the target model) (see Section 5.2.3.8.1) are presented in Sections 6.5.1, 6.5.2, and 6.5.3. The performance of the validated model supports the inadequacy of the previous use of multiple linear regression models (MLRMs) for analyzing the NRBCs. The reasons for the inadequacies of the MLRMs are highlighted as follows.

Firstly, it is observed that there are reasons for skepticisms over the use of regression models to validate conflict investigations. One of such reasons is that in the Large-N conflict cases where MLRMs are used, the samples are not necessarily drawn from the homogenous population (Badiuzzaman *et al.*, 2011).

Secondly, another challenge in the use of MLRMs is that in most of the previous quantitative assessments of conflicts, the role of the environment as a key driver of NRBCs is normally not revealed. However, as stated in Sections 1, 3, and 4, the environment is a highly significant factor in driving a community's vulnerability or its resilience to NRBCs. With remote sensing, the environmental parameters can be quantified. However, remote sensing is rarely applied in conflict studies because of the disciplinary dichotomy between the natural scientists and social scientists. Through the use of transdisciplinary approaches, it is possible to integrate "people and pixels"(National Research Council, 1998).

Thirdly, in the use of MLRMs and other related models to validate the relationship between natural resources and conflict occurrence, the observed conflict data sets are used with the binary specification of (conflict or no conflict) situations (Collier and Hoeffler, 2004, Collier *et al.*, 2009). In most of these previous Large-N studies, the temporal data sets are often used. However, the observed data sets are mainly large-scale violence cases such as civil wars. Here, conflicts are identified as civil wars, with the use of 25 or 1000 battle deaths. A critical hypothesis tested is often to evaluate whether the conflict is more related to greed (socio-economic and political issues) or whether they are related to grievances over environmental degradation or the shortage of environmental services. In the latter case, therefore, environmental drivers are seen as the justification for either territorial or rebel-based conflicts. But the problem with the focus on large-scale observed datasets is that the local or small conflicts are excluded (see Section 4 on joint problem framing).

Fourthly, another challenge in the use of MLRMs for conflict validation is that studies have yielded conflicting results (Ross, 2004). For example, the finding by Rustad and Binningsbø (2012) contradicts that of Collier *et al.* (2009). The latter argues that conflict will reoccur where feasible and where natural resources are used as a source of funding. Rustad and Binningsbø's study support the theories that suggest grievances as motivation for resistance in line with (Ǿstby *et al.*, 2009). The publication by Ross (2004) on "what do we know about natural resource and civil wars" gave reasons for the conflicting results. Some of the reasons include the fact that the dependent variables are based on coarse national data. National data sets are often poor proxies for the conditions where conflicts occur, and their use may lead to an ecological fallacy: inferring about individual behavior from aggregate data (Tollefsen *et al.*, 2012) This is where spatial disaggregation becomes more viable and attractive with the use of geo-referenced data and user-friendly GIS applications (Tollefsen *et al.*, 2012). As stated in the discussions in Section 1 and 3, new approaches and new datasets seem to be the way out. An example is the use of various data types such as using rainfall as a proxy for economic shocks, thereby demonstrating the usefulness of instrument indicators (Miguel *et al.*, 2004). Also, there are recent developments and the use of new databases such as the PETRODATA (Lujala *et al.*, 2007) and the DIADATA (Gilmore *et al.*, 2005). The right specification of mechanism at actor-level will enhance better measures of local level validation (Buhaug and Rød, 2006). The current validation strategy of this thesis is not only to test the earlier results for their robustness but to also investigate a new range of effects of the perceived views of the actors and how their understanding of the mechanisms of NRBCs can improve the model validation results.

Importantly, given these arguments on the validation of models that are often used to investigate real-world problems in the social sciences, the validation process of this work particularly requires an explanation of relationships and interactions rather than a prediction (Grüne-Yanoff, 2009, Rossiter *et al.*, 2010, David, 2013). Thus, with NRBCs being a "wicked" problem (see Sections 3 and 5), the validation process deals with one of the long-standing topics in the philosophy of the sciences. The validation of a social simulation is debatable in the literature (Rossiter *et al.*, 2010). This is because the choice of empirical data is never truly objective but it is influenced by theoretical considerations, biases, and modeling difficulties of real-world systems. For example, there is no obvious dividing line drawn between the drivers and the occurrence of conflicts (Martinez-Alier, 2001, Martinez-Alier, 2009b).

Notwithstanding, all the simulation models that use empirical data to analyze relationships in the underlying real-world system can be validated (McKelvey, 2002). The important factors to be considered in validating simulation models include the research, the research questions, the researcher's inherent epistemological perspective and how the results are interpreted (Becker *et al.*, 2005). See Figure 6.2, for representation of the overall social simulation process. As shown in Figures 6.1 and 6.2, simulation models in the social sciences cut across theory and practice. Therefore the challenge of validating such models is how to find a suitable strategy. There is a conclusion that such validation method should mediate between theory and data (see Figure 6.1 for example). In this thesis, therefore, in order to validate the modeling of NRBCs, under the transdisciplinary approach, some of the key aspects of the approach need to be captured, including the spatial, temporal and the dimensions of the NRBCs drivers. To achieve this. a multi-stage validation procedure is considered appropriate (Naylor *et al.*, 1967, Sargent, 2013).

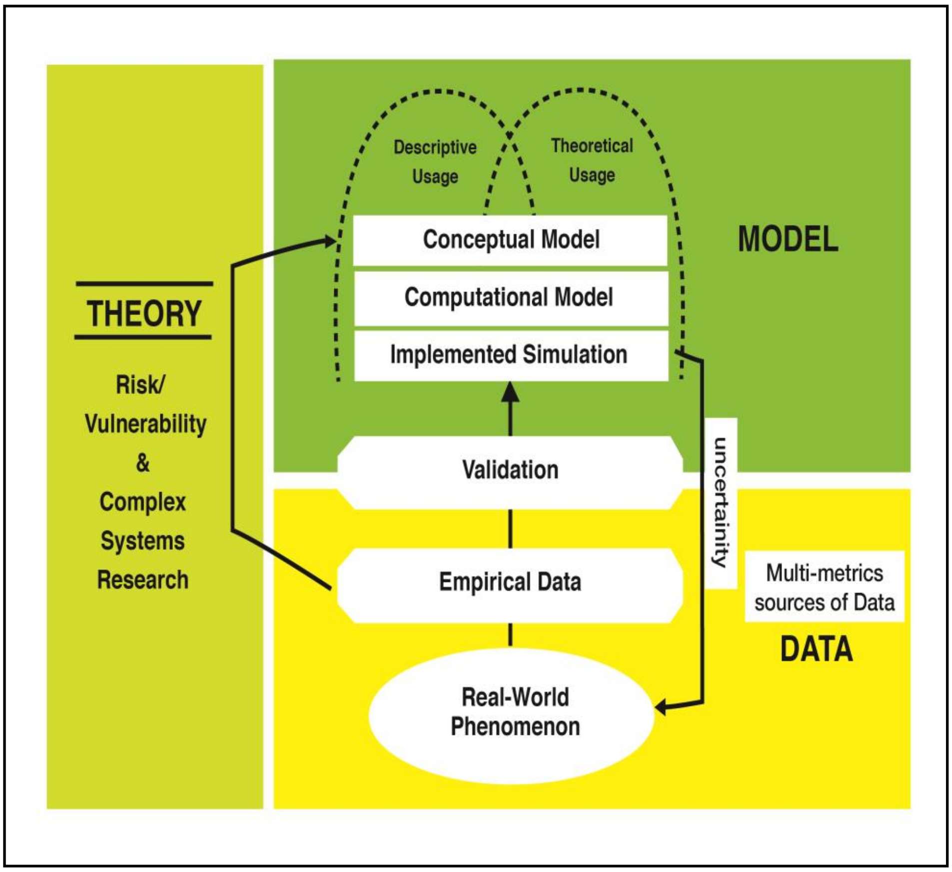


Figure 6.1: Interactions of theory and data in model simulation and validation process, adapted from (Rossiter *et al.*, 2010).

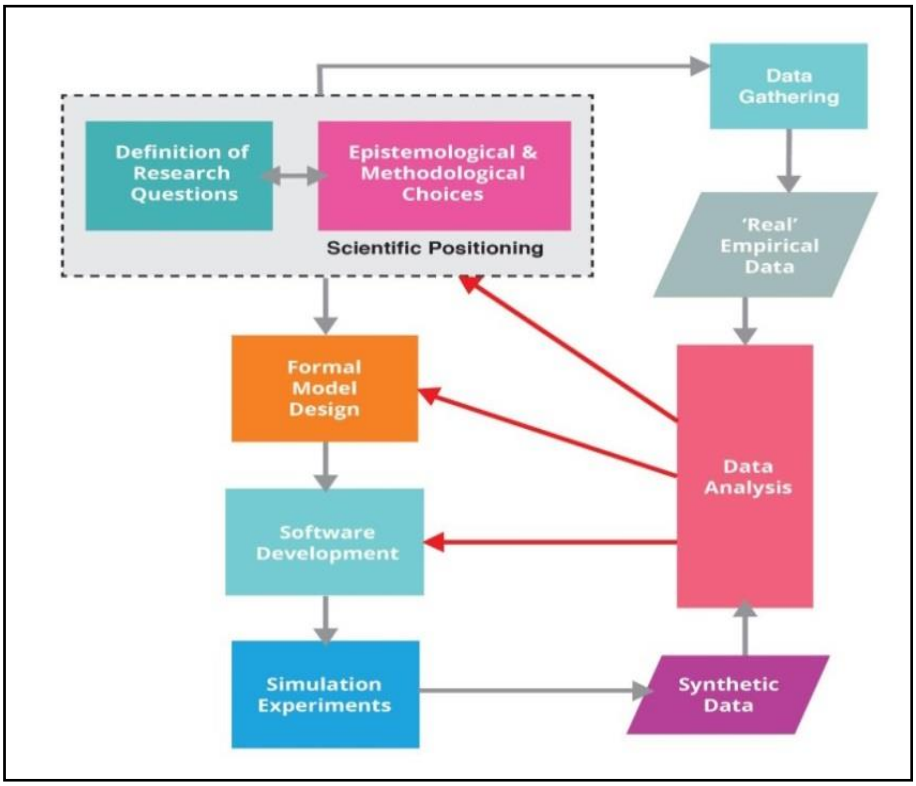


Figure 6.2: Representations of the overall social simulation process. Black arrows show broadly sequential processes. red arrows show the main feedback routes by which design decisions are adjusted, according to Rossiter et al. (2010).

6.2 The Multi-Stage Validation Process (MSVP): Validating Simulation Models in the Context of Natural Resource-Based Conflicts Vulnerability

The aim of the Multi-stage Validation (MSVP) strategy is to ultimately ensure the credibility of the application of SEFLAME-CM for solving real-world problems such as NRBCs (Balci, 1994). The credibility of simulation results do not only depend on model correctness but it is as well significantly influenced by the accurate formulation of the problem (Balci, 1994). The MSVP has been defined as an integrated approach to the validation of complex systems (Knauf *et al.*, 1999), involving different disciplines (Naylor *et al.*, 1967, Sargent, 2013). The success of MSVP would support the Hartmann's statement that simulations prove to be "a powerful tool" in transdisciplinary and interdisciplinary researches (Hartmann, 1996) (: 771).

In the MSVP strategy applied in this thesis, the validation process began with a qualitative start (QUASTA) (van Kouwen et al., 2007). QUASTA identifies the key elements to be modeled in a quantitative system, in order to address the problems as captured in the conceptual model (van Kouwen et al., 2007). This initial stage of validation entails the use of the data sets collected with the community key informants to validate the land use and land cover (LULC) data from a satellite imagery (see Section 5 for the remote sensing data and the validation process with the qualitative data). See Figure 6.3 for the initial change or no change image analysis prior to the pixel by pixel comparisons of thematic maps (i.e. the Persistence, Gain, Loss and Other Land Uses (PGLOLU)). See Figure 6.3 for the GPS positions and the sampling points collected for the validation. Appendix A.12.20 shows a list of the sample points selected for the remote sensing data validation.

Another important component of the use of MSVP is model verification. Thus scientists agree that in designing an intelligent system or any related system, the verification and validation of the real world systems in question is necessary (Balci, 1994, Naylor *et al.*, 1967, Sawyer, 2013, Vallverdú, 2014). Therefore such verification and/or validation of any kind of model (e.g., NRBCs modeling) needs to prove the model to be true or not. But to prove that a model is "true" implies: that we have established a set of criteria for differentiating between those models which are "true" and those which are "not true," and that we have the ability to apply these criteria to any given model (Naylor et al., 1967). Therefore, the model verification is then carried out before the operational validation with the aim of "ensuring that the computer programs of the computerized models and its implementation are correct" (Sargent, 2005). Computerized model verification deals with checking the adequacy among the conceptual and computerized models.

The next and the last validation step presented in this section is the operational validation. The operational validation (see Section 6.5 for procedures) refers to the process of substantiating that a model within its domain of applicability, possesses a satisfactory range of accuracy that is consistent with the intended application of the model (Sargent, 2005, Sargent, 2013). This entails a comparison of the input and the output relationships using the observed conflict data sets and a comparison of the model with other models. Preceding the operational validation is a selection of the test sites and the calculation of the observed conflicts datasets (see the results of the three main aspects of the operational validation reported in Sections 6.5.1, 6.5.2, and 6.5.3).

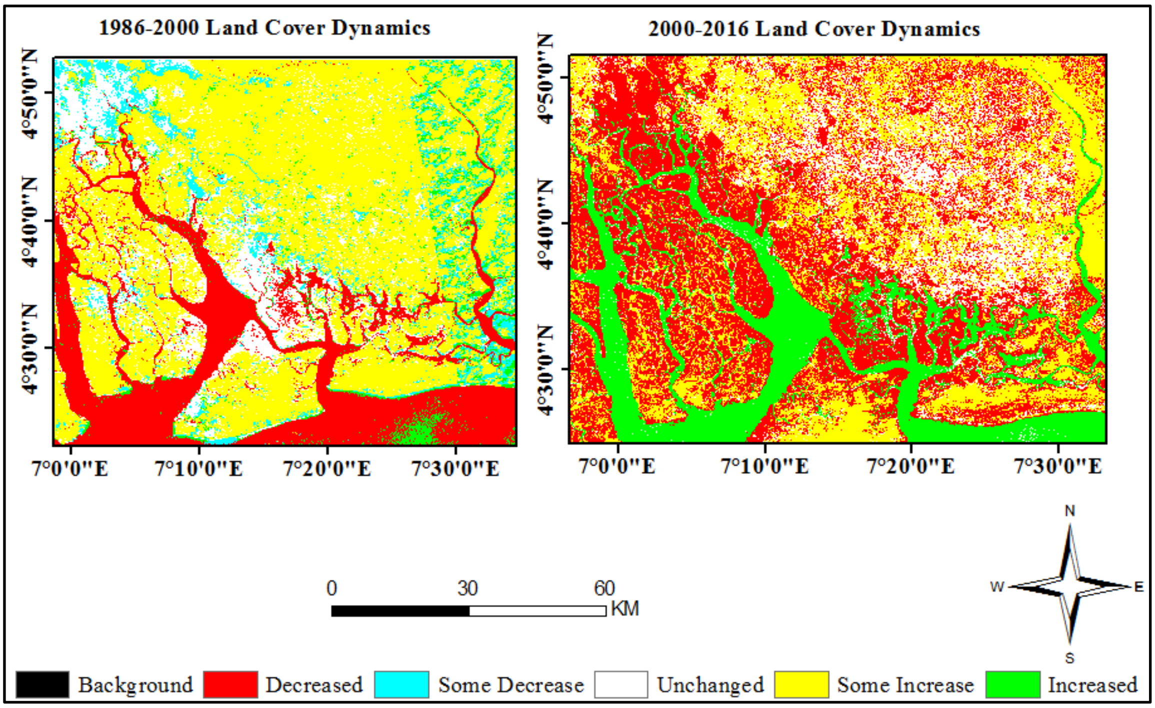


Figure 6.3: Initial change or no change image analysis before pixel by pixel comparisons of thematic maps: 1986-2000 (left), 2000-2016 (right).

6.3 Selection of Test Sites /Cases for Validation

The time scale of the data is based on three year periods. In this case (1986-2000) and (2000-2016) are chosen as reference years as stated in Sections 1 4. Therefore, for the environmental, the socio-economic and the political drivers of conflicts, three-year time series data are grouped into two. In the two reference year periods, the differences of the model input variables are calculated using *Equations 6.1 and 6.2* respectively.

$$P_1 = (Y_2Dt - Y_1Dt) \qquad \text{(Equation 6.1)}$$

$$P_2 = (Y_3Dt - Y_2Dt) \qquad \text{(Equation 6.2)}$$

P_1	=	*Data for period 1*
P_2	=	*Data for period 2*
Y_1	=	*Year1*
Y_2	=	*Year2*
Y_3	=	*Year3*
Dt	=	*Data*

6.3.1 Field Campaign

The model validation data sets were generated with the help of student assistants and local actors, during the field campaigns with a total of 12 drivers were selected within the three dimensions of conflict drivers (Section 5). The environmental dimension, as the “external” side of vulnerability, the socio-economic and political dimension, as the “internal” side of vulnerability assessment. There are two territories: Ogoni and Okrika territory (Figure 6.4). Within the two territories, 10 communities were selected. A total of selected 20 villages with two villages from each of the 10 communities are used (Section 2). See Section 5 for detailed methodology description.

6.3.2 Defining a Sampling Pattern

For every village, 40 structured questionnaires were administered to each category of actors (farmers, community leaders, youths, NGOs and local politicians) in each of the sampling periods (see Section 5 for a detailed description). For the selection of the villages, there was a consideration of villages that had oil infrastructure, those that had experienced conflicts in the past for at least once and those that did not have much of oil presence but had experienced conflicts as well. A handheld GPS receiver of the type Garmin 60 CSx was used to note the exact location of the villages being sampled (Figure 6.5).

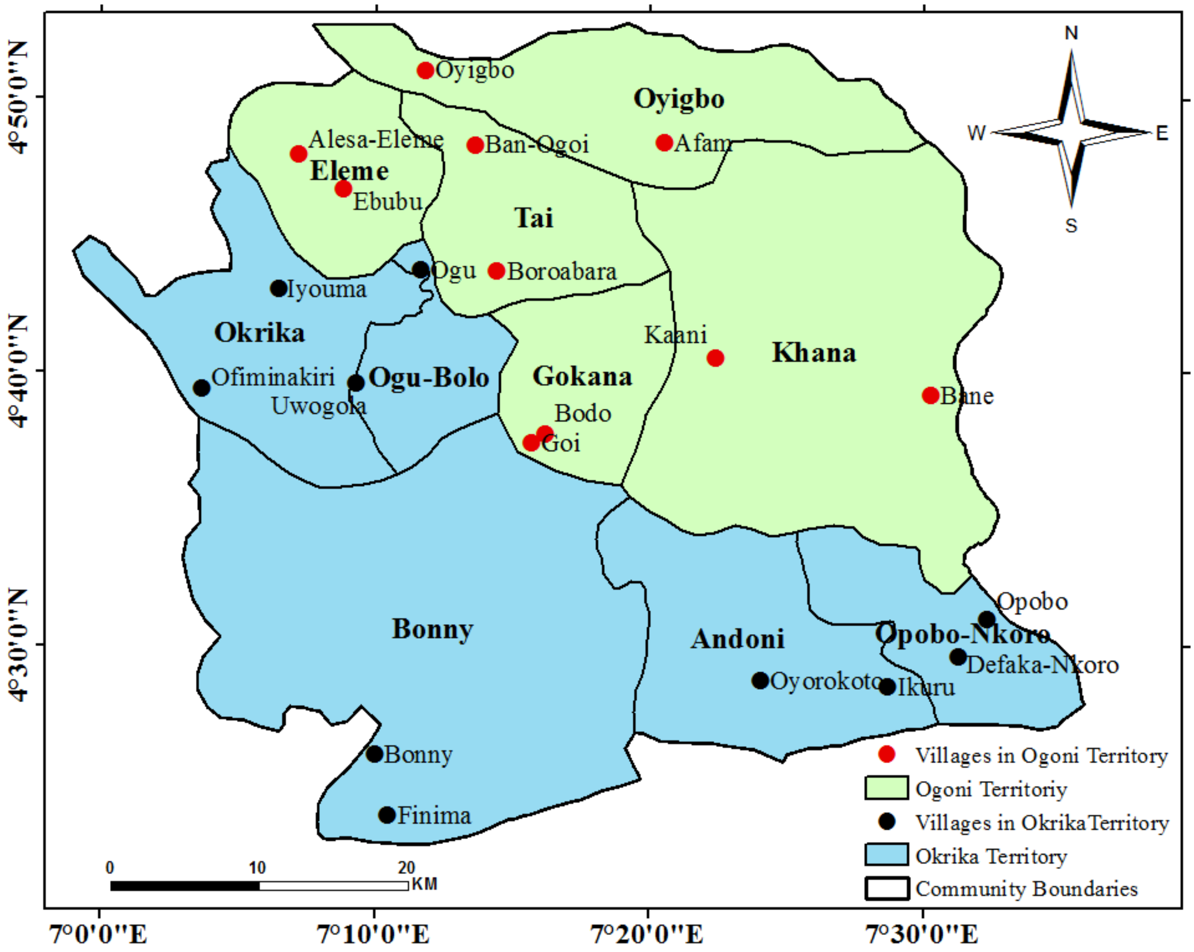


Figure 6.4: Map of test sites/fields visited for the intensive study (20 villages, 10 Communities, and 2 territories).

Scheme on the positioning of the sampling points

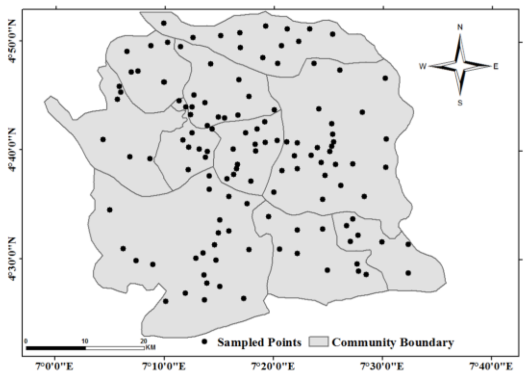


Figure 6.5:GPS for sampled points: a collection of points (top left); general pattern for the positioning of sampling points within a test field (top right) used for validation of the remote sensing data; sampling points (down).

6.4 Calculation of the Observed Conflicts (OBC)

In this study, NRBCs are distinguished as either the rebel or the territorial-based conflict typologies as reported in the literature (Raleigh et al., 2010). This can also be found in the case study description (Section 2).

1. **The rebel-based conflicts:** The rebel-based conflicts or the governmental conflicts are in most cases against the government forces by the rebel groups (Raleigh et al., 2010). They are organized violence by rebels and ethnic militias against government security, the oil companies. These are likened to the governmental conflicts by the UCDP. In distinguishing the conflicts that are related to resources, those conflicts that are not resource-based such as election violence are discarded.
2. **The territorial-based conflicts:** The territorial-based conflicts involve actors such as farmers, youths and community members that engage in riots, protests against other communities on issues relating to loss of livelihoods, social and political inequality, oil resource extractive benefits, and land-use related conflicts. It may arise mainly due to due to unprecedented scarce renewable resources in a locality.

The Uppsala Conflict Data Programme Geo-referenced Event Dataset (UCDP GED) and the Armed Conflict Location Event Data (ACLED) contain reasonably accurate data on the location of the conflict zones, and they make disaggregation or local assessment of resource conflicts studies much more feasible (Raleigh *et al.*, 2010) (see Section 2 for more information on the conflict data). The disaggregated assessment of NRBCs has led to many approaches of conceptualizing the dependent variables (Buhaug and Gates, 2002, Buhaug and Lujala, 2005, Buhaug and Rød, 2006, Rustad *et al.*, 2011). These include the use of administrative units, the use of conflict zones, and the recent use of artificial grid cells. For instance, Buhaug and Rød (2006) pioneered the use of the artificial grid, using 100 X 100 km^2 grid cells as the units of observation, where conflicts are measured with the binary representation of the years with conflicts and the years without conflicts. Buhaug and Rød (2006) however observed challenges with this type of measurement: First, each conflict contains an element of uniqueness of features that are impossible to operationalize and measure across space and time. Second, the sub-optimal performance of the previous empirical investigations is due to data limitations and unrealistic assumptions. In this work, a multi-scale conflict zone approach is used. This combined both the administrate scale of a local government/community and the grid cells as units of analysis. Both are linked at a fine-scale resolution or at a disaggregated scale (Raleigh *et al.*, 2010).

The observed conflicts (OBC) are measured as conflict intensity measurement (CIM) after (HIIK, 2017). The CIM is measured per distance per year (CIM/dist./year) as a simple count of conflicts that occurred within a certain year. These are measured within a distance from the village center to a conflict location. Distances are constructed from the center of a village and the number of conflict events that fall within the ranges of distance was counted based on the data sets described in (Raleigh et al., 2010). Figure 6.6 shows the map of the distribution of the observed conflicts studied. The distance measurement is thus based on the following:

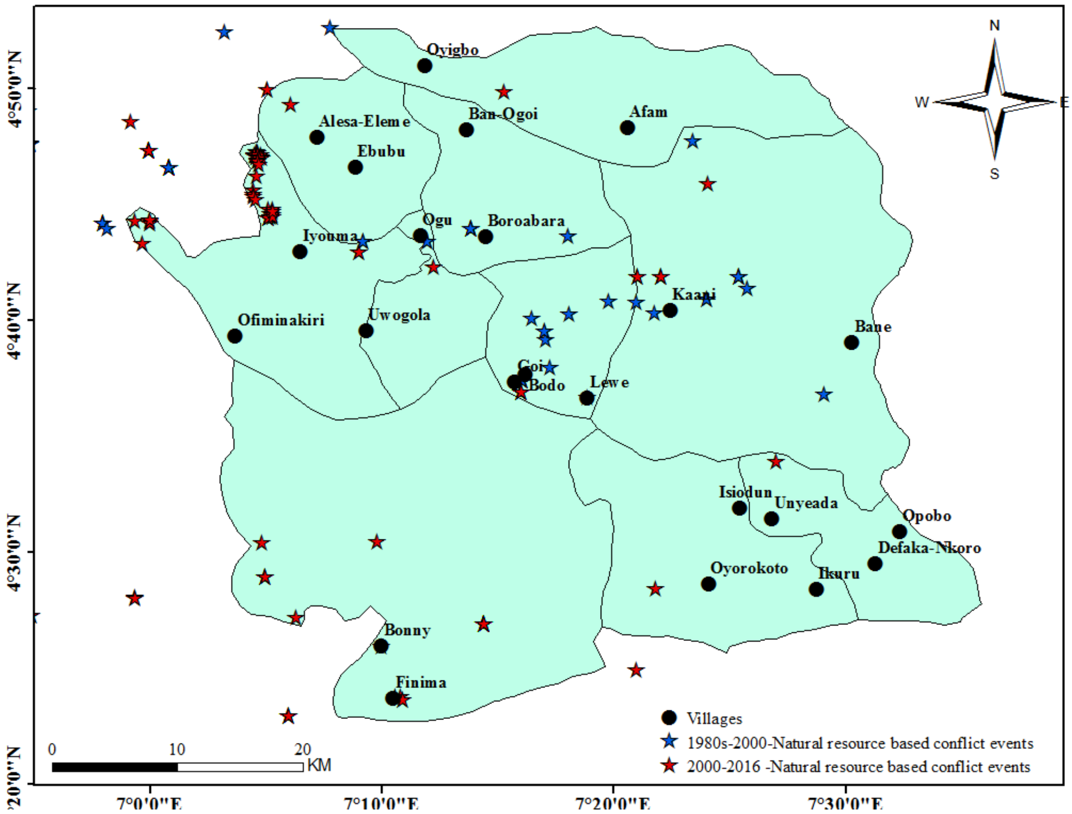


Figure 6.6: Map of distribution of observed conflicts. Source: UCDP GED and ACLED.

1. Calculation of the rebel-based conflicts (TBC): Distance breaks *>=5-10km, >=10-15km, >=15-20km*. A weighting system was developed to weight conflicts, according to their proximity to a village. There are two time periods: before 2000 and a period after 2000 (see Table 6.1). This consideration is based on the available timescale data sets (1986. 2000, and 2016) and the time conflicts were intense in the Niger Delta (See Section 5.2.1)
2. Calculation of the territorial-based conflicts (TBC): Distance breaks: *>=5-10km, >=10-15km, >=15-20km*. Similarly, a weighting system was developed to weight conflicts, according to the proximity of conflict to a village with two time periods before 2000 and after 2000 (see Table 6.1).
3. Calculation of the observed conflicts (OBC): The OBC is derived by calculating the average of the conflicts types for each year. To calculate the observed conflict that occurred within a village i.e. from the center coordinates of the location of conflict and the center coordinate of the village, distances are determined and all the number of conflicts that occurred within a period was then counted (see *Equations 6.3 and 6.4).* All the dependent variables, i.e. the overall OBC measured in this work are shown in Table 6.1.

Table 6.1: Measurement of the dependent variables from village to conflict location.

	Pre- 2000 and Post 2000		
Distance	Rebel based Conflicts	Territorial Based Conflicts	All Conflicts
0-5km	➢	✓	$\bar{X}$
5-10km	➢	✓	$\bar{X}$
10-15km	➢	✓	$\bar{X}$
15-20km	➢	✓	$\bar{X}$

✓ Measured

$\bar{X}$ Average

$$RBC = 3^4 * NoC_{adistkm} + 3^3 * NoC_{bdistkm} + 3^2 * NoC_{cdistkm} + 3^1 * NoC_{ddistkm} \quad \text{(Equation 6.3)}$$

$$TBC = 3^4 * NoC_{adistkm} + 3^3 * NoC_{bdistkm} + 3^2 * NoC_{cdistkm} + 3^1 * NoC_{ddistkm} \quad \text{(Equation 6.4)}$$

RBC = *Rebel Based Conflicts*
TBC = *Territorial Based Conflicts*
NoC = *Number of conflict events*
adistkm = *distance interval (0-5km)*
bdistkm = *distance interval (5-10km)*
cdistkm = *distance interval (10-15km)*
ddistkm = *distance interval (15-20km)*

6.5 Operational Model Validation Procedures

The design of the operational validation is shown in Figure 6.7. For adequate comparisons in the validation process, the model set up used fuzzy rules and weighting of the input variables from interviews and workshops as reported in Section 5. The focus of the model validation is a comparative judgment between the constructed conflict by the actors and the actual conflict (the observed conflicts). The OBC, i.e. the real-world could result in damages or losses of lives and properties (Kasperson *et al.*, 1988, Slovic, 2000, Burgess, 2015, Rustad, 2016) hence the need to reduce or manage them.

In the validation procedures, the two central aspects of quantitative assessment of NRBCs are incorporated. These are the temporal and spatial domains (Lujala *et al.*, 2007, Raleigh, 2011). Added to these two domains in the model validation are the cross-validation and the uncertainty checks. The various levels of operational validation are therefore shown in Figure 6.7 while the results are reported in Sections 6.5.1, 6.5.2, and 6.5.3: These are:

1. The temporal dimension of conflicts (see Section 6.5.1);
2. The cross-validation and the uncertainty check of the model, i.e. comparing the model versus the observed conflict and that of generating observed conflict (exponent of the log of observed conflict data) (Section 6.5.2);
3. The spatially explicit validation (Section 6.5.3).

In the validation procedures (the first and the second) are based on the FLAME-CM model, while the third is based on the SEFLAME-CM model. The FLAME-CM and the SEFLAME-CM are models used to derive the CVL Indices 1 and 2 respectively. Methodologically, the FLAME-CM and the SEFLAME-CM are the same. But the FLAME-CM is a non-spatially explicit model while the SEFLAME-CM-the target model is a spatially explicit model. In other words, the FLAME-CM generated the non-spatially explicit CVL Index, while the SEFLAME generated the spatially explicit CVL Index. FLAME-CM is used to calibrate SEFLAME-CM. The first CVL Index used the administrative unit scale while the second CVL Index used the grid cell size as the unit of analysis where the vulnerability assessments of NRBCs are also disaggregated to the two conflict typologies investigated (see Section 5.2.3.8.1). The full model implementation procedures can be seen in Section 5 (see Figure 5.18 for the simplified hierarchical structure of the data layers used for setting up the fuzzy logic modeling).

Drawing on the literature on the fuzzy logic methodology, the model validation set up considered the membership functions (MFs) to be very critical (Section 5.2.3.2). As stated there in Section 5.2.3.2, one of the most important decisions to be made in designing a FLAME-CM is to determine which MF type to use (Wu, 2012). There is a provision to customize the MFs in some fuzzy logic software or the use of hybrid MFs. Therefore, a choice of the best fit MFs was made in this work. To do this, the MFs are used to calibrate the model. In other words, the calibration and the fine-tuning of the FLAME-CM are based on the MFs with the aim of obtaining the optimal fit results. This is achieved by using a training dataset of 12 variables/drivers. These variables are grouped under the three sub-models for the environmental, the socio-economic and the political dimensions. The different MFs in the input and the output variables are alternated. Therefore, several simulations are run using the different MF types for both the inputs and the outputs. See Appendix A.12.21 for a complete visualization of the alternated input and output variables of MFs. The results of the model runs are compared with each other using R^2 (see Table 6.2 for the different MFs results with the input vs. the output variables). As clearly seen in Table 6.2, there is no much difference in the results when compared with the R^2 , however, the output with the highest R^2 is seen to be the best MF.

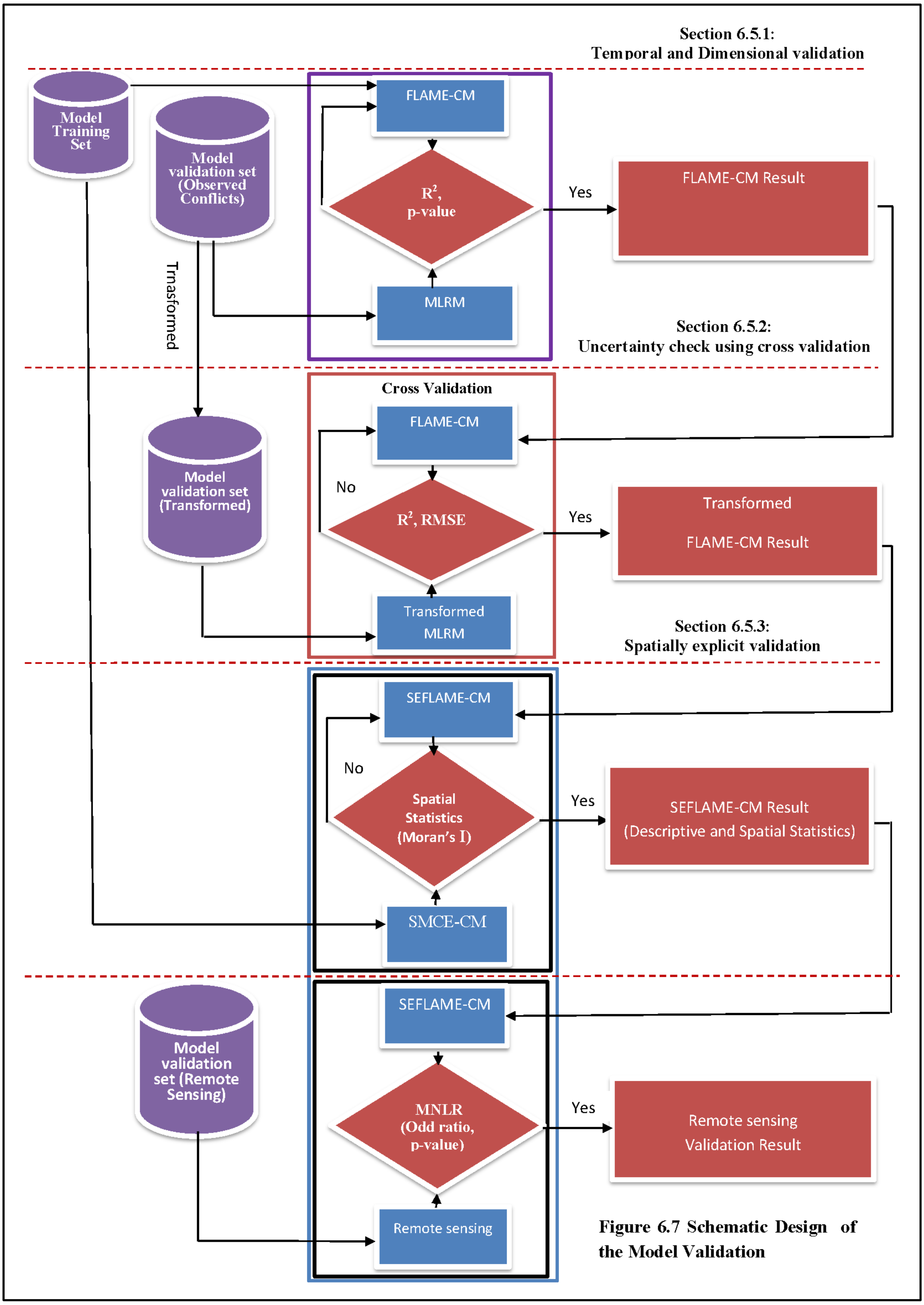


Figure 6.7: Schematic design of the operational model validation.

Table 6.2: Input MF vs output MF comparison.

Input vs. Output MFs	Corr (R^2)
1. Triangular vs Triangular	0.70
2. Triangular vs Trapezoidal	0.83
3. Triangular vs Gaussian	0.83
4. Trapezoidal vs Trapezoidal	0.86
5. Trapezoidal vs Triangular	0.85
6. Trapezoidal vs Gaussian	0.72
7. Gaussian vs Gaussian	0.82
8. Gaussian vs Trapezoidal	0.85
9. Gaussian vs Triangular	0.83

Figure 6.8 shows the interrelationships between the inputs, the rules, the membership functions, and the outputs. As shown in Figure 6.8, the fuzzy logic model set up works like a hierarchical tree (Dernoncourt, 2013). This means that *The input, the inpumf* (input membership functions), *the rules, the outputmf* (output membership functions) and *the output* are all interrelated ((The MathWorks, 1995), Figure 6.8). The outputs are expressed as four linguistic categories referring to the level of the intrinsic vulnerability likeliness to conflicts. These are: u*nlikely, likely, very likely, and most likely*. The observed conflict datasets are derived from the calculation of the OBC using *Equations. 6.3 and 6.4).*

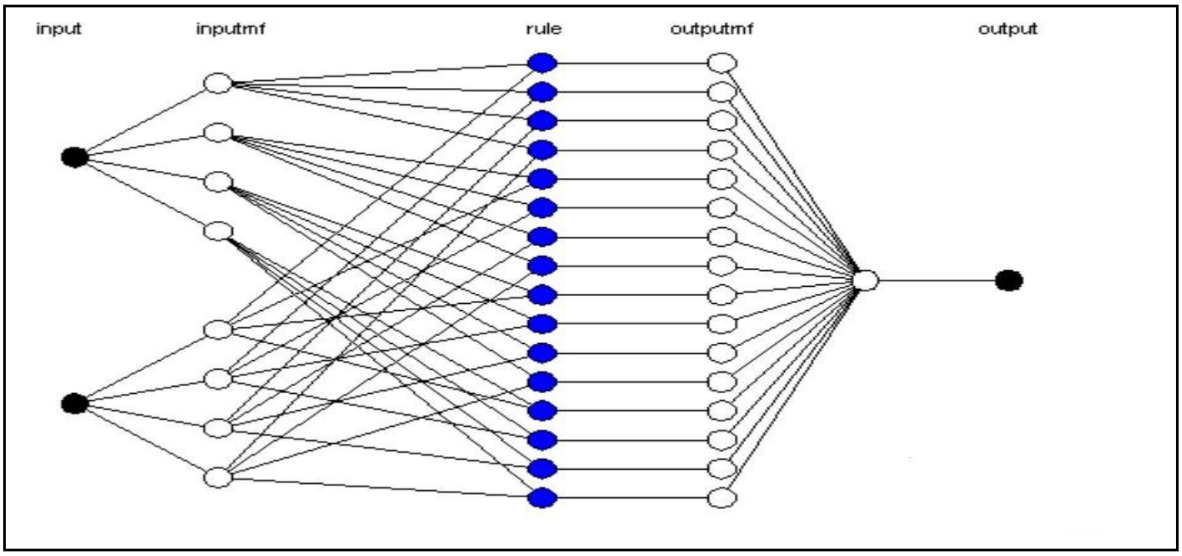


Figure 6.8: Interrelationships between the inputs, rules, membership functions and outputs.

6.5.1 The Temporal and Dimensional Model Validation: Qualitative and Quantitative Explanations

The FLAME-CM result is explained in this section using the qualitative and quantitative assessment results. The quantitative explanation includes the levels of conflict at the village scale under the three dimensions studied (Section 6.5.1.1). See Section 5.2.3.7 for the modeling Equations.

As shown in the following, the quantitative assessment of the model is a comparison between the results of the FLAME-CM and that of MLRM using the FUZZYCONDATA. The three sub-models of FLAME-CM are based on (*Equations 5.8, 5.9 and to 5.10)*, while the overall FLAME-CM is based on *Equation 5.15.* The validation model, MLRM is based on *Equations 6.3, 6.4 and 6.5.* This used the OBC data as the dependent variable (Section 6.5.1.2). The MLRM is used to establish and estimate a functional relationship between the conflict drivers and the OBC.

R^2 and p-values are used to compare the results between FLAME-CM and MLRM. For the p values, the cut off: $p < 0.001$. $p < 0.01$, and $P < 0.05$ are used as a common basis of accepting or rejecting the null hypothesis (Field, 2009). Both qualitative and quantitative validation results are derived and used to complement the other. The CVL Indices derived from the simulation runs are between 0 and 1. The various dimensions of vulnerability as the sub-system of the model are compared one after the other and the final CVL Index is derived by finding the average of the results of the three sub-models.

The analysis of the quantitative validation within the period of 1986-2000 and 2000-2016 is carried as follows:

(1) **The intra-temporal and the inter-temporal comparison between the FLAME-CM and the MLRM results.** Here the results from the FLAME-CM and MLRM are compared across the two temporal scales (1986-2000) and (2000-2016) (see Sections 6.5.1.2 and Section 6.5.1.3). In the comparison of the two models, in the case of FLAME-CM, the simulation result is taken as the validation set (dependent variable). In the second model, MLRM, the observed conflict datasets are used as the validation set (dependent variable). The two models have the same input variables for all the dimensions/categories of the vulnerability to NRBCs

(2) **The intra-temporal and the inter-temporal comparisons of all possible parameter combinations between the FLAME-CM and MLRM results**. Here all the possible combinations of the specific conflict drivers under the three dimensions are compared between the FLAME-CM and MLRM results across the two temporal scales (1986-2000) and (2000-2016). Their results are presented in (Sections 6.5.1.4) and (Section 6.5.1.5) respectively. For all possible combination regression, the R library, LEAP, is used. This helps to parameterize the output of the best model at each level (Goodenough et al., 2012). The results of all-subset combinations normally show the best model containing one parameter, and the best model containing any two or three parameters etc. The best model parameter at each level is determined by the comparisons of the R^2 scores and the p-values of the candidate model. The model of the conflict drivers with the highest R^2 value is normally selected as the best model (Goodenough *et al.*, 2012). Thus the parameters of the best model(s) are the best too. The Equations of conflict vulnerability dimensions under MLRM is given below:

$$Y_{ev}=b_0+b_1X_{1,ev} + b_2X_{2,ev}+\ldots+b_nX_{n,ev} +\epsilon_{ev}$$ *(Equation 6.5)*

$$Y_{se}=b_0+b_1X_{1,se} + b_2X_{2,se}+\ldots+b_nX_{n,se} +\epsilon_{se}$$ *(Equation 6.6)*

$$Y_{Po}=b_0+b_1X_{1,po} + b_2X_{2,po}+\ldots+b_nX_{n,po} +\epsilon_{po}$$

(Equation 6.7)

where

Y_{ev}	=	*Conflict index for environmental drivers (ev) as a dependent variable*
Y_{so}	=	*Conflict index for socio-conomic drivers (se) as a dependent variable*
Y_{po}	=	*Conflict index for political drivers (po) as a dependent variable*
$X_1, X_2,\ldots,X_n$	=	*Conflict drivers for the nth explanatory variable under each of ev,se and po*
b_0		*Intercept term*
$b_1, b_2,\ldots,b_n$	=	*The regression coefficient of the corresponding variable $x_1, x_2,\ldots x_n$*
n	=	*Number of observations*
ϵ_{ev}	=	*Error term for the evth observation*
ϵ_{se}	=	*Error term for the seth observation*
ϵ_{po}	=	*Error term for the poth observation*

6.5.1.1 Explanation of Qualitative Assessments

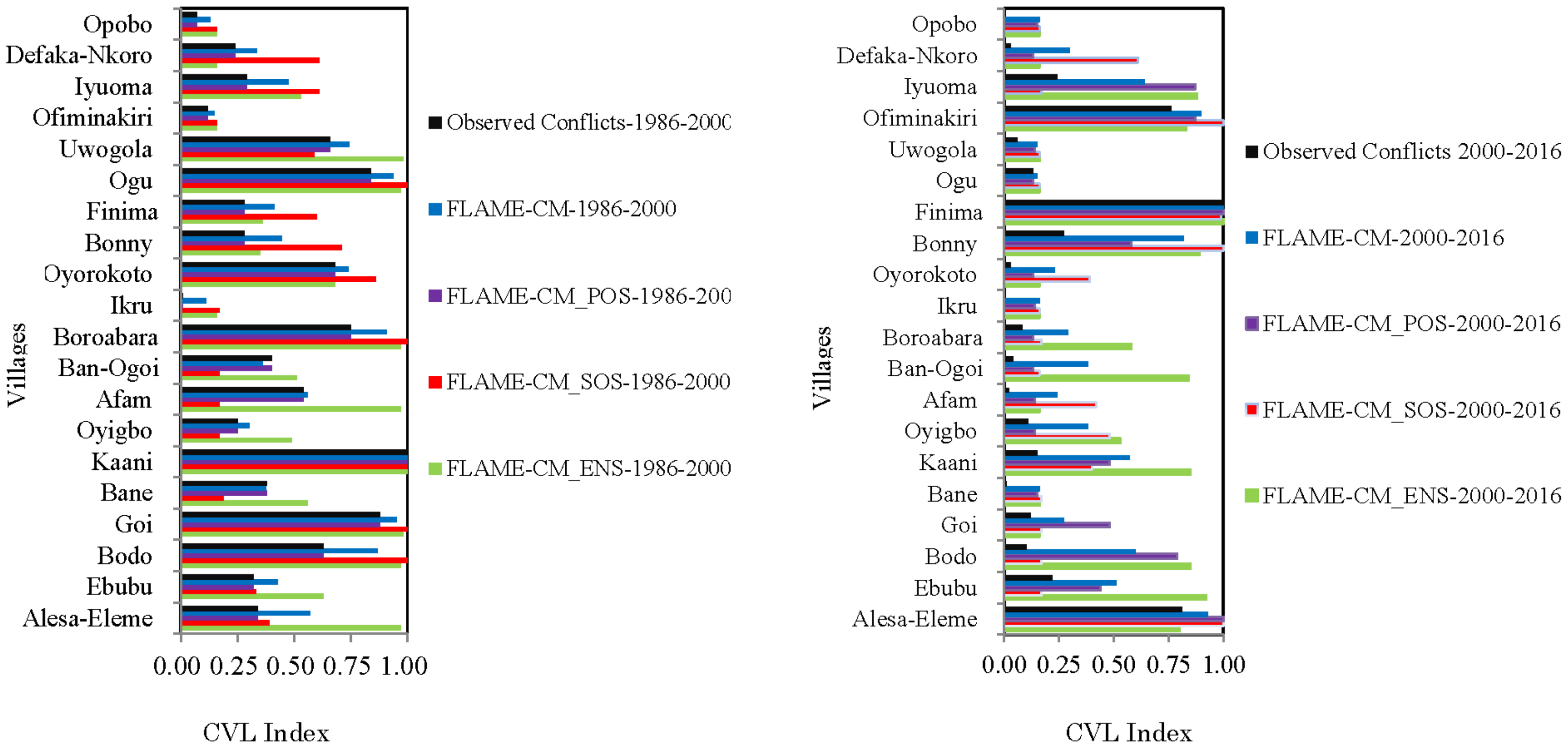
Table 6.3 shows the conflict indices under the three sub-models of vulnerability dimensions and the final conflict index. Figure 6.9 (left and right) shows the comparisons between the sub-models of environmental, socio-economic and political vulnerability, the overall CVL Index and the observed conflicts. Figure 6.10 shows only a comparison between CVL Index derived from FLAME-CM and the observed data at the village level in 1986-2000 (left) and 2000-2016 (right). As shown in Table 6.3, the temporal analysis of the (1986-2000) and (2000-2016) results appear to be under three dynamic levels. These levels include the major changes, the minor changes and the unchanged conflict levels in the villages studied.

- ***The Major changes.*** The sudden increase from *unlikely* to *most **likely*** conflicts or the sudden decrease from *most likely* to *unlikely conflicts*. For example, the level of conflicts in Goi between 1986-2000 periods is 0.95 (*most likely*) but it reduced to 0.27 (*likely*) in 2000-2016.
- ***The Minor Changes*:** This is a situation where the conflict level only increased or reduced marginally. For example, the conflict vulnerability likeliness of Alesa-Eleme increased only from *very likely* in 1986-2000 to *most likely* in 2000-2016.
- ***The Unchanged* (Consistent).** This is the case where there is almost no change in the CVL Index level in a village. This is perhaps because of the few villages that had no oil installations and hence had no incidences of conflicts as such. Although some of these villages still suffered the problems of oil pollution due to the fact that oil flows across their water. A good example can be seen in Opobo and Ikru villages. The level of conflicts for both villages was perceived to be the same i.e. (*unlikely*) in the two periods considered.

The *major changes in* conflict levels in villages could be as a result of the stoppage of oil extraction in some Ogoni communities. Hence the level of perception of conflicts in those areas reduced drastically. Shell, for instance, has not carried out any oil extractive activities around Goi village for the past 10 years because of ongoing court cases. The *unchanged or* the *minor changes* in village conflict levels may be traceable to the issues of memory and experiences of the past and the current conditions of the villages. People can forget about the bad past if the current situation improves because time heals. These results lend credence to those studies that concluded that collective memory as a socially shared representation of the past affects the perception of conflicts (Rouhana and Bar-Tal, 1998). It is reported that collective memory generally informs risk perception of conflicts within a group or between a group and an external body (Lewicki *et al.*, 2003, Bikmen, 2016, Doi, 2017). Connected to the issue of memory, in some cases, villagers also perceive resource conflicts to occur in their village even though actual conflicts were not recorded.

Table 6.3: Qualitative validation of FLAME-CM with observed conflicts: Level of conflicts in the villages.

Village	FLAME-CM_ ENS 1986-2000	FLAME-CM_ SOS 1986-2000	FLAME-CM_ POS 1986-2000	Observed Conflicts 1986-2000	All Simulated Conflicts 1986-2000	CVL Index	FLAME-CM_ ENS 2000-2016	FLAME-CM_ SOS 2000-2016	FLAME-CM_ POS 2000-2016	Observed Conflicts 2000-2016	All Simulated Conflicts 2000-2016	CVL Index
Alesa-Eleme	0.97	0.39	0.34	0.34	0.57	Very Likely	0.80	1.00	1.00	0.81	0.93	Most Likely
Ebubu	0.63	0.33	0.32	0.32	0.43	Likely	0.92	0.17	0.44	0.22	0.51	Very Likely
Bodo	0.97	1.00	0.63	0.63	0.87	Most Likely	0.85	0.17	0.79	0.10	0.60	Very likely
Goi	0.98	1.00	0.88	0.88	0.95	Most Likely	0.16	0.17	0.48	0.12	0.27	Likely
Bane	0.56	0.19	0.38	0.38	0.38	Likely	0.16	0.17	0.15	0.01	0.16	Unlikely
Kaani	1.00	1.00	1.00	1.00	1.00	Most Likely	0.85	0.40	0.48	0.15	0.57	Very Likely
Oyigbo	0.49	0.17	0.25	0.25	0.30	Likely	0.53	0.48	0.14	0.11	0.38	Likely
Afam	0.97	0.17	0.54	0.54	0.56	Very Likely	0.16	0.42	0.14	0.02	0.24	Unlikely
Ban-Ogoi	0.51	0.17	0.40	0.40	0.36	Likely	0.84	0.16	0.13	0.04	0.38	Likely
Boroabara	0.97	1.00	0.75	0.75	0.91	Most Likely	0.58	0.17	0.13	0.08	0.29	Likely
Ikru	0.16	0.17	0.01	0.01	0.11	Unlikely	0.16	0.16	0.14	-	0.16	Unlikely
Oyorokoto	0.68	0.86	0.68	0.68	0.74	Very Likely	0.16	0.39	0.13	0.03	0.23	Unlikely
Bonny	0.35	0.71	0.28	0.28	0.45	Likely	0.89	1.00	0.58	0.27	0.82	Most Likely
Finima	0.36	0.60	0.28	0.28	0.41	Likely	1.00	0.99	1.00	1.00	1.00	Most Likely
Ogu	0.97	1.00	0.84	0.84	0.94	Most Likely	0.16	0.16	0.13	0.13	0.15	Unlikely
Uwogola	0.98	0.59	0.66	0.66	0.74	Very Likely	0.16	0.16	0.14	0.06	0.15	Unlikely
Ofiminakiri	0.16	0.16	0.12	0.12	0.15	Unlikely	0.83	1.00	0.87	0.76	0.90	Most Likely
Iyuoma	0.53	0.61	0.29	0.29	0.48	Likely	0.88	0.17	0.87	0.24	0.64	Very Likely
Defaka-Nkoro	0.16	0.61	0.24	0.24	0.34	Likely	0.16	0.61	0.13	0.03	0.30	UnLikely
Opobo	0.16	0.16	0.07	0.07	0.13	Unlikely	0.16	0.16	0.15	0.00	0.16	Unlikely



0-0.25 = Unlikely, 0.25-0.50= Likely, 0.50-0.75=Very Likely, 0.75-1.00= Most Likely

FLAME-CM-ENS-Environmental Subsystem (ENS)
FLAME-CM-SOS-Socio-economic Subsystem (SOS)
FLAME-CM-POS-Political Subsystem (POS)

Figure 6.9: Village level of conflicts under different dimensions and observed conflicts: left (1986-2000), right (2000-2016).

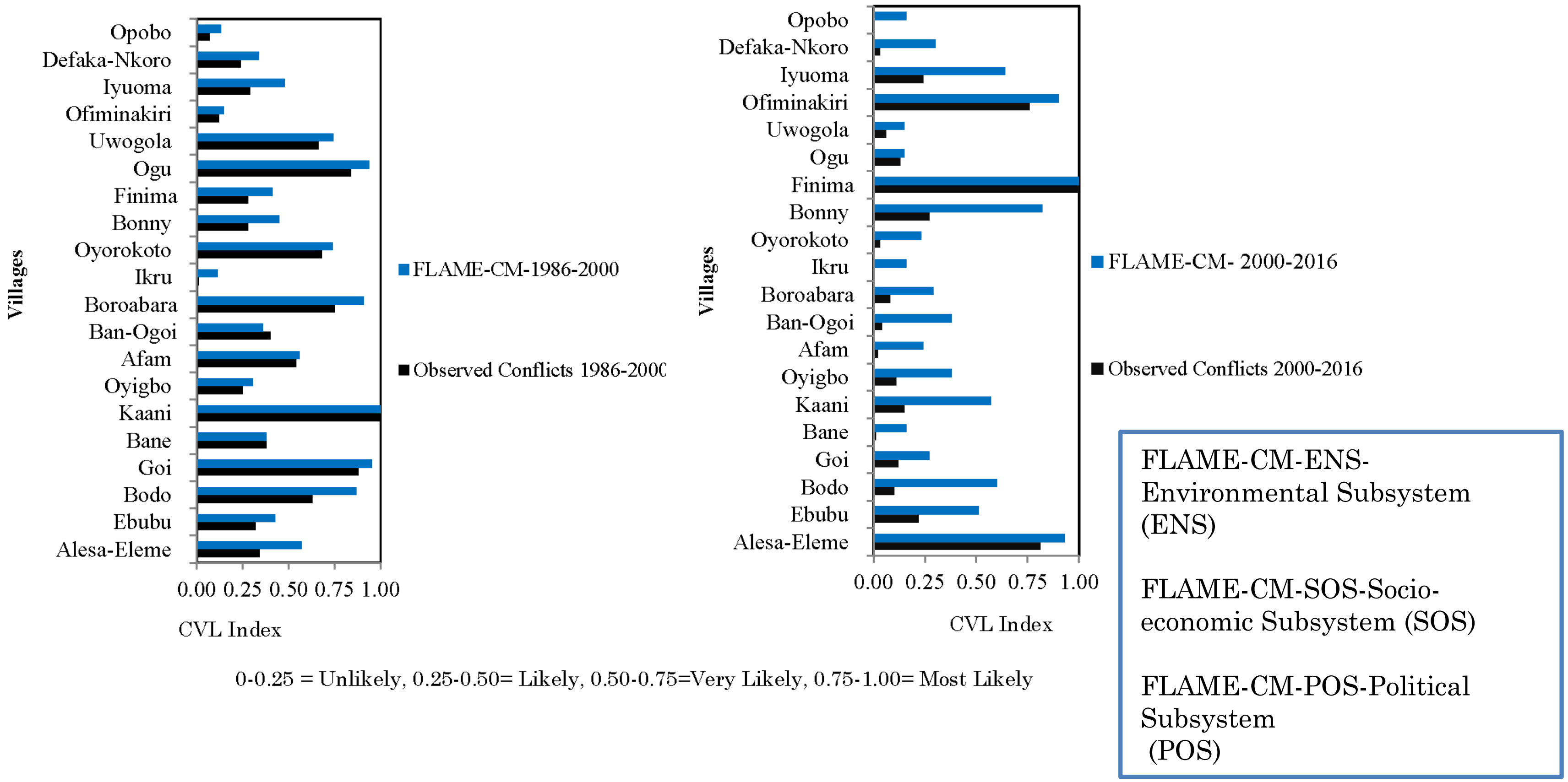


Figure 6.10: Village level of conflict vs. observed conflicts: 1986-2000 (left), 2000-2016 (right).

Given the above results on conflict levels in villages, the key phenomena that impacted the dynamics of the NRBCs in spatiotemporal terms may be due to:

- The collective memory of past resource conflicts.
- Long-term effects of environmental impacts and resource scarcity
- Environmentally induced migration. There were such cases where directives from the regional government encourage villagers to leave areas that are highly polluted by oil extraction (see Figure 4.5).

6.5.1.2 Intra-Temporal Comparison of FLAME-CM and MLRM (1986-2000)

Table 6.4 shows a summary of the R^2 and p-values for the comparison between the FLAME-CM and MLRM under the various vulnerability dimensions in 1986-2000. The result for 1986-2000 is shown at the upper part of Table 6.4.

Figures 6.11 to 6.16 show plots of the R^2 for the various conflict drivers. The figures also show the results when the individual drivers of the NRBCs are combined. It is clearly seen that the FLAME-CM is better than MLRM in all the conflict driver dimensions investigated. See Section 6.5.1.4 for further explanation on the combination of various drivers with each other.

As shown in Table 6.4, the FLAME-CM model under the environmental drivers has (R^2=0.96) in 1986-2000. The environmental drivers are key to explaining NRBCs as they have the highest values of R^2 among the three main vulnerability dimensions examined. The R^2 value for the environmental driver dimension, using the MLRM still remains fairly high (R^2=0.75). Under the socio-economic drivers, the FLAME-CM and MLRM results show (R^2=0.65) and (R^2=0.58) respectively. The lower R^2 value of the socio-economic dimension may be ascribed to the fact that communities attach less importance to local economic issues as being responsible for conflicts. This however only becomes evident at a fine-grained scale study but not revealed in most cross-country studies. This is also supported by the actors' views gathered during the open interviews (see Section 4). In 1986-2000, under the political drivers, the FLAME-CM result shows the value of (R^2 = 0.76). But the result shows a weak (R^2=0.39) using the MLRM. This finding depicts a low impact of politics in NRBCs in the surveyed villages of the Niger Delta in comparison with other driver dimensions. This role of politics in NRBCs in the Niger Delta only becomes glaring when actors collectively deliberate, and value the importance of conflict drivers (Kenter *et al.*, 2016). See Section 6.5.1.4 under the discussion on political drivers for the elaboration of this assertion.

From Table 6.4, during the 1986-2000 period, the p-values of the FLAME-CM result of environmental and political drivers are statistically highly significant ($p<0.001$), while that of socio-economic drivers are only significant at ($p<0.01$). In the case of MLRM, only environmental drivers are significant at ($p< 0.001$).

6.5.1.3 Intra-Temporal Comparison of FLAME-CM and MLRM (2000-2016)

Table 6.4 shows a summary of the R^2 and p-values for the comparisons between the FLAME-CM and MLRM. The result of the comparison for the 2000-2016 period is shown at the lower part of the table.

In the 2000-2016 period, the environment has (R^2=0.99) as the highest of all the conflict vulnerability dimensions using the FLAME-CM. There is a reduction of (R^2=0.76) using the MLRM. This reveals the relevance of the valuation of the driving forces of conflicts by the local actors. In the socio-economic driver dimension, the R^2 for the FLAME-CM and MLRM are the same. These are (R^2=0.92) and (R^2=0.92) respectively. Socio-economic valuation did not make much difference in the lens of local communities studied. This may be as a result of the recent Presidential Amnesty Programmes (PAP) (Section 2.5). This programmes initiated by the federal government authority led to the reduction of conflicts around the year 2010. Since then the people seemed to shift their focus away from the socio-economic issues as drivers of conflicts towards the concern for environmental degradation. Under the political driver dimensions, the FLAME-CM value is given as (R^2=0.92). This, however, reduced to (R^2=0.78) in the MLRM. As reported in Section 4 by a village Chief, "I can do without politics but we cannot do without the environment".

The p-values of FLAME-CM for all dimensions are statistically highly significant (<0.001). It was rather expected that the results of the year 2000-2016 for both FLAME-CM and the MLRM would be better than that of 1986-2000 as the perceived risk. This may have been partly determined by the process of remembrance of information.

The FLAME-CM and MLRM results in the studied periods of 1986-2000 and 2000-2016 reveal the impact of environmental degradation on resource conflict likeliness. Environmental degradation plays a major role in the amplification of NRBCs. This is in contrast with studies by Tresman (2004) but supported by observations that environmental change has socio-economic consequences (Akpomuvie, 2011, Odoemene, 2011, Rustad, 2016). The actors' perception shows that NRBCs are directly linked to environmental resources, but only indirectly linked to socio-economic issues. The sufferings and the inability of local communities to cope with life and their tolerance for the pressure for resistance are traceable to the scarcity of environmental services. The present result is supported by studies on the effect of environmental scarcity on conflict likeliness (Bernauer *et al.*, 2012). This is only revealed with a better specification of conditions that facilitate indirect conflicts causal dynamics

Table 6.4: Overall FLAME-CM vs. MLRM Results (1986-2000) and (2000-2016).

1986-2000		**FLAME-CM**	**MLRM**	
Conflict Driver Dimension				
	R^2	p-value	R^2	p-value
Environment Drivers	0.96	0.000***	0.75	0.000***
Socio-economic Drivers	0.65	0.002**	0.58	0.008**
Political Drivers	0.76	0.000***	0.39	0.093
2000-2016				
Environment Drivers	0.99	0.000***	0.76	0.000***
Socio-economic Drivers	0.92	0.000***	0.92	0.000***
Political Drivers	0.92	0.000***	0.78	0.000***

Section 6.5.1.4 provides an explanation of the role of each of the individual drivers of NRBCs.

6.5.1.4 Comparison of All Possible Combinations of Conflict Drivers across Vulnerability Dimensions (1986-2000)

This section presents the results of all possible combinations of individual parameters. It is aimed at examining the impact of each input parameter on the likeliness of NRBCs. It further assesses how the actors' knowledge generate information that could be helpful in mitigating future NRBCs (Agbonifo, 2011). Figures 6.11 to 6.16 show the plots of the different combination of model parameters. They also show both the individual and the combined effects of the drivers of NRBCs likeliness. Similarly, Tables 6.5, 6.6, and 6.7 show the possible combination of the specific and the combined parameters of the evaluated conflict drivers in 1986-2000 under the various dimensions. The tables present the order of the combination of the parameters, the p-values of the individual parameters, the overall p-values, and the overall R^2. The results are presented in the following:

The External Vulnerability Drivers of Conflicts (1986-2000):

Environmental Dimension (1986-2000)

FLAME-CM: Table 6.5 shows the FLAME-CM results for the 1986-2000 time periods. Under the environmental drivers, all the other parameters are statistically highly significant at ($p <0.001$), except the farmland loss where ($p< 0.01$). The model of the best 1 parameter is oil infrastructure ($R^2= 0.89$), followed by that of mangrove loss ($R^2= 0.86$), while the model of the worst 1 parameter is that farmland loss ($R^2= 0.25$). The model of the best 2 parameters is that of oil infrastructure and water ($R^2= 0.94$), and the worst 2 parameters model is made up of farmland loss and mangrove loss ($R^2= 0.85$), while the model of the best 3 parameters is made up of oil infrastructure, water and mangrove ($R^2= 0.95$). Without oil infrastructure, the worst 3 parameters model became farmland loss, water and mangrove loss ($R^2= 0.22$). It can be deduced from this result that the location of oil infrastructure as an indication of oil extraction remains an important determinant of grievances in the Niger Delta. Oil infrastructure through pipeline breakage may cause pollution and lead to land degradation. These chain effects increase the grievances and the anger of people.

MLRM: In the case of the MLRM, the parameter combinations are also statistically highly significant ($p <0.001$) except farmland loss ($p <0.01$), while the R^2 for most parameters reduced under MLRM in comparison with the FLAME-CM results. Among the single parameters, mangrove loss has the highest ($R^2=0.69$) which is less than that of the FLAME-CM ($R^2 =0.86$) reported earlier. Mangrove loss is a key driver of conflicts because of the non-monetary environmental services derived by the local people. Farmland loss has the lowest value of ($R^2=0.42$) under the MLRM, but the R^2 is lower under the FLAME-CM ($R^2=0.25$). As shown in Table 6.5, while the model of the best 1 parameter is mangrove loss ($R^2=0.69$), the model of the worse 1 parameter is farmland loss ($R^2=0.42$). The best 2 parameters are mangrove loss and farmland loss ($R^2=0.74$), and that of the worst 2 parameters are oil and water ($R^2=0.61$). The best 3 parameters ($R^2=0.75$) are mangrove loss, water and oil infrastructure, while, the worst 3 parameters are oil, farmland loss and water ($R^2=0.67$). It is clear from the results that farmland loss as a single driver of NRBCs plays a minimal role in both the FLAME-CM and the MLRM models. But the reality (MLRM) is a bit more than what the FLAME-CM says.

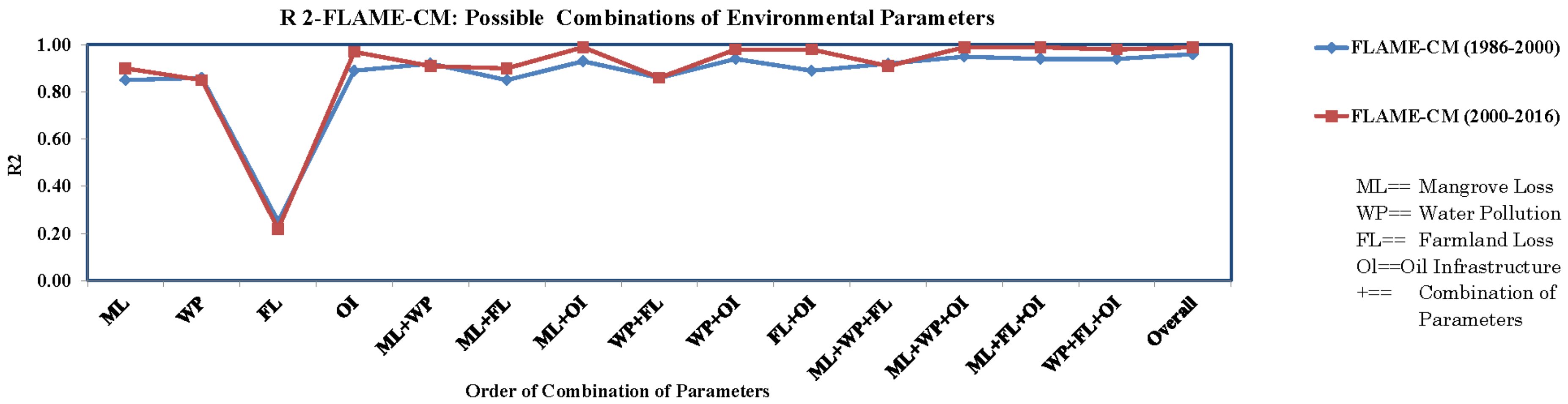


Figure 6.11: R^2 - FLAME-CM for environmental drivers.

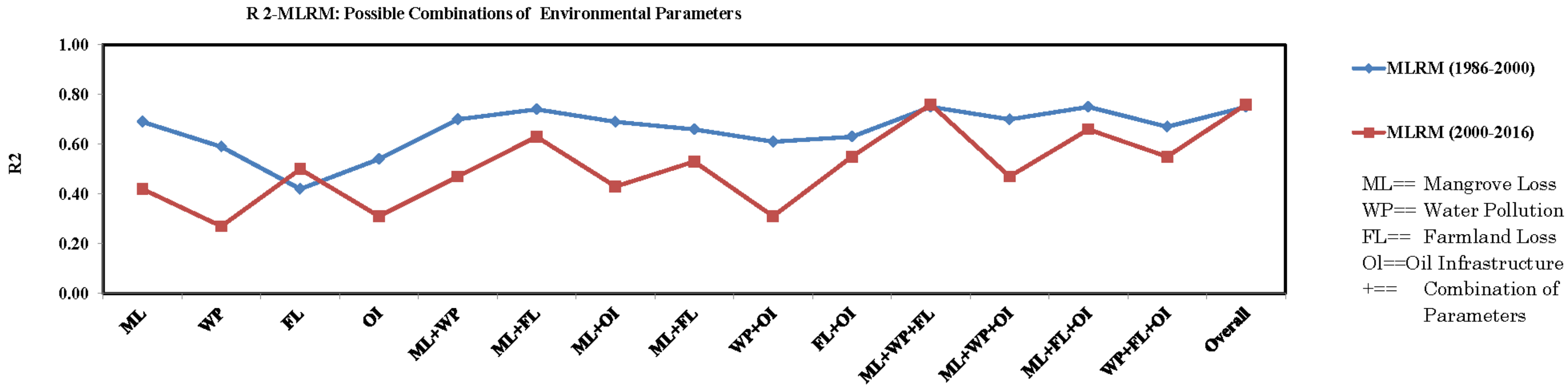


Figure 6.12: R^2 - MLRM for environmental drivers.

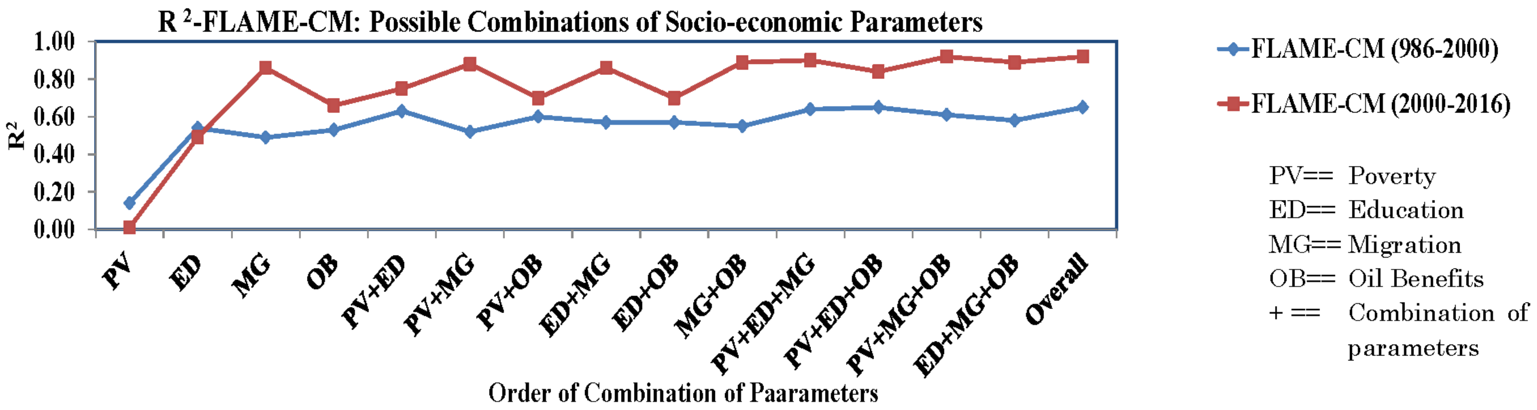


Figure 6.13: R^2 - FLAME-CM for socio-economic drivers.

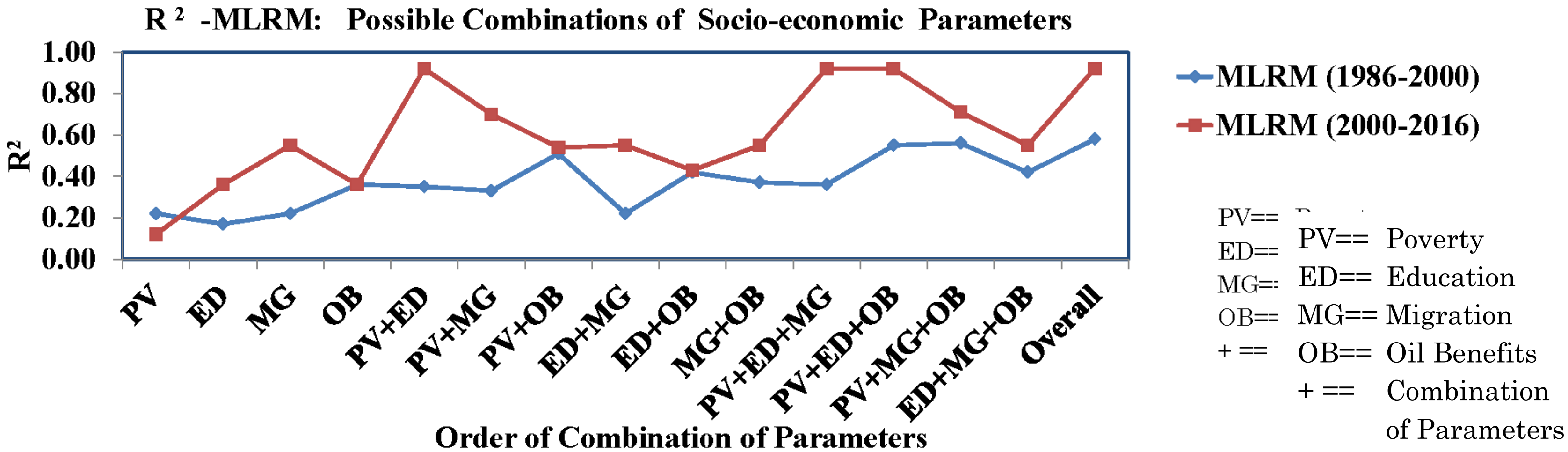


Figure 6.14: R^2 - MLRM for socio-economic drivers.

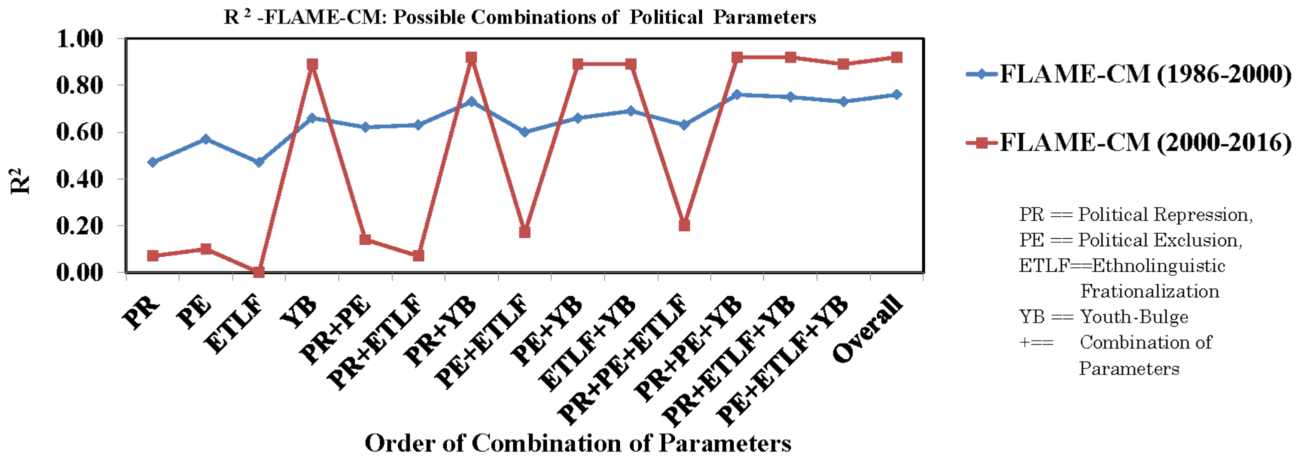


Figure 6.15: R^2 - FLAME-CM for political drivers .

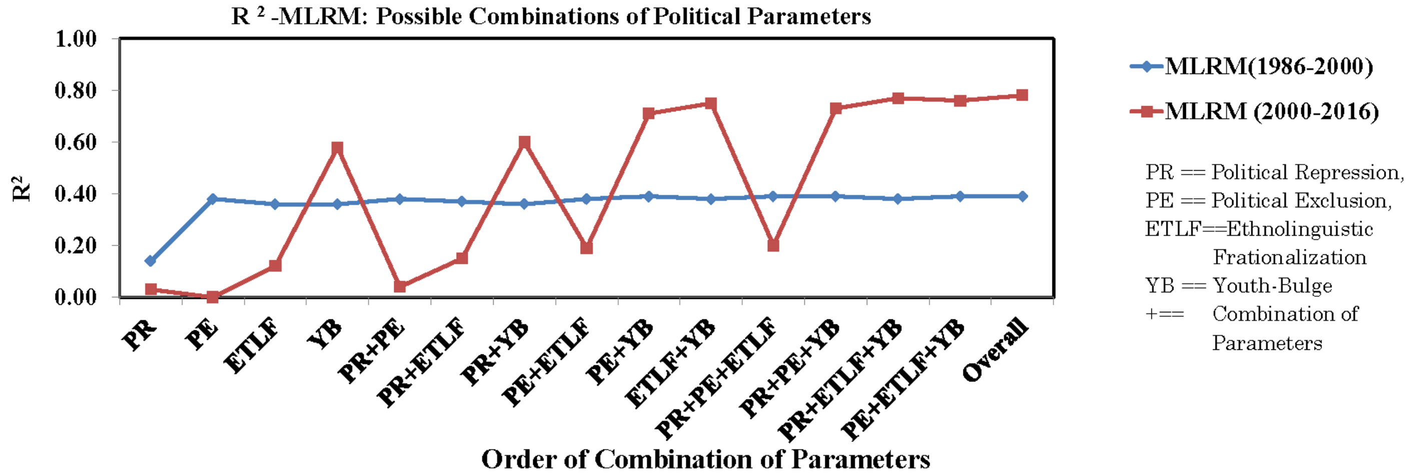


Figure 6.16: R^2 - MLRM for political drivers.

Table 6.5: Environmental drivers and possible combinations of parameters under FLAME-CM and MLRM (1986-2000).

Order of Combinations of Parameters															
ML WP FL OI	ML	WP	FL	OI	ML WP	ML FL	ML OI	WP FL	WP OI	FL OI	ML WP FL	ML WP OI	ML FL OI	WP FL OI	ML WP FL OI
FLAME-CM :P values and R^2															
P-values															
ML	0.000***				0.005*	0.000***	0.003**				0.004**	0.045*	0.004**		0.036*
WP		0.000***			0.002**			0.000***	0.002**		0.002**	0.028*		0.002**	0.019*
FL			0.023*			0.985		0.753		0.979	0.440		0.542	0.392	0.2530
OI				0.000***			0.000***		0.000***	0.000***		0.003**	0.000***	0.000***	0.003**
Overall P-values	0.000***	0.000***	0.023*	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.86	0.85	0.25	0.89	0.92	0.85	0.93	0.86	0.94	0.89	0.92	0.95	0.94	0.94	0.96
MLRM: P values and R^2															
P- values															
ML	0.000***				0.025*	0.000	0.010**				0.031*	0.042*	0.016*		0.046*
WP		0.000***			0.528***			0.003**	0.100		0.791	0.536		0.196	0.733
FL			0.002**			0.073		0.087		0.053*	0.099		0.082	0.105	0.108
OI				0.000***			0.885		0.419	0.007**		0.868	0.914	0.488	0.804
Overall P-values	0.000***	0.000***	0.002**	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.69	0.59	0.42	0.54	0.70	0.74	0.69	0.66	0.61	0.63	0.75	0.70	0.75	0.67	0.75

*** = p<0.001; **=p<0.01; *=P<=0.05 ☐=Not Available, ML=Mangrove Loss, WP=Water Pollution, FL=Farmland Loss, Ol=Oil Infrastructure

The Internal Vulnerability Drivers of Conflicts (1986-2000):

Socio-economic Drivers (1986-2000)

FLAME-CM: Table 6.6 shows the possible combinations of socio-economic parameters. In the FLAME-CM results, under the socio-economic vulnerability dimension, among the single parameters, all the other drivers are statistically highly significant ($p < 0.001$) except poverty. In terms of the R^2, education has the highest value of single parameters (R^2=0.54), while the lowest is poverty (R^2=0.14). The extremely poor, need to depend on the higher income class to be involved in any organized protest or violence. However, the model of the best 2 parameters is education and poverty (R^2=0.63). This shows that when extreme poverty and low education are combined they become potent forces of conflicts in the villages of the Niger Delta. This may be the case where the poor and those without formal education engage in individual violence such as crime and oil theft. The worst 2 parameters model, on the other hand, is that of oil benefits and migration (R^2=0.55). But the model of the best 3 parameters includes oil benefits, education, and poverty (R^2=0.65), while the worst 3 parameters are oil benefits, migration, and education (R^2=0.58). The villagers that benefit from social responsibilities of oil companies and equally have a formal education are not likely to move away to other communities. Hence they are not likely to be prone to violence.

MLRM: The MLRM results for the socio-economic drivers show that none of the models are statistically highly significant ($p > 0.001$). However, it is also shown that among the single parameters, oil benefits is the best model parameter (R^2=0.36), and the worst 1 parameter model is education (R^2=0.17). This is in contrast with the FLAME-CM results above, where education appeared to be the best 1 parameter model. This implies that local actors perceive low education to be a main driver of conflicts, even though in reality this is not the case. The best 2 parameters are oil benefits and poverty (R^2=0.51) and the worst 2 parameters are migration and education (R^2=0.22). The best 3 parameters are oil benefits, migration, and poverty (R^2=0.56), and the worst 3 parameters model are migration, education, and poverty (R^2=0.36).

Table 6.6: Socio-economic drivers and possible combinations of parameters under FLAME-CM and MLRM (1986-2000).

Order of Combinations of Parameters															
PV ED MG OB	PV	ED	MG	OB	PV ED	PV NA MG	PV OB	ED MG)	ED OB	MG OB	PV ED MG	PV ED OB	PV MG OB	ED MG OB	PV ED MG OB
FLAME-CM Results-P values and R^2															
P values															
PV	0.103				0.053*	0.309	0.099				0.104	0.073	0.159		0.101
ED		0.000			0.000***			0.090	0.220		0.037*	0.151		0.316	0.184
MG			0.001***			0.002**		0.283		0.370	0.664		0.674	0.554	0.987
OB				0.000***			0.000***		0.264	0.134		0.352	0.075	0.507	0.424
Overall P-values	0.103	0.000***	0.001***	0.000***	0.000***	0.002**	0.000***	0.001***	0.001***	0.001***	0.001***	0.001***	0.002**	0.003**	0.002**
Overall R^2	0.14	0.54	0.49	0.53	0.63	0.52	0.60	0.57	0.57	0.55	0.64	0.65	0.61	0.58	0.65
MLRM-P values and R^2															
P-values															
PV	0.038*				0.043*	0.100	0.040*				0.084	0.047*	0.020*		0.032*
ED		0.075			0.080			0.812	0.212		0.480	0.224		0.258	0.388
MG			0.039*			0.102		0.298		0.641	0.714		0.198	0.890	0.339
OB				0.005			0.006		0.014	0.055		0.016	0.012	0.031	0.012
Overall P-values	0.038*	0.075	0.039*	0.005**	0.026*	0.032*	0.003*	0.123	0.010**	0.019**	0.065	0.004**	0.004**	0.029*	0.008**
Overall R^2	0.22	0.17	0.22	0.36	0.35	0.33	0.51	0.22	0.42	0.37	0.36	0.55	0.56	0.42	0.58

*** = $p<0.001$; **=$p<0.01$; *=$P<=0.05$

☐=Not Available, PV=Poverty, ED=Education, MG=Migration, OB=Oil Benefits

Political Drivers (1986-2000)

FLAME-CM: Table 6.7 shows that using the FLAME-CM results, under the political dimension, all the parameters are significant ($p < 0.001$). However, there is less emphasis on politics as a key issue in resource conflicts in the Niger Delta. This is not so when compared with the 2000-2016 result explained below. This may be connected to the then-nascent democratic system which has now grown in the last few years with stronger anti-corruption agencies. Many NGOs have also sprung up in recent times with aggressive environmental protection campaigns. These have helped to shift focus from politics to environmental concerns. In terms of the R^2, youth-bulge has the highest value (R^2=0.66) while the lowest is political repression (R^2=0.47). The best 2 parameter model includes youth-bulge and political repression (R^2=0.73), and the worst 2 parameter model includes political exclusion and political repression (R^2=0.60). Then the best 3 parameter model is made up of youth-bulge, political exclusion and political repression (R^2=0.75), while the worst 3 parameters are ethnolinguistic fractionalization, political repression, political exclusion (R^2=0.63).

MLRM: The MLRM results show that none of the models are statistically highly significant ($p > 0.001$). Only political exclusion is significant at ($p<0.01$). The reason being that the real world somewhat differs from what actors say. In terms of the R^2, political exclusion has the highest (R^2=0.38), while political repression has the lowest single parameter (R^2=0.14), thus differing from the simulated model above. The best 2 parameter model includes youth-bulge and political exclusion (R^2=0.39), and the worst 2 parameter model is made up of youth-bulge and political repression (R^2=0.36). The best 3 parameters are youth-bulge, political exclusion and political regression (R^2=0.39), while the worst 3 parameters are youth-bulge, ethnolinguistic fractionalization and political repression (R^2=0.38). When the perception of conflicts is compared with the real conflict situation, from the perspective of the political drivers, it is obvious that youth-bulge is perceived to be a major driving force of conflicts likeliness. However, in the real-world situation, conflict is most prominent in communities that suffer political exclusion. Similar to the socio-economic forces described above, there is a disparity between the thinking of the people in terms of conflicts and the real conflict situation.

Table 6.7: Political drivers and possible combinations of parameters under FLAME-CM and MLRM (1986-2000).

Order of Combination of Parameters															
PR PE ETLF YB	PR	PE	ETLF	YB	PR PE	PR ETLF	PR YB	PE ETLF	PE YB	ETLF YB	PR PE ETLF	PR PE YB	PR ETLF YB	PE ETLF YB	PR PE ETLF YB
FLAME-CM Results-P values and R^2															
P-values															
PR	0.001***				0.137	0.016**	0.048**				0.250	0.022*	0.061		0.181
PE		0.000***			0.017**			0.036*	0.974		0.842	0.209		0.154	0.530
ETLF			0.001***			0.015**		0.291		0.223	0.590		0.267	0.064	0.796
YB				0.000***			0.001***		0.053*	0.004**		0.010**	0.013**	0.015**	0.014**
Overall P-values	0.001***	0.000***	0.001***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.47	0.57	0.47	0.66	0.62	0.63	0.73	0.60	0.66	0.69	0.63	0.76	0.75	0.73	0.76
MLRM Results-P values and R^2															
P-values															
PR	0.100				0.766	0.646	0.830				0.681	0.836	0.782		0.688
PE		0.004**			0.020*			0.498	0.426		0.526	0.441		0.623	0.575
ETLF			0.005*			0.023*		0.908		0.540	0.754		0.534	0.990	0.728
YB				0.005			0.027*		0.710	0.567		0.765	0.668	0.732	0.737
Overall P-values	0.100	0.004**	0.005**	0.005**	0.016**	0.020*	0.021*	0.017**	0.016**	0.018**	0.044*	0.044*	0.049*	0.045*	0.093
Overall R^2	0.14	0.38	0.36	0.36	0.38	0.37	0.36	0.38	0.39	0.38	0.39	0.39	0.38	0.39	0.39

*** = p<0.001; **=p<0.01; *=P<=0.05

☐ = Not Available, PR=Political Repression, PE=Political Exclusion, ETLF=Ethnolinguistic Fractionalization YB=Youth-Bulge

6.5.1.5 Comparison of All Possible Combination of Conflict Drivers across Vulnerability Dimensions (2000-2016)

The External Vulnerability Drivers of Conflicts (2000-2016):

Environmental Dimension (2000-2016)

FLAME-CM: Table 6.8 shows the FLAME-CM results in 2000-2016 time periods under the environmental drivers of conflicts. All the parameters are significant ($p < 0.001$), except farmland loss. The model of the best 1 parameter is oil infrastructure (R^2= 0.99), followed by mangrove (R^2= 0.90), water (R^2= 0.85), while the model of worst 1 parameter is farmland loss (R^2= 0.22). The model of the best 2 parameters includes oil infrastructure and mangrove (R^2= 0.99), and the worst 2 parameters model is made up of farmland and water (R^2= 0.86). Then the model of the best 3 parameters is that of mangrove loss, oil infrastructure and farmland loss (R^2= 0.99).

MLRM: As shown in Table 6.8, some of the parameter combinations are significant even those combinations that include the farmland loss ($p > 0.001$). R^2 shows that among the single parameters, the model of the best 1 parameter is farmland loss (R^2=0.50), and the worst model of 1 parameter is water pollution (R^2=0.27). The model of the best 2 parameters is made up of farmland loss and mangrove loss (R^2=0.63), and the worst 2 parameters are oil infrastructure and water pollution (R^2=0.31). The model of the best 3 parameters has a value of (R^2=0.76). These are made up of mangrove loss, water pollution, and farmland loss. On the other hand, the worst 3 parameters are also mangrove loss, water and oil infrastructure (R^2=0.47). As it can be seen, when the 2000-2016 and the 1986-200 results are compared it is obvious that the farmland parameter became more important at the later period. This is particularly when combined with other parameters.

Table 6.8: Environmental drivers and possible combinations of parameters under FLAME-CM and MLRM (2000-2016).

Order of Combinations of Parameters															
ML	ML	NA	NA		ML	ML	ML				ML	ML	ML		ML
WP		WP			WP			WP	WP		WP	WP		WP	WP
FL			FL			FL		FL		FL	FL		FL	FL	FL
OI				OI			OI		OI	OI		OI	OI	OI	OI
FLAME-CM Results-P values and R^2															
P-values															
ML	0.000***				0.003**	0.000***	0.000***				0.004**	0.001***	0.000***		0.000***
WP		0.000***			0.112			0.000***	0.132		0.128	0.547		0.071	0.777
FL			0.038			0.788		0.822		0.157	0.887		0.027*	0.083	0.038*
OI				0.000***			0.000***		0.000*	0.000		0.000***	0.000***	0.000***	0.000***
Overall P-values	0.000***	0.000***	0.038*	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.90	0.85	0.22	0.97	0.91	0.90	0.99	0.86	0.98	0.98	0.91	0.99	0.99	0.98	0.99
MLRM Results-P values and R^2															
P-values															
ML	0.002**				0.019*	0.028*	0.081				0.001***	0.040*	0.031*		0.003**
WP		0.020*			0.208			0.322	0.932		0.010**	0.245		0.766	0.029
FL			0.001***			0.007		0.007**		0.009**	0.001***		0.004**	0.010**	0.001***
OI				0.011			0.677		0.309	0.194		0.877	0.192	0.386	0.677
Overall P-values	0.002**	0.020**	0.001***	0.012**	0.004**	0.000***	0.009**	0.002**	0.043*	0.001***	0.000***	0.014**	0.000***	0.004**	0.000***
Overall R^2	0.42	0.27	0.50	0.31	0.47	0.63	0.43	0.53	0.31	0.55	0.76	0.47	0.66	0.55	0.76

*** = $p<0.001$; **= $p<0.01$; *= $P<=0.05$

☐ =Not Available, ML=Mangrove Loss, WP=Water Pollution ,FL=Farmland Loss ,OI=Oil Infrastructure

The Internal Vulnerability Drivers of Conflicts (2000-2016):

Socio-economic Drivers (2000-2016)

FLAME-CM: Table 6.9 shows the possible combinations of socio-economic parameters in 2000-2016. In 2000-2016, the FLAME-CM result for the socio-economic dimension is similar to that of 1986-2000. Single parameters are statistically highly significant except poverty. The results show that the model of the best 1 parameter is migration (R^2=0.86), followed by oil benefits (R^2=0.66) and the worst 1 parameter is poverty (R^2=0.01). The model of the best 2 parameters is made up of migration and oil benefits (R^2=0.89), while the worst 2 parameters are poverty and migration (R^2=0.89). The best 3 parameters are poverty, migration, and oil-benefits (R^2=0.92), followed by education, migration, and oil-benefits (R^2=0.89). Poverty becomes important in driving conflicts when combined with other drivers such as low education.

MLRM Result: As shown in Table 6.9, MLRM results show that among the single parameters, only migration is statistically highly significant, ($p <0.001$). It is also shown that among the single parameters, migration is the best model parameter (R^2=0.55), and the worst 1 parameter model is poverty (R^2=0.12). The best 2 parameters are poverty and migration (R^2=0.70), followed by education and migration (R^2=0.53), while the worst 2 parameters are education and oil-benefits (R^2=0.43). The best 3 parameters are poverty, education, migration/oil benefits (R^2=0.92).

As in the 1986-2000 period, poverty as a stand-alone driver of conflict at the local level does not have much effect. This is contrary to the previous studies at the cross-country scale. It is underscored in many previous studies of civil war that high levels of GDP are strongly related to lower levels of armed conflict. However, as earlier mentioned, poverty becomes a major contribution to conflicts when it is combined with other drivers such as low education and low oil benefits.

Table 6.9: Socio-economic drivers and possible combinations of parameters under FLAME-CM and MLRM (2000-2016) .

Order of Combinations of Parameters															
PV ED MG OB	PV	ED	MG	OB	PV ED	PV MG	PV OB	ED MG	ED OB	MG OB	PV ED MG	PV ED OB	PV MG OB	ED MG OB	PV ED MG OB
FLAME-CM Results-P values and R^2															
P- values															
PV	0.703				0.001***	0.096	0.177				0.025*	0.002**	0.035*		0.021*
ED		0.000***			0.000***			0.913	0.147		0.119	0.002***		0.534	0.222
MG			0.000***			0.000***		0.000***		0.000***	0.000***		0.000***	0.000***	0.001***
OB				0.000***			0.000***		0.003**	0.0526		0.008	0.020*	0.048*	0.040*
Overall P-values	0.703	0.001***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.01	0.49	0.86	0.66	0.75	0.88	0.70	0.86	0.70	0.89	0.90	0.84	0.92	0.89	0.92
MLRM Results P- values and R^2															
P- values															
PV	0.133				0.000***	0.009**	0.021*				0.000***	0.000***	0.009*		0.000***
ED		0.005**			0.000***			0.742	0.169		0.000	0.000		0.804	0.000
MG			0.000			0.000***		0.016**		0.015**	0.892		0.006**	0.050*	0.867
OB				0.005*			0.001***		0.177	0.738		0.953	0.470	0.799	0.906
Overall P-values	0.133	0.005**	0.000***	0.005**	0.000***	0.000***	0.002**	0.001***	0.009**	0.001***	0.000***	0.000***	0.000***	0.004**	0.000***
Overall R^2	0.12	0.36	0.55	0.36	0.92	0.70	0.54	0.55	0.43	0.55	0.92	0.92	0.71	0.55	0.92

*** = $p<0.001$; **= $p<0.01$; *= $P<=0.05$

☐ =Not Available, PV=Poverty, ED=Education , MG=Migration, OB=Oil Benefits

Political Drivers (2000-2016)

FLAME-CM: Table 6.10 shows the possible combinations of political parameters in 2000-2016. In the FLAME-CM results, from the political driver's dimensions, among the single parameters, only youth-bulge is significant at ($p < 0.001$). This is contrary to 1986-2000 result for political dimension reported earlier. Although there is less and less emphasis on politics as a driver of resource conflicts, youth-bulge is still a major problem. In terms of the R^2, youth-bulge has the highest value (R^2=0.89) followed by the political exclusion (R^2=0.10). While the lowest is that of ethnolinguistic fractionalization (R^2=0.00). The best 2 parameters are youth-bulge and political repression (R^2=0.89), and youth-bulge and political exclusion (R^2=0.89). The worst 2 parameters include political regression, ethnolinguistic fractionalization (R^2=0.07). The best 3 parameter model is made up of youth-bulge, political repression and political exclusion (R^2=0.92), while the worst 3 are ethnolinguistic fractionalization, political repression, political exclusion (R^2=0.20)

MLRM: In comparison with the observed conflicts, from the political driver's dimensions (Table 6.10), only the youth-bulge model ($p < 0.001$) is statistically highly significant. In terms of the R^2, the best 1 parameter model is the youth-bulge (R^2=0.58), while the worst 1 parameter model is the political exclusion (R^2=0.00). The best 2 parameter model includes youth-bulge and ethnolinguistic fractionalization (R^2=0.75), followed by youth and political exclusions (R^2=0.71). Then the best 3 parameters are youth-bulge, ethnolinguistic fractionalization and political regression (R^2=0.77), followed by youth-bulge, political exclusion and ethnolinguistic fractionalization (R^2=0.76), while the worst 3 parameter models are ethnolinguistic fractionalization, political repression and political exclusion (R^2=0.38).

The above result suggests the importance of youth-bulge as a significant parameter that could determine a village's vulnerability to conflicts in the Niger Delta communities. This is further supported by the presence of the huge problem of lack of gainfully employed youths (Oyefusi, 2010). Ethnolinguistic fractionalization on the other hands is of least importance. This is despite the existing diversities of groups in the Niger Delta as mentioned in Section 2. Rather than ethnic diversities, it is the dominance of some large groups such as Ogoni and Ijaw groups with oil-bearing communities that contribute to community resistance. The Niger Delta conflict is not necessarily associated with a diversity of groups, but the conditions that favor it (Fearon and Laitin, 2003) However, ethnolinguistic fractionalization as a driver of NRBCs only becomes important when combined with youth-bulge.

Table 6.10: Political drivers and possible combinations parameters under FLAME-CM and MLRM (2000-2016) .

Order of Combinations of Parameters															
PR	PR				PR	PR	PR				PR	PR	PR		PR
PE		PE			PE			PE	PE		PE	PE		PE	PE
ETLF			ETLF			ETLF		ETLF		ETLF	ETLF		ETLF	ETLF	ETLF
YB				YB			YB		YB	YB		YB	YB	YB	YB
FLAME-CM Results-P values and R2															
P-values															
PR	0.274				0.362	0.288	0.018**				0.438	0.014**	0.018**		0.020**
PE		0.184			0.242			0.083	0.567		0.120	0.307		0.976	0.660
ETLF			0.958			0.967		0.247		0.389	0.300		0.316	0.532	0.691
YB				0.000***			0.000***		0.000***	0.000***		0.000***	0.000***	0.000***	0.000***
Overall P-values	0.274	0.184	0.958	0.000***	0.277	0.559	0.000***	0.213	0.000***	0.000***	0.303	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.070	0.10	0.00	0.89	0.14	0.07	0.92	0.17	0.89	0.89	0.20	0.92	0.92	0.89	0.92
MLRM Results-P values and R2															
P-values	0.437				0.431	0.413	0.438				0.548	0.203	0.320		0.258
	0.437				0.431	0.413	0.438				0.548	0.203	0.320		0.258
PR															
PE		0.884			0.790			0.244	0.017		0.316	0.012		0.488	0.369
ETLF			0.142			0.143		0.066		0.003	0.086		0.004	0.073	0.097
Youth				0.000***			0.000***		0.000***	0.000***		0.000***	0.000***	0.000***	0.000***
Overall P-values	0.437	0.884	0.142	0.000***	0.720	0.248	0.000***	0.174	0.000***	0.000***	0.287	0.000***	0.000***	0.000***	0.000***
Overall R^2	0.03	0.00	0.12	0.58	0.04	0.15	0.60	0.19	0.71	0.75	0.20	0.73	0.77	0.76	0.78

*** = p<0.001; **=p<0.01; *=P<=0.05

□ = Not Available, PR=Political Repression, PE=Political Exclusion, ETLF=Ethnolinguistic Fractionalization YB=Youth-Bulge

The temporal comparison of FLAME-CM and the MLRM (1986-2000 and 2000-2016) shows that under environmental dimension, the best parameters that explain vulnerability to NRBCs include oil infrastructure, mangrove loss, and water pollution, and farmland loss in their order of importance. The FLAME-CM results show that the people perceive conflicts to be mostly associated with oil extractive activities. The important issues in this context include both the mere locations of infrastructure and ongoing extractive activities. The location of resources is critical to the return of peace after resource conflict occurrence (Rustad and Binningsbø, 2012).

It is also clearly seen from the FLAME-CM results that farmland loss seemed to be the least singular important driver of the NRBCs. This is true for both the 1986-2000 and 2000-2016 periods. However, MLRM results show that in reality, farmland loss determines the likeliness of conflicts in villages. For example, it is shown that in 1986-2000, under the FLAME-CM result farmland loss has (R^2=0.25). But this is below the MLRM result (R^2 =0.42) which represents the reality. The result is in support of Ross (2004) regarding the links between agricultural commodities and conflicts.

Similar to the 1986-2000 period, in the 2000-2016 period, the result of MLRM shows that farmland loss alone has (R^2=0.22), but when combined with mangrove loss and water pollution it rose to (R^2=0.91). This indicates that though farmland loss can make villages aggressive, the effect is more when the same people also suffer mangrove loss and pollution of their source of water. This explanatory power of the model seems better than that of previous studies such as Raleigh and Urdal (2007). They believed that medium to high levels of land degradation is related to the increased conflict not mainly the combination of drivers. It is revealed in this study that the detail explanations given here may be due to the specifications of the model by integrating the actors' views at a disaggregated scale. The implication of the effect of farmland loss on conflicts includes:

Firstly, there is a recent abandonment of farmland because of paid jobs and rural-urban migration as a coping strategy. Due to environmental degradation and the search for a better livelihood, the inhabitants of the oil extractive territories leave their original communities to engage in non-agricultural activities in urban areas in order to make a living. These have led to the loss of interest in farming. While they still need mangrove for firewood, their less dependence on agricultural activities has reflected in the perception of conflict likeliness. This supports studies that advocate for consideration of environmental issues in resource-related conflicts (Homer-Dixon, 1991, Percival and Homer-Dixon, 1998).

Secondly, related to the above, as people depend less on farming partly due to the dominance of oil on the local economy and due to perceived benefits from oil extraction, they begin to have more quest for corporate social responsibility projects and benefits from the oil extractive companies (Idemudia, 2009b, Idemudia, 2010, Idemudia, 2017).

Under the socio-economic dimensions, the local knowledge of risks of NRBCs differs from reality. NRBCs could be explained mainly by the knowledge of the people than what obtains in reality (Kasperson and Kasperson, 1996). The effects of the drivers of conflicts become more obvious when combined with other drivers. For example, as the results depict, in both 1986-2000 and 2000-2016 periods, poverty as a single parameter does not seem to contribute much to conflict. The FLAME-CM model in both 1986-2000 and 2000-2016 show low poverty values of (R^2=0.14), and (R^2=0.01) respectively. But, the combination of poverty and low education is (R^2=0.75) in 2000-2016. As reported earlier, the effect of poverty, when combined with low education, is supported by evidence that those who are poor and without formal education and are unemployed are more prone to militarized struggles (Oyefusi, 2010). This makes them more prone to move away from their native lands to nearby villages.

Under the political dimension, the 2000-2016 results equally show a disparity between the thinking of the people in terms of conflicts and the real conflict situation. It is shown that youth-bulge is perceived to be a major driving force of conflict likeliness. This is in line with the evidence that large youth population is more likely to increase the risk of internal conflict where there is particularly low secondary education (Barakat and Henrik, 2008). This situation obtains in both democratic and autocratic governments (Urdal, 2006). However, under the MLRM, conflict is most prominent in communities that suffer political exclusion and in those that have high ethnolinguistic fractionalization.

It is clearly evident from the above-presented results that there are hidden conflicts that can only be managed by integrating the participation of actors at the local level (Rustad *et al.*, 2011, Rustad, 2016). Using a cross-validation, the results of a further test of the robustness of the model-FLAME-CM are shown in Section 6.5.2.

6.5.2 The Cross-Validation

The aim of cross-validation as presented in this section is to evaluate the performance of FLAME-CM using the FUZZZCONDATA (Section 5.2.4). The FUZZYCONDATA is compared with the exponent of the logarithm of observed conflict data (ELOBCONDATA). ELOBCONDATA is the transformed data format of FUZZYCONDATA. The ELOBCONDATA is generated to correct the distance effect on the use of the observed conflict data for validation.
The assumption behind the generation of ELOBCONDATA is that the severity of conflict risk will reduce as one moves away from the village center towards the periphery of a village (see Figure 6.17 for illustration). Four main steps are involved in deriving and using the ELOBCONDATA.

- First, taking a logarithm of the observed conflict for the model run.
- Second, running the model.
- Third, calculating an exponent of the result to arrive at the same level as the observed data, and
- Fourth and finally running a cross-validation.

The function of the logarithm helped to increase the effect of fewer conflicts happening at the village center, as well as helping to reduce the effect of more conflicts happening outside the village center. It is assumed that a non-linear relationship exists between NRBCs and distance. As seen in Figure 6.17, villagers or properties closer to the scene of conflicts are at the highest risk. In other words, the exposure levels of community members can affect their perceptions. The uncertainty concept is applied with reference to the problems of NRBCs in the study area. The difference between the perceived risk and the real risk (observed conflicts) is examined. There are unknown effects of risk perception of conflicts which are not easily revealed. Uncertainty in the context of NRBCs may be affected by the knowledge of what is known and what is not known, the geographical factors, the temporal scale, and the dimension of conflicts drivers. For example, the people in different social-structural and geographical locations often have different kinds of knowledge about environmental risks based on the influence of locational factors on their experiences (Barbour and Kitzinger, 1998, Sjöberg, 2001, Lindbladh and Lyttkens, 2003, National Research Council, 2009, Power, 2007).

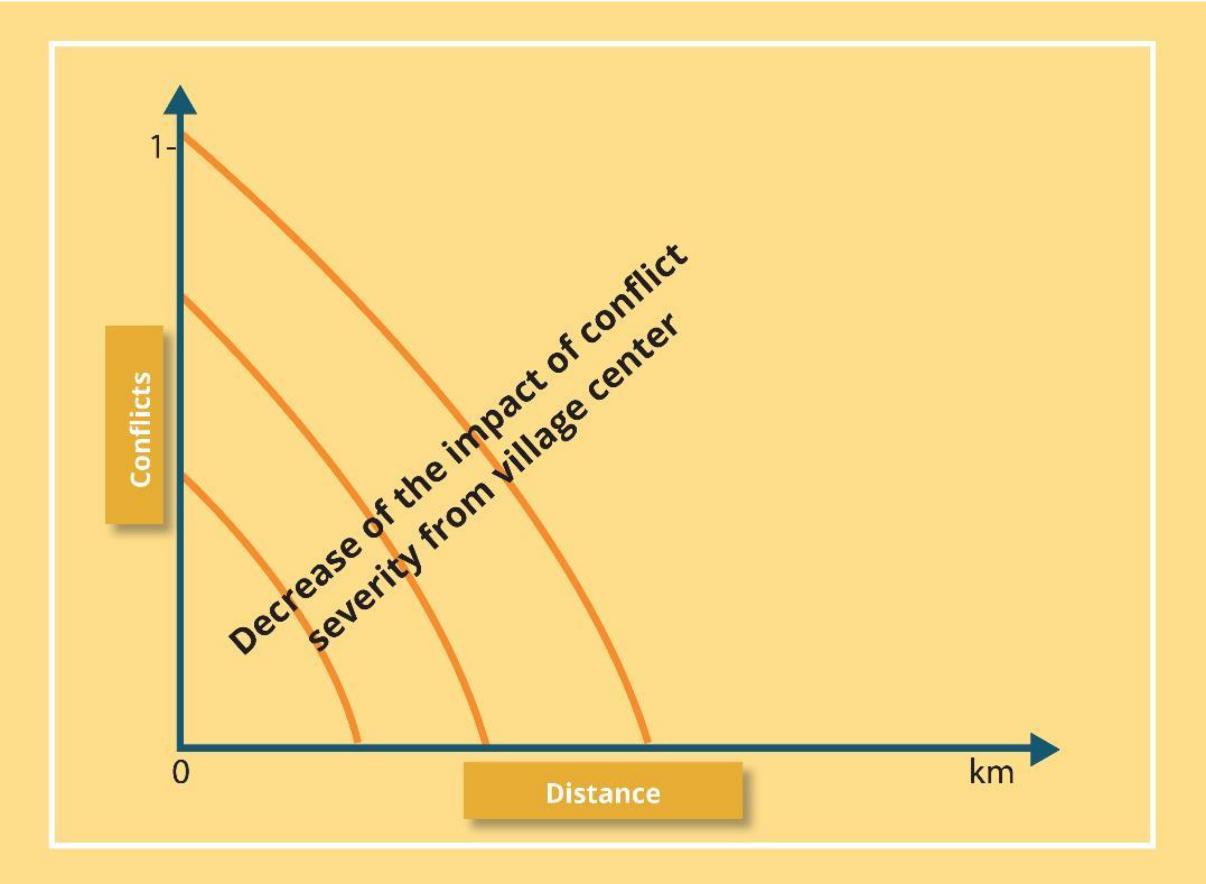


Figure 6.17: Relationship between distance and severity of conflicts..

Thus after generating the ELOBCONDATA, a cross-validation strategy is carried out. This is achieved with a comparison of FUZZYCONDATA vs. ELOBCONDATA.

A cross-validation (CV) has been used as a strategy for the evaluation of model performance and the quantification of uncertainties (Arlot and Celisse, 2010). CV schemes can differ in the size of training and validation subsamples. Here, CV schemes are applied to analyze the potential changes in the uncertainty level resulting from different aspects of the analysis: the vulnerability dimension and the temporal dimension of NRBCs. A CV strategy of leave-one-out (LOO) is applied. FUZZYCONDATA and ELOBCONDATA are compared under the two temporal scales of 1986-2000 and 2000-2016. In this context, with the LOO strategy, all but one sample point are included for model identification, and the remaining data points are used for model evaluation. This procedure is repeated so that at each point (n=20) is left out. A correlation R^2 (coefficient of determination) and Root Mean Squared Error (RMSE) are used to explain the model uncertainty (Shmueli, 2010, Chai and Draxler, 2014) (see *Equations 6.8 and 6.9*). The RMSE is a standard metric for model errors in the field of geosciences and noted for its low ambiguity (Chai and Draxler, 2014).

$$R^2 = 1 - \frac{\sum(x_p - x_i)^2}{\sum_i^n (x_i - \bar{x})^2}$$ *(Equation 6.8)*

(Equation 6.9)

$$\text{RMSE}=1 - \sqrt{\frac{\sum_{i=1}^n (x_p - \bar{x}_p)^2}{\sum_i^n (x_p - x_i)^2}}$$

6.5.2.1 Cross-Validation of the model uncertainty (1986-2000)

Table 6.11 shows a summary of the cross-validation result with correlation (R^2) and RMSE of the comparison between the FUZZYCONDATA and ELOBCONDATA for the time period of 1986-2000. Figures 6.18 to 6.20 show the plots for the various dimensions of conflict drivers in 1986-2000. While Table 6.11 is a summary of the average LOO values for the various dimensions. To avoid having to produce 60 plots for the three dimensions, the original values before the LOO strategy was used for the plots.

In the case of the FUZZYCONDATA, the overall correlation (R^2) involving the environmental, socio-economic and political drivers is 0.50 (50%). This improved to 0.74 (74%) using ELOBCONDATA for all the dimensions in 1986-2000. The R^2 is known to be an indicator of the accuracy of the model to be close to 1. The slope of the regression equation is closest to unity as expected under the environmental drivers using the ELOBCONDATA. This shows the superiority of ELOBCONDATA data as seen in the improvement of the R^2 . This tells much of the effect of distance in explaining conflicts in the Niger Delta. The effect of distance is much more in recent times as the effect of pollution has made the available resources closer to the village centers very vital. In addition, as discussed in Section 6.5.2, environmental drivers have more influence on NRBCs, particularly when the actors are involved in the valuation.

As further shown in Table 6.10, the RMSE of the model in 1986-2000 shows better results in the use of ELOBCONDATA. The RMSE of FUZZYCONDATA and ELOBCONDATA are 0.285, and 0. 233 respectively. Environmental data sets have the least RMSE indicating the fact that these data sets have less noise. The remote sensing plays a key role in this context. The less agreement of the slope of socio-economic and political drivers is an indication of the difficulties involved in modeling real-world problems such as the NRBCs. This may also be ascribed to the fact that actors across the villages studied associate conflict more to the environment than to social issues.

Table 6.11: Comparison of results between FUZZYCONDATA and ELOBCONDATA 1986-2000

FUZZYCONDATA			**ELOBCONDATA**	
Conflict Drivers	R^2(Corr.)	RMSE	R^2(Corr.)	RMSE
Environmental Drivers	0.74	0.242	0.95	0.228
Socio-economic Drivers	0.60	0.231	0.69	0.235
Political Drivers	0.15	0.383	0.58	0.236
OVERALL	**0.50**	**0.285**	**0.74**	**0.233**

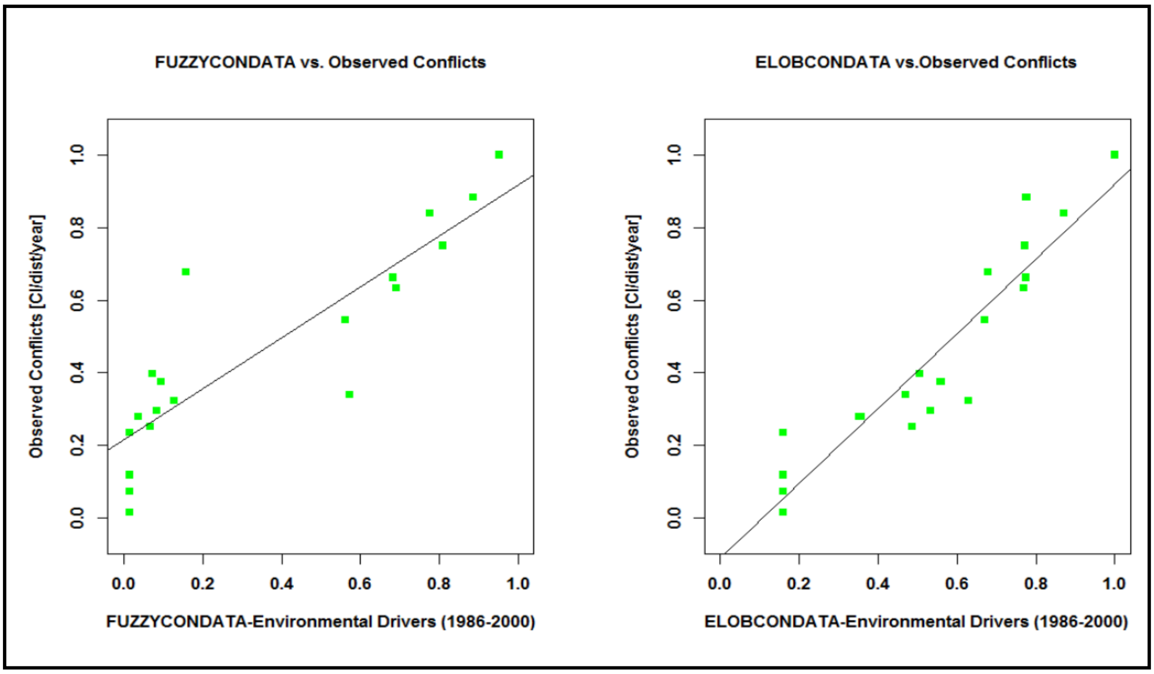


Figure 6.18: FUZZYCONDATA vs. ELOBCONDATA (environmental drivers-1986-2000.

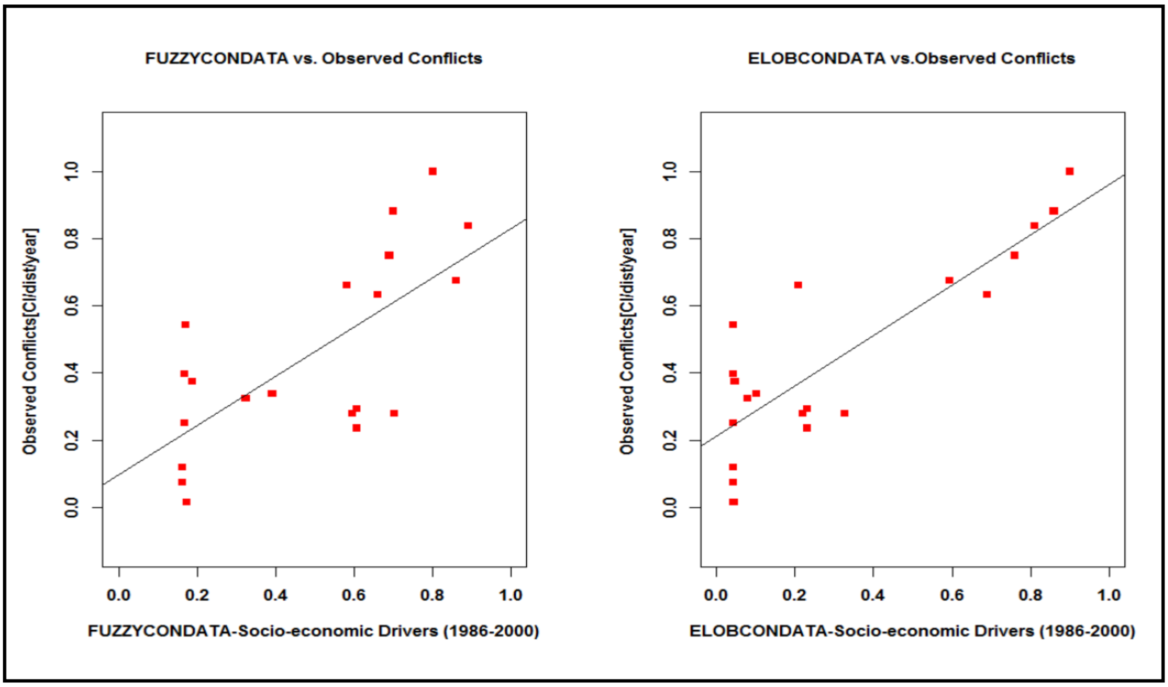


Figure 6.19: FUZZYCONDATA vs. ELOBCONDATA (socio-economic drivers-1986-2000.

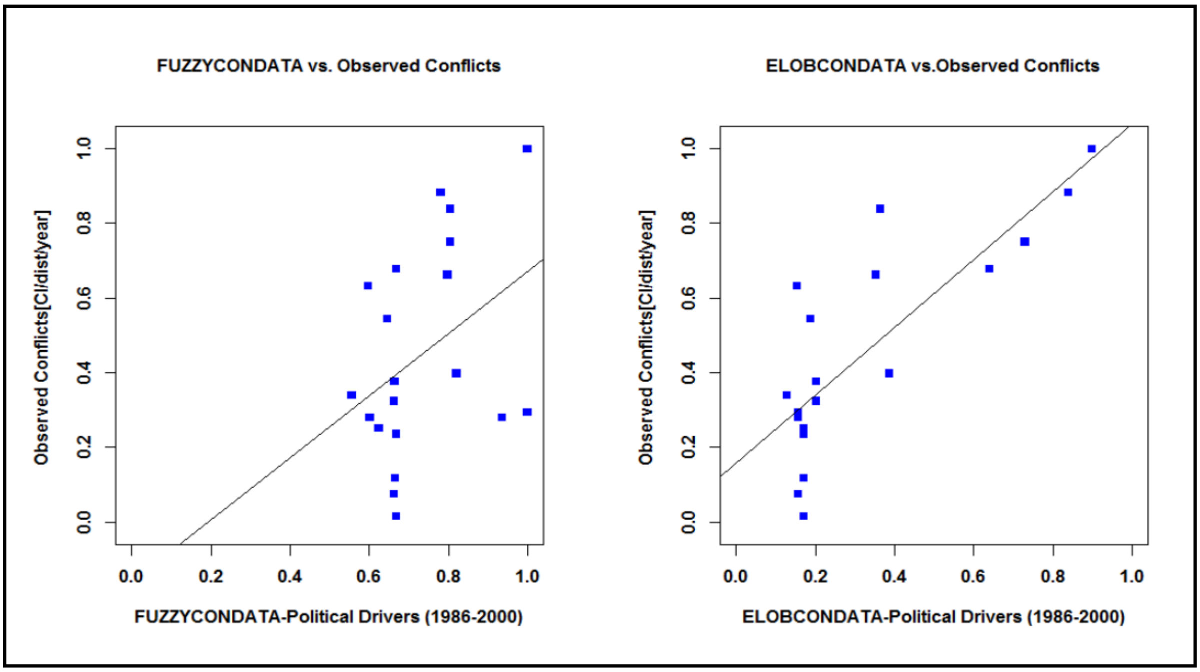


Figure 6.20: FUZZYCONDATA vs. ELOBCONDATA (political drivers,1986-2000).

6.5.2.2 Cross-Validation of the Model Uncertainty (2000-2016)

Table 6.12 shows a summary of the cross-validation result with the correlation (R^2) and RMSE of the comparison between the FUZZYCONDATA and ELOBCONDATA for the period of 2000-2016. Figures 6.21-6.23 show the plots for the various dimensions of conflict drivers for 2000-2016. The R^2 of the correlation involving the environmental drivers, the socio-economic and the political drivers is 0.69 (69%). This improved to 0.83 (83%) using the ELOBCONDATA. All the R^2 for the other dimensions are better with the ELOBCONDATA in a similar way to the 1986-2000 years. Using the ELOBCONDATA, the R^2 of the environmental driver is the highest at 0.94 (94%), followed by the R^2 of the political 0.81 (81%), and the socio-economic 0.74 (75%) dimensions. This is due to the fact that in recent times the majority of the conflicts that take place within villages are environmentally related. The limited unpolluted lands closer to residents are indeed very important to villagers than those farther away.

From Figure 6.22, one can notice a cluster of points in the political drivers plot in 2000-2ß16 (right). These are perhaps some villages in Ogoni territory that collectively do not recognize political issues as key drivers of NRBCs. When the 2000-2016 CV result is compared with that of 1986-2000 result, it is obvious that all the results improved. The implication of the use of LOO is that the results became better, mainly for drivers that have low R^2 in the MLRM as reported in Section 6.5.1.3 and Section 6.5.1.4. In 2000-2016, the overall RMSE reduced from 0.262 using the FUZZYCONDATA to 0.163 by using the ELOBCONDATA. The lower RMSE in the ELOBCONDATA model is reflected in all the dimensions and the overall value. However, the RMSE of the environment (0.054) is obviously the lowest, reflecting the better quality of the recent data used to derive the environmental drivers and the contribution of the environment in disaggregated conflict study.

Table 6.12: Comparison of results between FUZZYCONDATA and ELOBCONDATA 2000-2016.

FUZZYCONDATA			**ELOBCONDATA**	
Conflict Drivers	R^2(Corr.)	RMSE	R^2(Corr.)	RMSE
Environmental Drivers	0.79	0.242	0.94	0.054
Socio-economic Drivers	0.62	0.280	0.75	0.200
Political Drivers	0.68	0.265	0.81	0.236
OVERALL	0.69	0.262	0.83	0.163

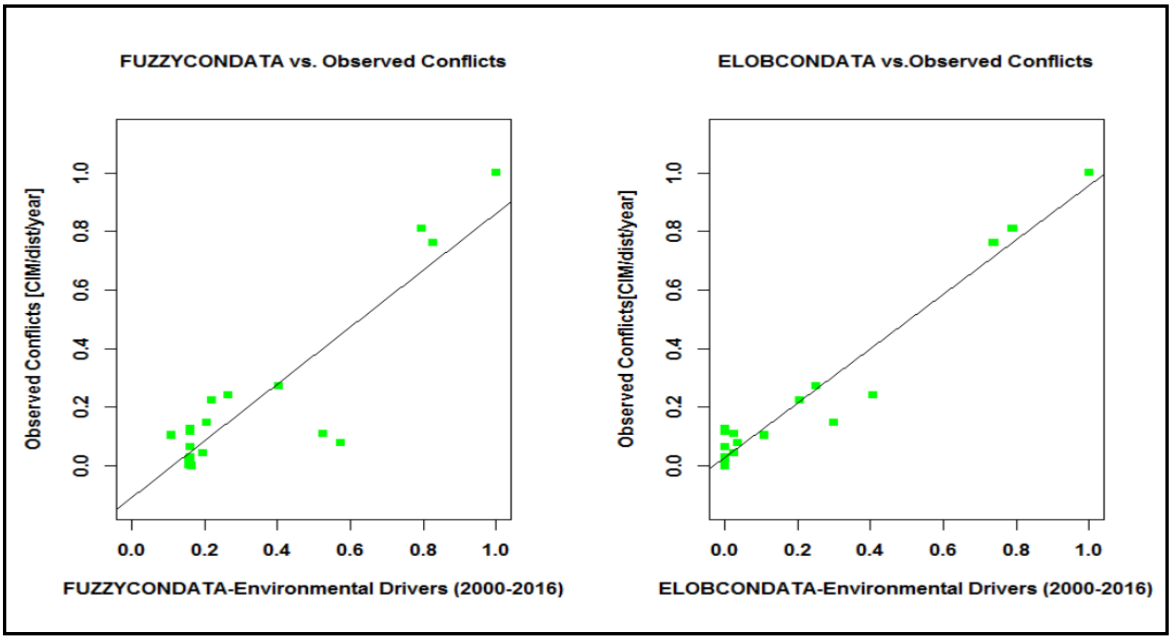


Figure 6.21: FUZZYCONDATA vs. ELOBCONDATA (environmental drivers, 2000-2016.

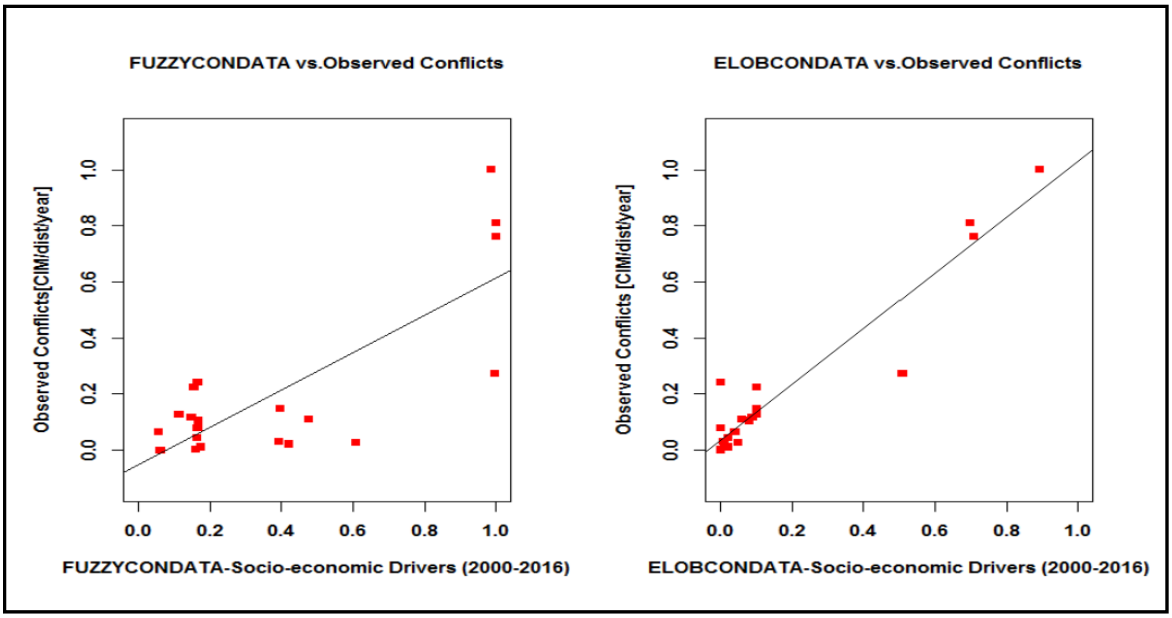


Figure 6.22: FUZZYCONDATA vs.ELOBCONDATA (socio-economic drivers, 2000-2016).

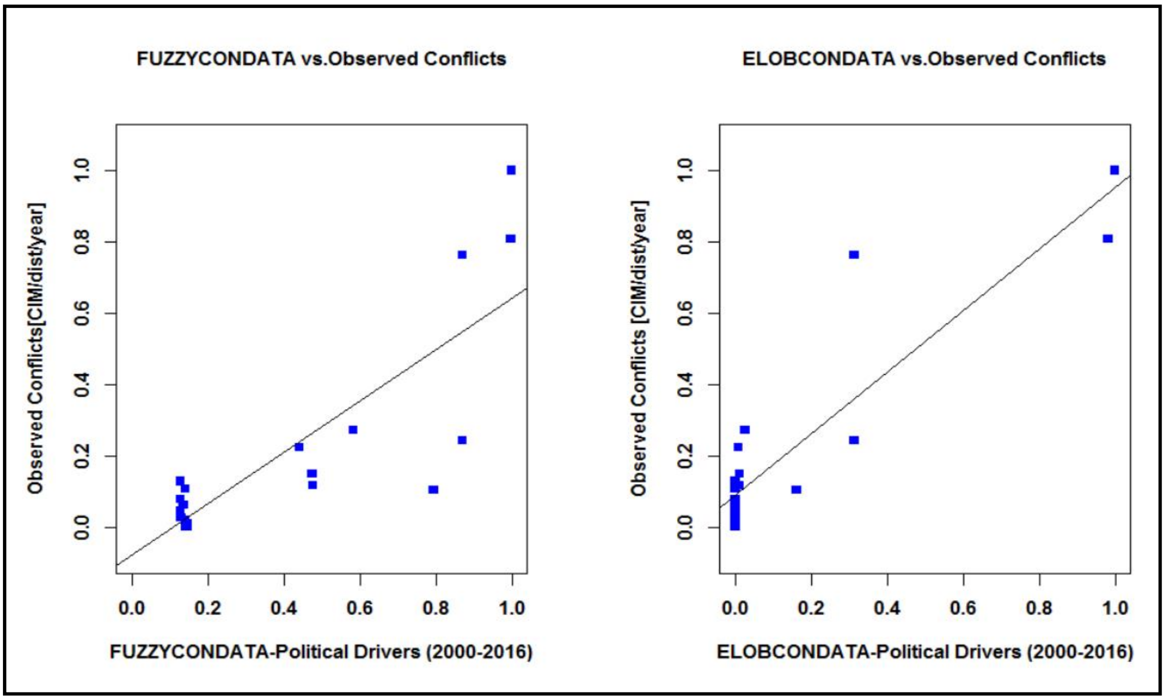


Figure 6.23: FUZZYCONDATA vs. ELOBCONDATA (political drivers, 2000-2016.

There are clear implications in the reported result using the CV strategy. Overall the ELOBCONDATA significantly improved the FLAME-CM model result over the FUZZYCONDATA. As seen in Figures 6. 21 to 6.23, the slope of the regression line is best in the case of environmental drivers, particularly the use of ELOBCONDATA in the two year periods. ELOBCONDATA helps to address the uncertainty issues in the data, particularly considering the fact that conflict impacts could be more severe with closer distances to the village center. The following are implications of the CV results:

Firstly, based on the available information, this is the first attempt of using a holistic approach to conflict vulnerability assessment and examining the influence of different driver of conflicts side by side. In the explanation of the vulnerability likeliness of NRBCs, the weighting of the factors plays an important role as reported earlier. The results support the increasing debates on human perception and integrated assessment by researchers. For example, since this observation was made, no obvious attempt has been made to examine them together. "The close linkages between economic, political and environmental variables indicate that future research should pay more attention to the interaction of these factors" (Hauge and Ellingsen, 1998) (:314)).

Secondly, the integration of actor's knowledge into the assessment of NRBCs at a disaggregated scale departs from the greed hypothesis but tend either towards that of grievance hypothesis (Collier and Hoeffler, 2004, Collier and Hoeffler, 2012) or the Neo-Malthusian perspectives (Homer-Dixon et al., 1993, Homer-Dixon, 1994, Schwartz et al., 2000). CM policies will need to consider the importance of the environment. This lends credence to the role of deliberative value formation in NRBCs assessments (Kenter et al., 2011, Kenter et al., 2016).

With the transformed data set, a spatially explicit context of the model process is introduced in the following section where conflict typologies are integrated into the SEFLAME-CM.

6.5.3 The Spatially Explicit Validation

This section presents the spatially explicit validation process and results. The spatially explicit design of sub-national research on conflict vulnerability assessments produces findings that elucidate local patterns and processes (Raleigh, 2011). The problem of Modifiable Area Unit Problem (MAUP) often arises when point-based measures of spatial phenomena are aggregated into districts. MAUP has been extensively discussed (Openshaw, 1984, Weeks, 2004, Dark and Bram, 2007).

In this work the problem of MAUP is addressed by using multi-level spatial scale approach and by rescaling of data through multiple processes. It is believed that “Vulnerability Cube” provides a structure for the different notions of scales and ultimately for a spatial analysis workflow (Kienberger et al., 2013, Khatiwada, 2014). In GIS science, the concept of *geons* has been used for transforming singular domains of information to components which are integrated and adapted to a policy-defined realm (Kienberger et al., 2009, Lang et al., 2014).

The various datasets are assigned to an artificially generated grid cells (see Section 6. 5.3.1). With the aid of GIS, this study disaggregated the validated parameters (see Section 6.5.2) to a grid cell scale. The output is then upscaled to a territorial scale of the study area, as a representation of the regional level. Different scales are applied such as individual, household, village, grid cells, LGA/community to territorial areal units (see Figure 6.24). These different levels were important during the data collection. For spatially explicit validation, the validated model of FLAME-CM is transferred for spatially explicit validation under the SEFLAME-CM. The spatially explicit validation is addressed in two major ways:

Firstly, the SEFLAME-CM is used to create a spatially explicit CVL Index. The results of SEFLAME-CM are compared with that of the spatial multi-criteria evaluation for conflict management (SMCE-CM) using spatial statistics (Section 6.5.3.2). With the SMCE there are alternatives, criteria and other elements of the decision problem which have explicit spatial dimensions (Malczewski, 1999) (see Section 5.2.3.8.2). The SMCE refers to the application of SMCE and GIS in a spatial context. Besides the NRBCs, SMCE has been used in addressing other spatial decision and complex suitability problems ((Thill, 1999, Malczewski, 2004, Kiker *et al.*, 2005), Section 5.2.3.8.2).

Secondly, the spatially explicit CVL Index is further validated with external data-remote sensing data using a multinomial logistic regression model (MNLR). MNLR is used to establish how the various types of environmental changes are systematically associated with conflicts or cooperation (Bernauer et al., 2012).

6.5.3.1 Spatial Statistics and Conflict Vulnerability Assessment

Studies on spatial assessment of NRBCs at a disaggregated scale using GIS usually permits researchers to combine spatial and statistical data to examine existing problems in novel ways (Gadjanova *et al.*, 2014, Cederman and Gleditsch, 2009). For example, the GIScience community often uses spatial statistics in location-based analysis and socio-spatial analysis. Spatial statistics is recently seen as the future of the application of spatial analysis in the social sciences and in the recent demand of addressing real-world problems in cross-disciplinary studies (Anselin, 1999a, Anselin, 1999b, Goodchild *et al.*, 2000, Brennan and Martin, 2012, Anselin, 2013). This link between GIS, social sciences, and cross-disciplinary studies is what

Goodchild *et al.* (2000) termed "spatially integrated" social sciences. Therefore, this development of location-based analysis informs the need for spatial disaggregation of global statistics (Fotheringham, 2000).

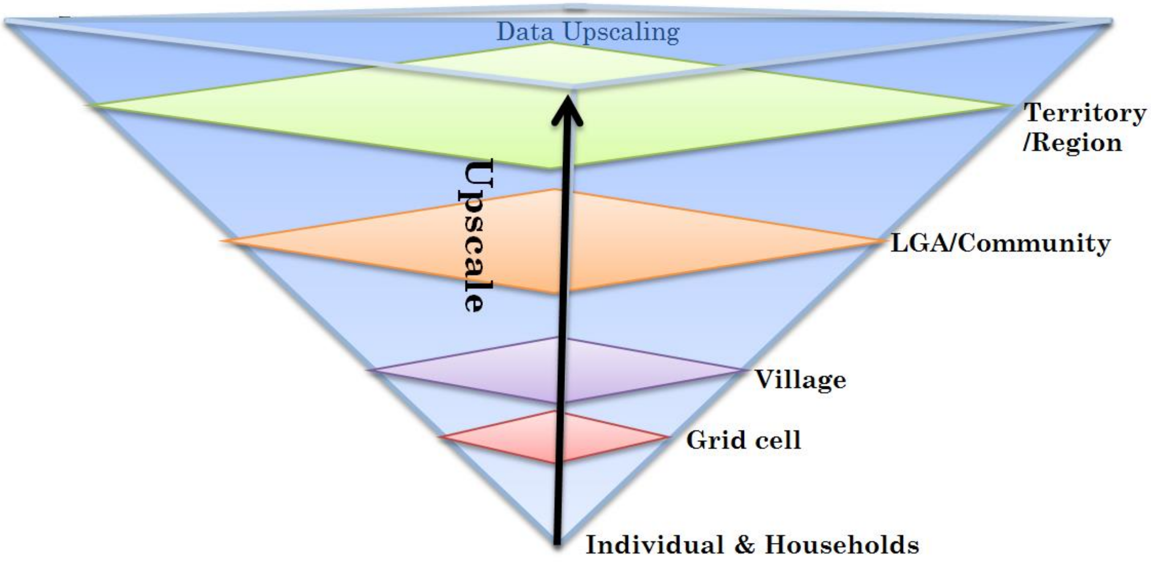


Figure 6.24: Examples of different spatial scales important for the spatially explicit modeling.

This work applied spatial statistical techniques to the assessment of NRBCs. Exploratory Spatial Data Analysis (ESDA), global and local spatial autocorrelation are used to validate the SEFLAME-CM. In this context, the Moran's *I* is used to compare the final results of SEFLAME-CM and the SMCE-CM (see Section 6.5.3.2).

The ESDA, the global and the local Moran's *I are* used as measures for describing the overall spatial autocorrelation across geographic scale (Yang, 2010). These are briefly described below:

(I) ESDA: ESDA is a collection of techniques to describe and visualize spatial distributions, detecting patterns of spatial association, clusters or hot spots, and other forms of spatial heterogeneity (Anselin, 1999b, Le Gallo and Ertur, 2003). Spatial data analysis and social sciences have helped to develop the ESDA, especially among those researches that require data disaggregation to a local scale using GIS (Goodchild *et al.*, 1999, Goodchild *et al.*, 2000, Goodchild and Janelle, 2010, Logan *et al.*, 2010). Essentially, **in spatial clustering measurements, indices can be derived that define the spatial association and relationships in the interactions of the drivers of conflicts.** The test statistic quantifies a relevant aspect of spatial pattern and develops indices based on (e.g. Moran's I, Geary's C, Local Indicators of Spatial Association (LISA), and other spatial clustering metrics, etc.) (Anselin, 1999b, Jacquez, 2008, Anselin, 2013). ESDA methods generally have two main groups of assessments used in spatial relationships. These are the measures of global and local spatial autocorrelation (Le Gallo and Ertur, 2003).

(II) Spatial Autocorrelation (the Global and Local Moran's *I*): Spatial autocorrelation has been defined as the coincidence of value similarity with locational similarity (Anselin 2000). Positive spatial autocorrelation implies high or low values of a random variable in space **while negative spatial autocorrelation occurs when geographical areas tend to be surrounded by neighbors with very dissimilar values.**

In the measurement of spatial autocorrelation, Moran's *I* statistic is the most widely known measures of spatial clustering and it is important for spatial pattern analysis and provides a weighted correlation coefficient used to detect departures from spatial randomness (Getis, 1995, Getis, 2010).

The global cluster statistics such as Moran's *I* is sensitive to spatial clustering or departures from the null hypothesis, that occur anywhere in the study area (Moran, 1950). While global statistics can identify whether the spatial structure (e.g. clustering, autocorrelation, uniformity) exists, they do not identify where the clusters are, nor do they quantify how spatial dependency varies from one place to another. Hence global statistics do not encourage the appreciation of the regional structure of spatial autocorrelation (Le Gallo and Ertur, 2003, Jacquez, 2008).

The local spatial autocorrelation has been developed by spatial statisticians to complement the global spatial autocorrelation (Khatiwada, 2014). The analysis of local spatial autocorrelation is carried out using the Moran's *I* scatterplot and the LISA.

- The use of the local Moran's *I* scatterplot (Anselin, 1993). The local Moran's *I* scatterplot is used to visualize local spatial instability. In the local Moran's *I* scatter plot, the x-axis is the value of *I* (the CVL index) while the y-axis is the spatial lag. The spatial lag is the weighted average of neighboring values (Khatiwada, 2014).
- The use of LISA (Anselin, 1995). LISA is used to test the hypothesis of random distribution by comparing the values of each specific location with the values in the neighboring locations. See *Equations 6.10 and 6.11* for the mathematical relations of the global and the local Moran's *I* respectively (Yang, 2010).

$$\text{Moran's } I = \frac{N\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{(\sum_i \sum_j w_{ij}) \sum_i (x_i - \bar{x})^2} \quad \textit{(Equation 6.10)}$$

where

I	=	*the Morans index, ranging from 1 for negative spatial correlation to +1 for positive spatial autocorrelation*
N	=	*the total number of areas*
W_{ij}	=	*spatial weights*
x_i	=	*attribute values for areas i*
x_j	=	*attribute values for areas j*

$$I_j = \frac{x_i - \bar{x}}{S_x^2} \sum_j \left[w_{ij}\left(x_j - \bar{x}\right) \right] \quad \textit{(Equation 6.11)}$$

where

$S_x^2 \quad = \quad \sum_j (x_i - \bar{x})^2/n$, *this is variance.*

Note that the summation of j does not include the area I itself, i.e. j ≠ I (Khatiwada, 2014). Other notations are the same as in the above equation.

The interpretation of the local Moran's *I* is similar to that of the product moment correlation coefficient. In this regard, +1 indicates a strong positive spatial autocorrelation (i.e., clustering of similar values), 0 indicates random spatial ordering, while -1 indicates strong negative spatial autocorrelation (i.e., a checkerboard pattern) *(Equation 6.11).*

In the comparing SEFLAME-CM and SMCE-CM results, the hypothesis is that a better model will have a stronger positive relationship between the x and y variables given the same input variables. The actors' risk perception and the knowledge over conflicts differ in space and these produce different responses over space as well. This idea that human perception can vary intrinsically over space is consistent with post-modernist beliefs on the importance of place and locality as frames for understanding such behavior. This is the basis of *spatial turn,* where GIS and social science are integrated (Goodchild *et al.*, 2000). The identification of these local variations is therefore seen as a useful pre-cursor to more intensive studies which would attempt to highlight why such differences occur (Fotheringham, 2000).

The Local Moran's *I,* therefore, provides four types of spatial pattern grouped under the positive and negative correlation (see Table 6.13). See Section 6.5.3.2.3 for the spatial statistics results.

Table 6.13: Local Moran's *I*: four categories of spatial pattern analysis.

Correlations	Four Categories of Moran's I
Positive correlation	High-High (HH)
	Low-Low (LL)
Negative correlation	Low-high (LH)
	High-Low(HL)

- The positive correlation: High-high (HH) refers to observations with high value surrounded by observations with high values. Low-Low (LL) refers to observations with low values surrounded by those with low values
- The negative correlation. This also indicates two conditions: Low-High (LH) refers to an observation with low value surrounded by observations with high values, and High-Low (HL) refers to an observation with high value surrounded by low values. These patterns can be illustrated by a local Moran's *I* cluster map (Anselin, 1995).

According to Yang (2010), the HH and HL can be taken as hot spots while the LL and LH can be taken as cold spots. As regards the pattern of the NRBCs, the Local Moran's *I,* is mapped thus:

- Hot spots: These are concentration points of NRBCs. They are areas made up of grids with high values and surrounded by conflict grids of low or high values. They are made up of HH and the HL.
- Cold spots: These are areas where the grids have low values and are surrounded by either low values or high values. They are made up of LL and LH.

- Randomness: These are grids with values that are not significant and belong to none of the four categories outlined above (HH, LL, LH, and HL).

6.5.3.1.1 Estimating the Spatially Explicitly CVL Index with Grid Cells as Unit of Analysis using SEFLAME-CM

The maps of all the input parameters of SEFLAME-CM were produced (see Section 5.2.4), See Appendix A.12.14 to A.12.19 for the GIS input parameters. The inputs of the SEFLAME-CM are GIS layers processed at 200 X $200m^2$ vector grid cells. An estimate of the spatial CVL Index is made for all the vulnerability dimensions against the conflict typologies (Section 6.5.3). But in the temporal and the dimensional validation reported earlier in Sections 6.5.1 and 6.5.2, all the conflict datasets are without the conflict typologies. In this section of the theses, a similar set of fuzzy rules are developed to differentiate the conflict typologies: the rebel-based and the territorial-based conflicts (see Figure 5.18 for the simplified hierarchical structure of the nested multi-method model with the integration of multiple drivers in the design of the SEFLAME-CM). The spatial estimation of the vulnerability of NRBCs presented here is performed as a 'two-fold' approach:

Firstly, FLAME-CM is integrated into GIS. Here the vulnerability likeliness of communities experiencing NRBCs is simulated and visualized with GIS. This requires three sub-stage procedures:

- Transferring the validated parameters/variables based on FLAME-CM (see Section 6.5.2) into a spatial format.
- Simulating the three vulnerability dimensions of conflict drivers versus the conflict typologies using *Equations 5. 11 to 5.14* as presented in Section 5.2.3.7. See also layer 3 in Figure 5.18.
- Creating the final spatial CVL Index by combining the conflict typologies derived (see Equation 5.16) as a result of the second-sub stage. See layer 4 in Figure 5.18. The spatially explicit CVL indices are used to determine the extent to which the spatial conditions explain the conflict likeliness, under the coastal and the non-coastal territories.

The process of deriving the spatially explicit CVL Index using SEFLAME-CM involves four different levels of analysis like that used under the FLAME-CM (see Figure 5.18):

- Fuzzification and aggregation of 36 parameters into 12 variables (layer 1)
- Fuzzification and aggregation of 12 variables into 3 dimensions (layer 2)
- Fuzzification and aggregation of 3 dimensions into 2 typologies of conflicts (layer3)
- Developing a final spatially explicit CVL Index (see Figure 5.19 for implementation structure) (layer 4)

Secondly, the CVL index developed with SEFLAME-CM is validated with SMCE using spatial statistics.

The spatially explicit validation used as a starting point the LULC maps of the study area which was produced from satellite image in 1986 (prepared for each of the territories during field work). This covers the two main territories considered: Ogoni and the Okrika territories (Figure 6.25).

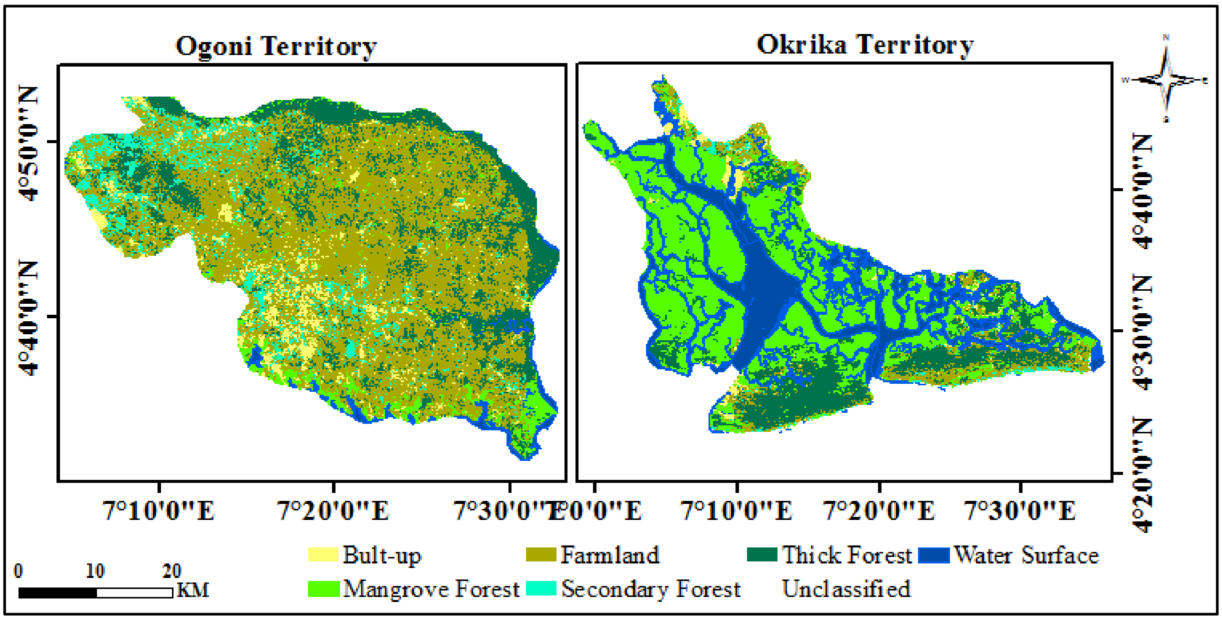


Figure 6.25: LULC map of the study area used as a starting point for developing the disaggregated spatially explicit CVL Index.

6.5.3.1.2 Developing Grid Cells as Unit of Analysis for the Spatially Explicit CVL Index

The grid cells are used as the unit of identifying the spatial vulnerability likeliness of NRBCs. The objective is to detect conflict hot spots or cold spots. Conflict clusters can generally be of any size, located anywhere in the study region (Kulldorff and Nagarwalla, 1995, Schutte and Weidmann, 2011). Although visual analyses (mapped evidence) strengthened by exploratory analyses are mostly sufficient for cluster analysis. But the formal testing of certain hypotheses or the estimation of relationships, for example, the environmental covariates and the spatial relationship with intervening variables require quantitative modeling. This is able to capture the spatial uncertainties in conflict likeliness. This is where the role of GIS became relevant.
for the transfer of FLAME-CM to SEFLAME-CM.

With the square grid dimensions of 200 X 200m², the full data set comprises of 63,452 polygon squares. Grid squares are assigned to the village in which they fall. All the individual parameters under each of the three vulnerability dimensions are first visualized using the grid cells. Upscaling the grid cell is necessary in order to answer the 'where' and 'why' questions in spatial conflict clustering or diffusion (De Juan, 2012). The grids are upscaled to the territories of Ogoni and Okrika in the study area. Figure 6.26 shows a sample of the vector grids cells.

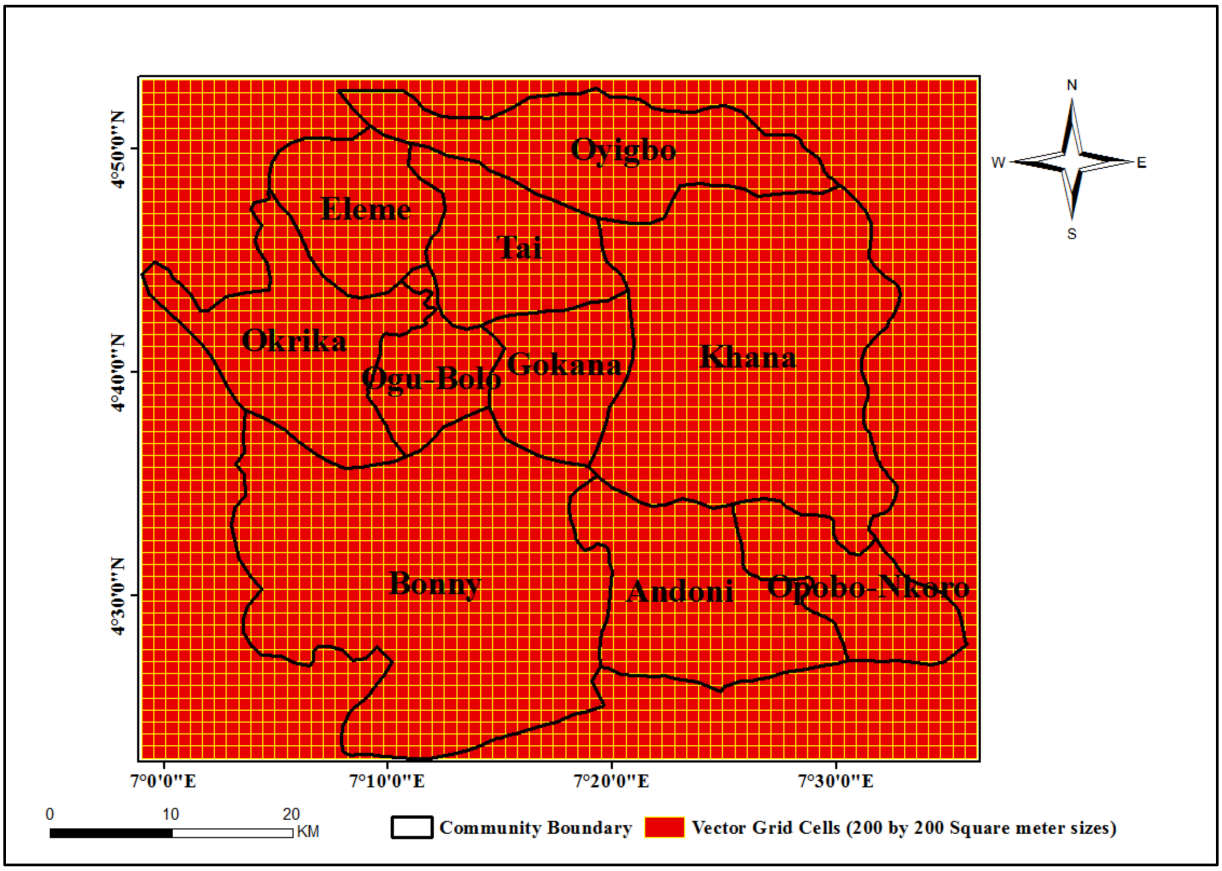


Figure 6.26: Sample conflict grid cells.

6.5.3.2 The Spatial Validation Results: Descriptive and Spatial Statistics

This section presents results of the spatial conflict vulnerability assessment at a local scale using ELOBCONDATA as an improved data of the FUZZYCONDATA. The disaggregated conflict research requires analysis to address how the environment, economy, and social institutions and politics are spatially and temporally varied, and how these create different levels of conflicts (Raleigh, 2011).

In the presented results (see Section 6.5.3.2.1) it is worth noting that the use of the percentages is to quantify the areas of grid cells that fall under any of the CVL Indices: *unlikely, likely, very likely, and most likely* categories. Percentages are derived under each of the conflict vulnerability dimensions i.e. the "external" side (environmental drivers dimension), and the "internal" side (i.e. the socio-economic and political drivers dimension) of NRBCs.

6.5.3.2.1 Descriptive Statistics and Spatially Explicit Validation

The Environmental Drivers Dimension vs. Conflict Typologies: Figure 6.27 (top and down) shows maps of the environmental drivers vs. conflict typologies in the 1986-2000 and 2000-2016 periods, while Figure 6.28 (up and down) shows the descriptive statistics of the spatial CVL Index for environmental drivers of the rebel and territorial conflicts for the same two periods investigated. The descriptive statistics specifically show the CVL Index percentages under the *unlikely, likely, very likely and most likely* categories.

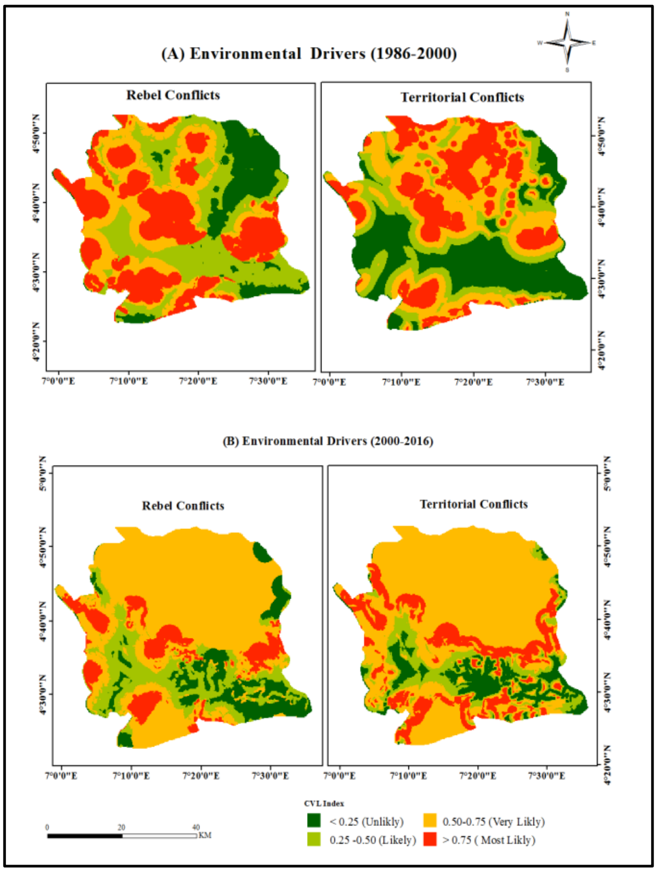


Figure 6.27: CVL Index maps: environmental drivers vs. conflict typologies (1986-2000) and (2000-2016).

As shown in Figure 6.27 (A and B), between 1986-2000, the CVL Index, under the environment vs. rebel conflicts, the *most likely* spatial CVL Index has 31% of the grid cells, while in the case of the environment vs. territorial based conflicts the spatial CVL Index, *most likely* is 25%. However, in 2000-2016, but still under the *most likely* category, the spatial CVL Index of environment vs. rebel conflicts and environment vs. territorial conflicts reduced to 11% and 16% of the grid cells respectively. The situation where the spatial CVL index for *most likely* reduced between 1986-2000 and 2000-2016 reveals that even though there is an indication of a reduction in the intensities of NRBCs in a locality, such reduction may not have been as a result of the actual conflict reduction but it may be due to internal processes such as diffusion of conflicts over space and time (e.g. migration) (Raleigh, 2011).

In 1986-2000, 23% of the grid cells fall under the spatial CVL Index of *very likely* in the environment vs. rebel conflicts comparison, while 30% of the grid cells fall under *very likely* in the environment vs. territorial conflicts category. This indicates that territorial conflicts under the environment dimension are more prevalent than the rebel-based type of conflicts. However, during the 2000-2016 time period, the spatial CVL Index clearly increased. In this case, 63% and 60% of the grid cells are under the *very likely* category for the environment vs. rebel conflicts and environment vs. territorial conflicts respectively.

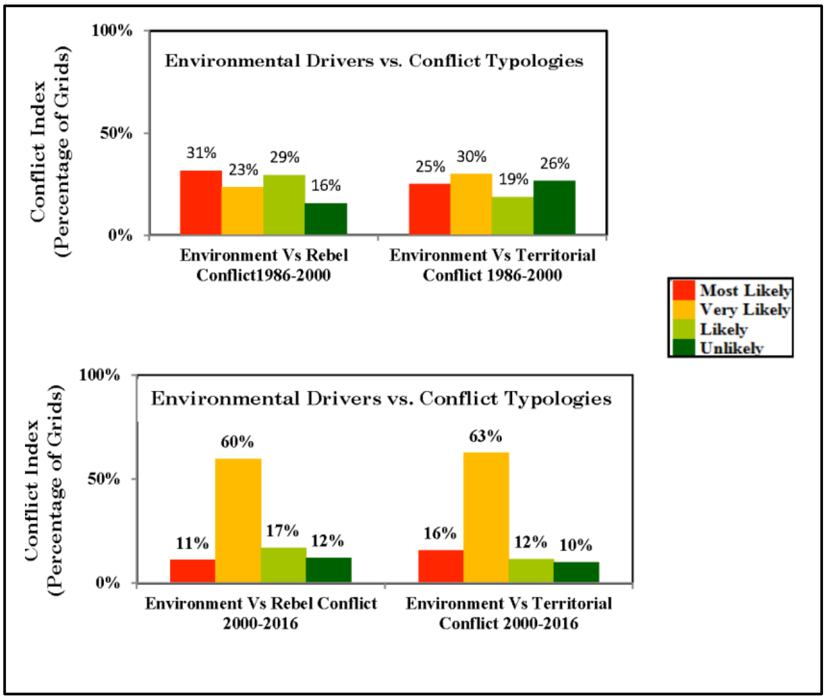


Figure 6.28: Descriptive statistics of environmental drivers vs. conflict typologies. 1986-2000 (top) and 2000-2016 (down).

The Socio-economic Drivers Dimension vs. Conflict Typologies: Figu down) shows the spatial CVL Index for the socio-economic dimension of rebel and territorial conflicts in the 1986-2000 and 2000-2016 periods while Figure 6.30 (top and down) shows the descriptive statistics of the map results. In 1986-2000, the spatial CVL Index for the socio-economic vs. rebel conflicts is *most likely* (39%), and for the socio-economic vs. territorial-based conflicts, under the *most likely* it is 58%. In 2000-2016, the spatial CVL Indices for socio-economic vs. rebel-based conflicts and for the socio-economic vs. territorial-based conflicts are 25% under the *most likely* and 48% under the same *most likely* category respectively. On the other hand, the spatial CVL Indices for the socio-economic vs. rebel-based conflicts and the socio-economic vs. territorial-based conflicts are under the *very likely* (0%) and *very likely* (18%) respectively. From the results presented under the socio-economic drivers of conflicts, it can be clearly seen that, despite having the same spatial CVL Index category of *very likely*, the occurrence of the territorial-based conflicts seems to be much more than that of the rebel-based conflicts.

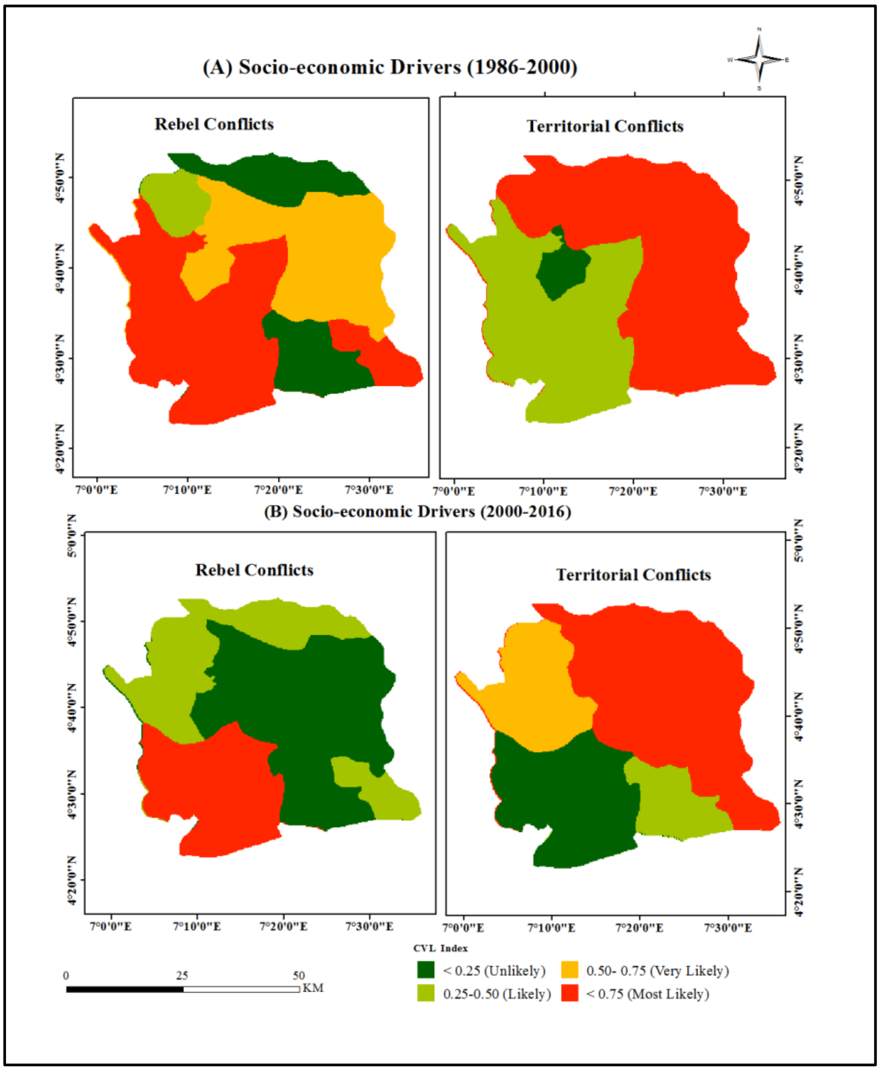


Figure 6.29: CVL Index maps: socio-economic drivers vs. conflict typologies (1986-2000) and (2000-2016).

As seen in both Figures 6.29 and 6.30, between the 1986-2000 and 2000-2016, while the rebel-based conflicts as associated with socio-economic drivers seem to have reduced upland, that of territorial-based conflicts have remained somewhat unchanged.

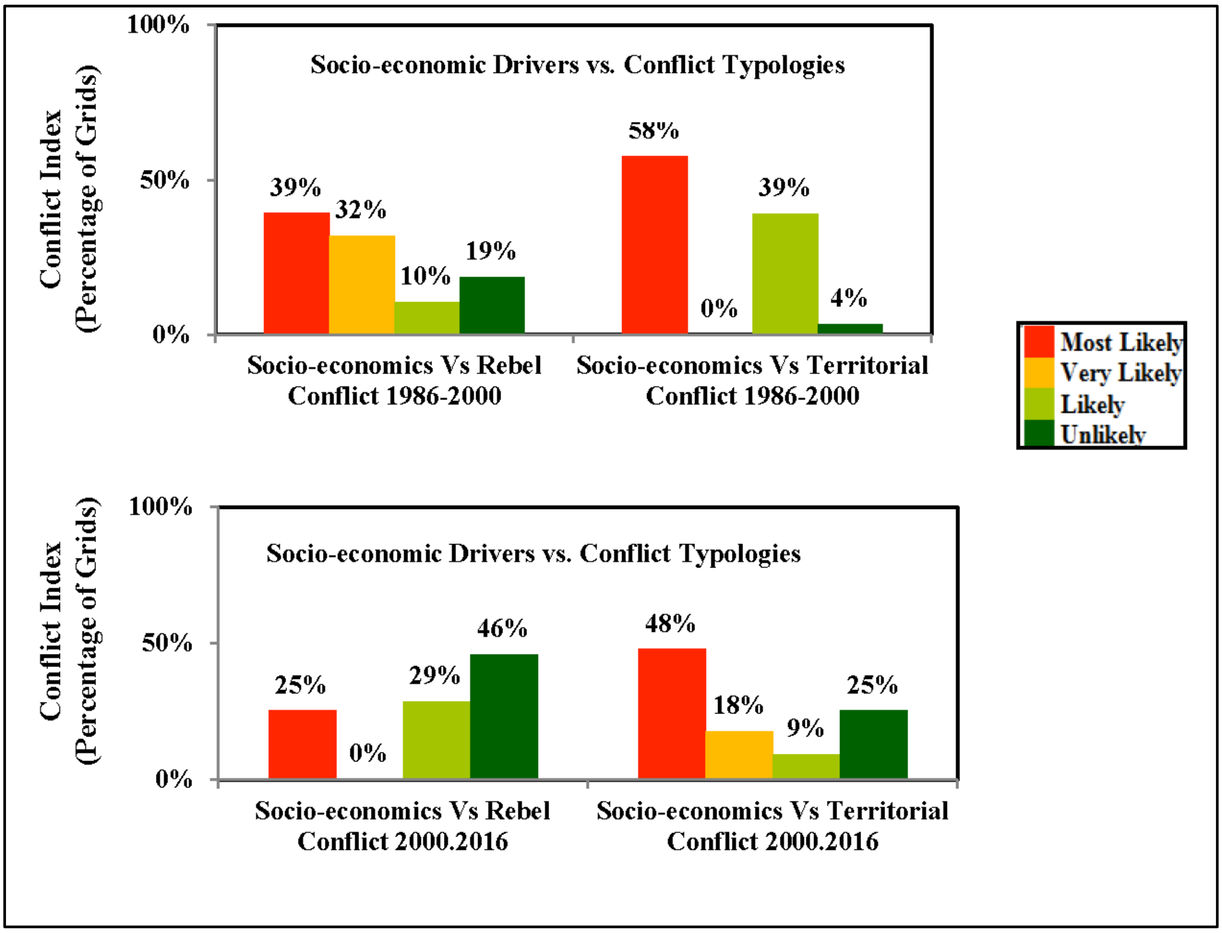


Figure 6.30: Descriptive statistics of the socio-economic drivers vs. conflic
1986-2000 (top) and 2000-2016 (down).

The Political Drivers Dimension vs. Conflict Typologies: Figure 6.3 s that in 1986-2000 the spatial CVL Indices of the political dimension vs. the rebel-based conflicts is *most likely* (25%), while that of political dimension vs. the territorial-based conflicts is *most likely* (33%) respectively.

On the other hands in 2000-2016, the indices of the political dimension vs. rebel-based conflicts and political dimension vs. territorial-based conflicts are both *most likely* but with 25% and 5% respectively. The reduction of the territorial-based-conflicts under the political drivers from 33% to 5 % between the two-year periods is critical. As seen in the map the 5 % is mainly concentrated around the coast, specifically within the area of the Opobo community. The significance is that politics is gradually becoming unimportant in the way the local actors understand the territorial-based conflict.

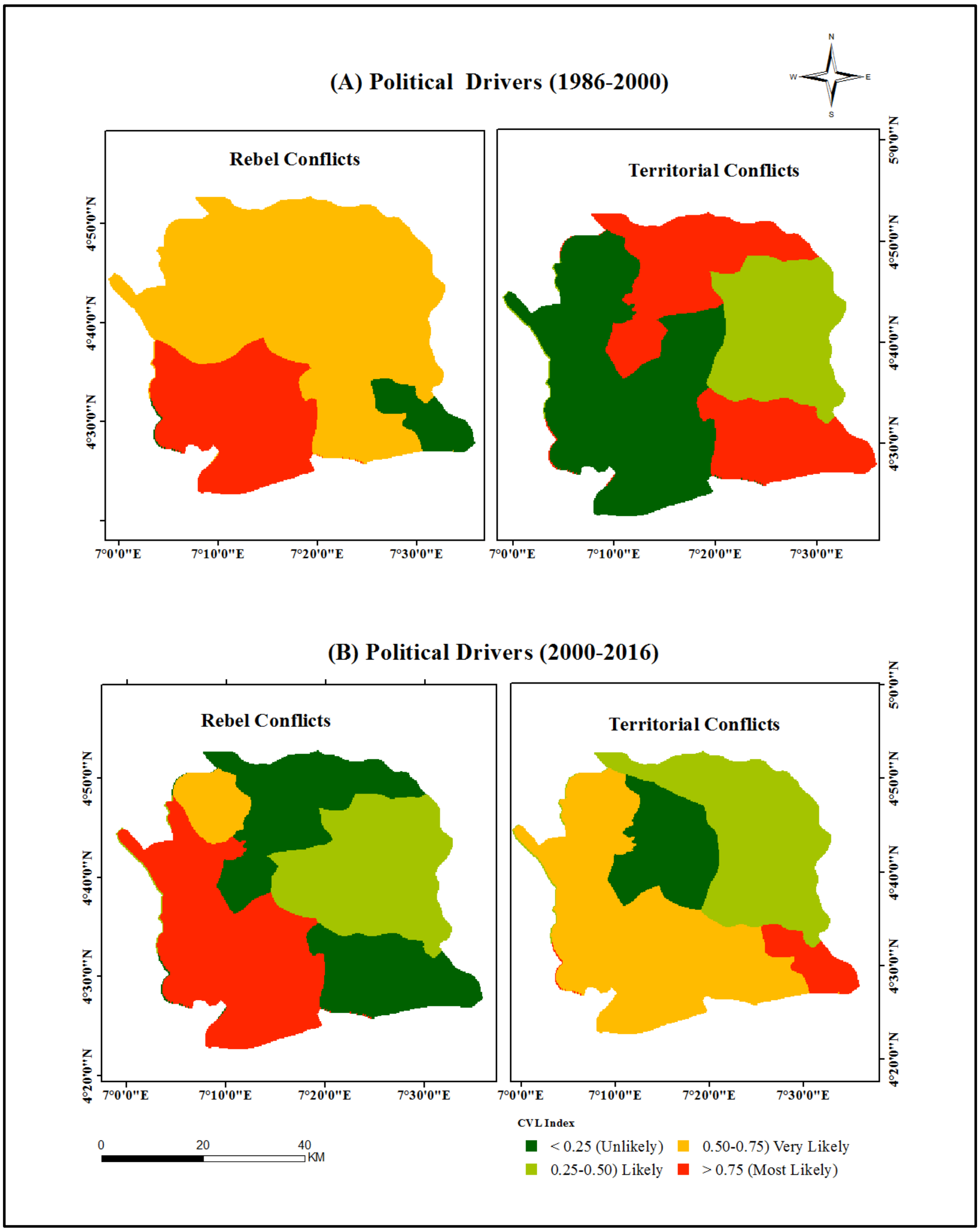


Figure 6.31: CVL Index maps: political drivers vs. conflict typologies (1986-2000) and (2000-2016).

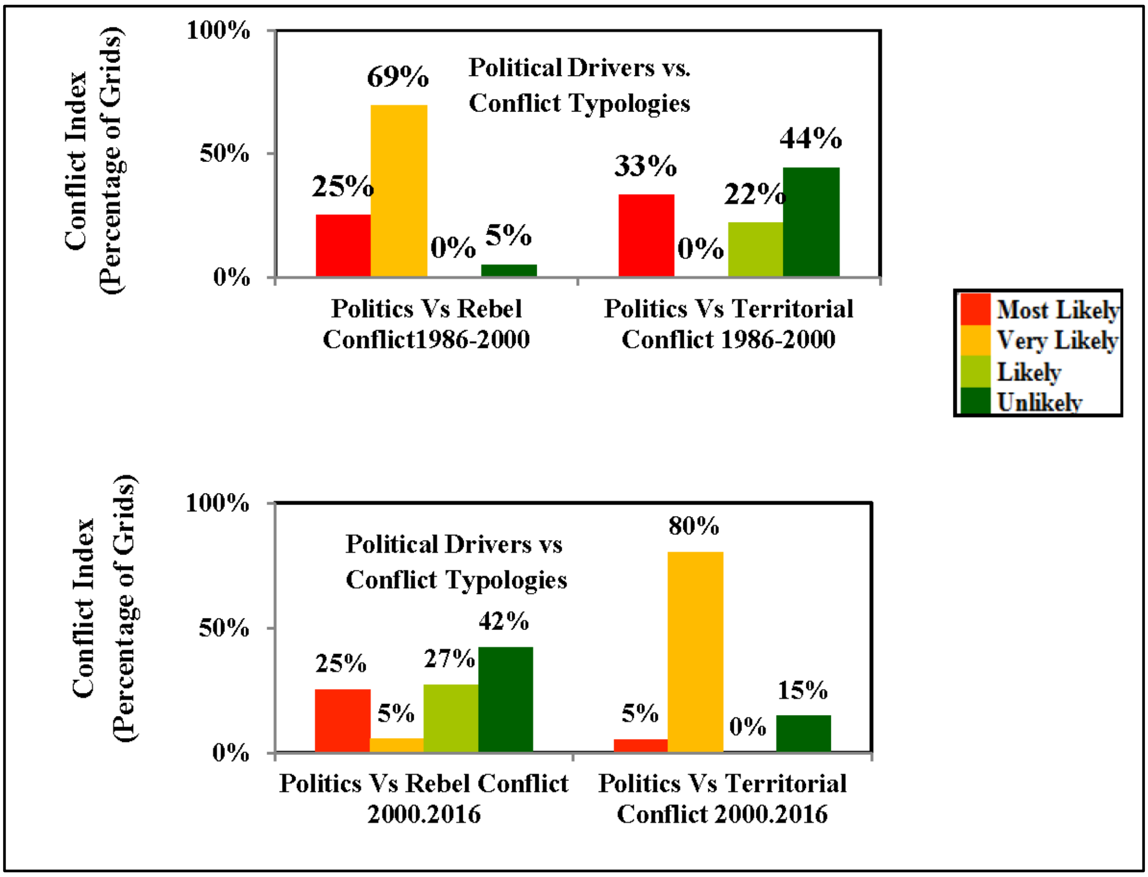


Figure 6.32: Descriptive statistics of the political drivers vs. conflict typology,1986-2000 (up) and 2000-2016 (down).

The above results of the conflict drivers vs. conflict typologies have key implications:

Firstly, the environment vs. conflict typology results shows that the perception of the environment as a driver of territorial-based conflicts such as land use conflicts and conflicts over renewable resources such as mangrove lands in various communities increased over time. The people's awareness of the environment as a possible trigger of the conflicts that are directly related to resources seemed to have increased over time. Although the link between environmental change and vulnerability of communities to NRBCs is clearly seen, it should not only be interpreted as a function of environmental degradation but in consideration with other interacting factors such as societal inequalities,

Secondly, regarding the socio-economic vs. conflict typologies result, it is revealed as mentioned in Section 6.5.2 that there is a decreasing association of conflicts over socio-economic issues in the studied communities. The implication of the result, therefore, is that the association of conflicts with socio-economic characteristics of communities is mainly through the environmentally induced economic hardships. The effects of environmental degradation on the socio-economic characteristics of the people often take root from the environmental impacts of oil extraction. Such economic deprivations and hardships could lead to migration and likely lead to violent conflicts particularly when people compete over scarce resources.

Thirdly, regarding the political drivers dimension, the result has two main implications. First, there is a reduction of the impact of political issues as drivers of resource conflicts. Second, there is a significant reduction of conflicts inland and an increase of conflicts towards the coastal areas. In many developing countries, in Africa, all land belongs to the government. For example, in Nigeria, the Land Use Act of 1979 stipulates that the government owes every land and it can be allocated to oil companies for use in the perceived interest of the government for revenue. Such new resource governance system overrides the local traditional and customary land ownership systems. Such law is against the customs of the local people. For example, in Ogoni land, because of the scarcity of resources, such as firewood from mangrove due to oil pollution, there is a problem of forced migration to the coast for firewood and farming on the perceived fertile lands. This increases the social tension of the territory and the increase of territorial conflicts mainly around the coastal area. As noted in Cuvelier *et al.* (2013), a newly created system of local governance in fragile or conflict-affected areas usually impacts on people's access to, and control over, local resources and thereby enhancing political tension and violent conflicts.

6.5.3.2.2 CVL Index Maps: Comparison across the Ogoni and Okrika Territories

This section presents the results of the final conflict indices for each of the typologies based on the two main territories of the study: Inland areas (Ogoni territory) and the coastal areas (Okrika territory). Figure 6.33 shows a map of the comparison of the spatial CVL Index for the typologies of NRBCs studied: the rebel-based conflicts and the territorial-based conflicts and all the conflict categories. Figure 6.34 shows the descriptive statistics of the map.

- **The Rebel-based Conflicts in Ogoni:** Under the Rebel-conflicts typology, the spatial CVL Index of *most likely* is (0%) in both the 1986-2000 and 2000-2016 year periods, but the index decreased from *very likely* (12%) in 1986-2000 to *very likely* (55%) in 2000-2016. As expected, the index, *unlikely* reduced from (55% in 1986-2000 to 33% in 2000-2016.
- **The Territorial-based Conflicts in Ogoni**: The dynamics of the conflicts are most evident in the cases of the territorial-based conflicts. From 1986-2000 for instance, the spatial CVL Index of *most likely* is (0%), but this increased to (33%) in 2000-2016, while the spatial CVL Index for *very likely* increased from (39%) to (47%) in 1986-2000 and 2000-2016 respectively. When compared to the rebel-based conflicts in Ogoni therefore, the increase of the spatial CVL Index under the *most likely* for the territorial-based conflicts clearly shows that there are more grievances associated with landed resources and the claiming of territories than rebel-based uprising and youth belligerence
- **All Conflicts in Ogoni:** The spatial CVL Index is *most likely* (3%) and (0%) in 1986-2000 and 2000-2016 respectively. Conflicts seem to have reduced in the latter years in the inland areas (Ogoni territory). There seems to be a significant diffusion of conflicts from inland areas towards coastal areas over time. This reduction of conflicts and diffusion to certain geographic area could not be unraveled by earlier studies of NRBCs that mainly examined the onset and duration of wars and resource conflicts over time (Collier and Hoeffler, 2004), except when conflicts are accounted for or measured at the sub-national scale (Buhaug and Lujala, 2005, Buhaug *et al.*, 2009).

- **The Rebel-based Conflicts in Okrika:** In Okrika, under the rebel-conflicts typology, the spatial CVL Index *most likely* is (49%) in the 1986-2000 period. This increased to (65%) in the 2000-2016 period. This increase also reflected in the reduction of *very likely and likely* categories. In 1986-2000 and the 2000-2016 year periods, spatial CVL Index under *very likely* reduced from (17%) to (1 %), while that of *likely* reduced from (30%) to (0%) within the two reference periods respectively.
- **The Territorial Conflicts in Okrika:** In 1986-2000 the spatial CVL for *most likely* is (33%) and this slightly increased to (34%) in 2000-2016. When compared with the Ogoni territory (Inland), it clearly shows that the coastland seemed to be more attractive resource conflicts that are associated with telluric resources (Korf, 2011), thereby giving a strong indication of increased territorial conflicts in the future and mainly around the coastal area.
- **All Conflicts in Okrika:** The spatial CVL Index under the *most likely* category, increased from (16%) in 1986-2000 to (30%) in 2000-2016, while the spatial CVL Index *very likely* increased from (48%) in 1986-2000 to (60%) in 2000-2016 respectively. As pointed out earlier, when this is compared with that of the inland territory (Ogoni), results show that conflict seems to have diffused from the inland territory but clustered towards the coastal area.

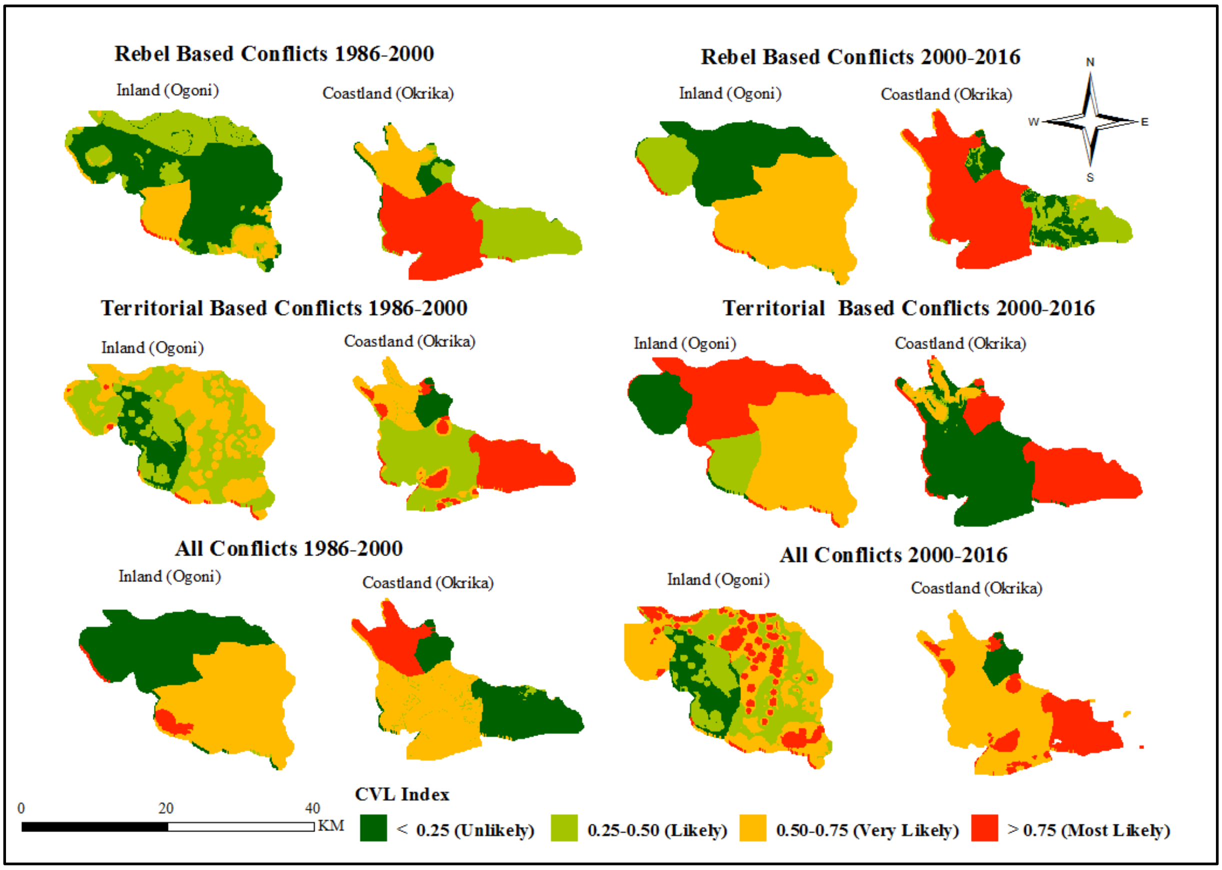


Figure 6.33: Map of the typologies of NRBCs in the inland (Ogoni) and coast (Okrika) territories (1986-2000) and (2000-2016)

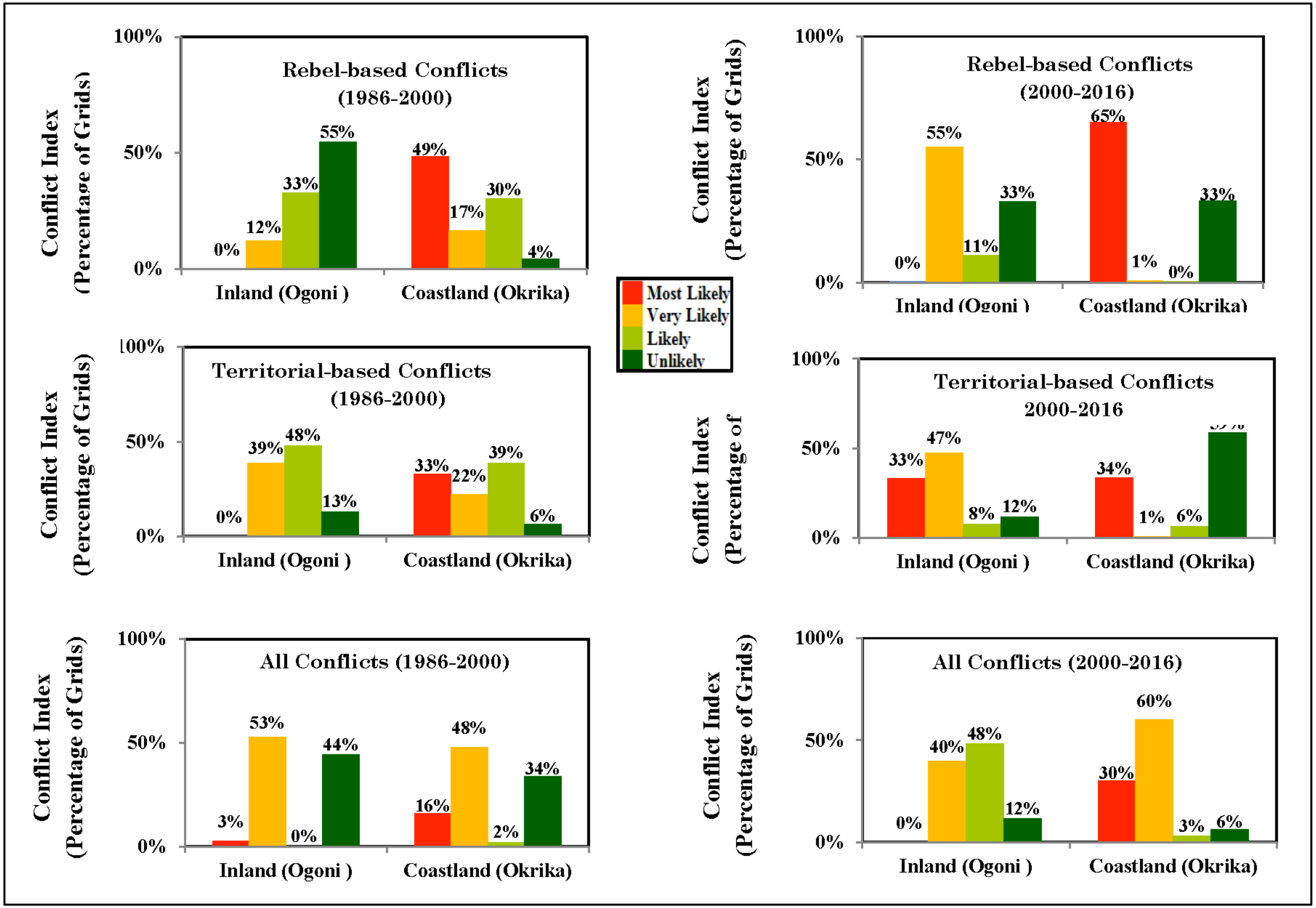


Figure 6.34: Descriptive statistics of natural resource based conflicts for the inland (Ogoni) and coastal (Okrika)

6.5.3.2.3 Spatial Statistics: SEFLAME-CM vs. SMCE-CM

Figure 6.35 and 6.36 show the final conflict maps using both SEFLAME-CM and SMCE-CM for the 1986-2000 and 2000-2016 periods.

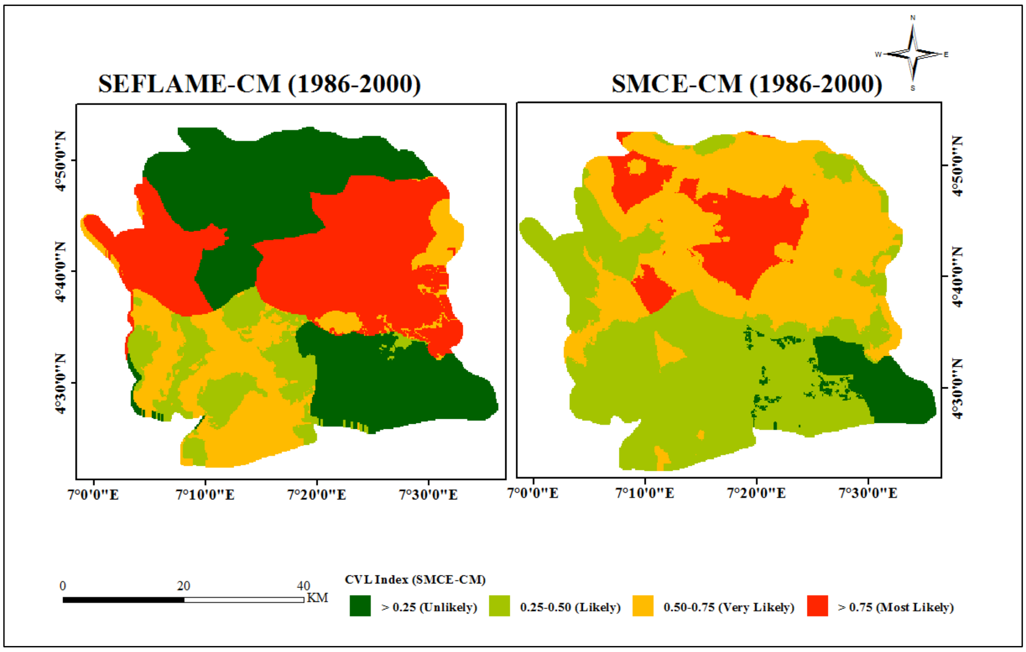


Figure 6.35: Final CVL Index maps for the SEFLAME-CM vs. SMCE-CM (1986-2000).

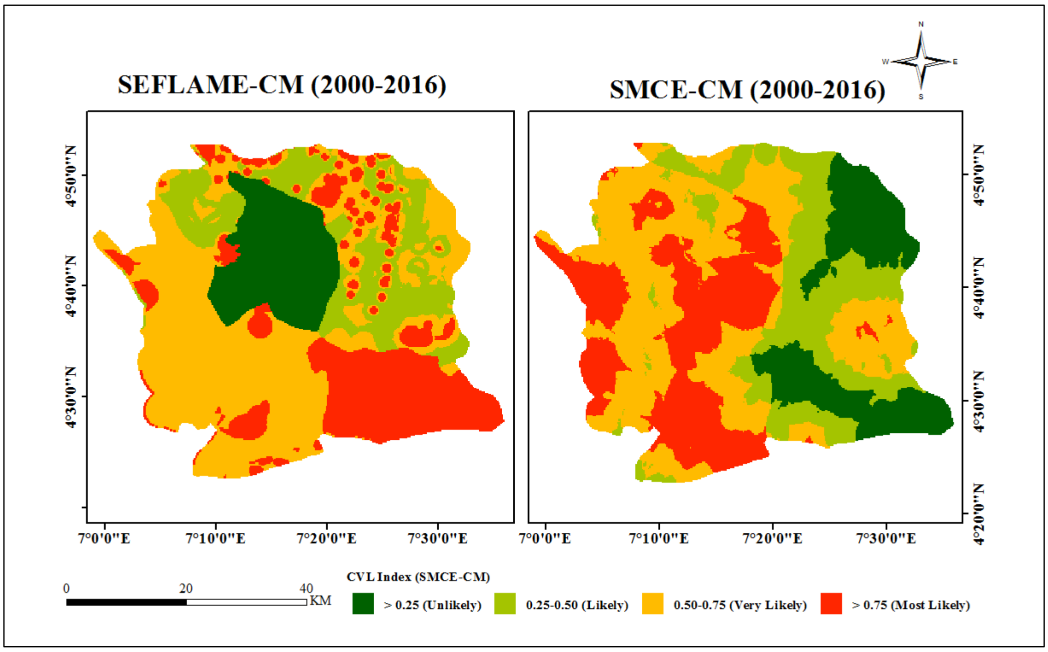


Figure 6.36: Final CVL Index maps for the SEFLAME-CM vs. SMCE-CM (2000-2016).

It is clearly seen from the Figures 6.35 and 6.36 that NRBCs diffused from the Inland areas (Ogoni territories) and clustered towards the coastal areas (Okrika territories).

Moran's I result

Figures 6.37 and 6.38 show the Moran's *I* scatter plots for the overall conflicts in 1986-2000 and 2000-2016. It shows the significant value of 0.99 and 0.98 for both the SEFLAME-CM and SMCE, respectively, indicating the presence of significant spatial autocorrelation in both models. In the Moran's *I* scatter plots, the horizontal axis shows the CVL Index as generated in the simulation using the SEFLAME-CM and the SMCE-CM, while the y-axis is the spatial lag (the weighted average of neighboring values) (Khatiwada, 2014).

As mentioned earlier (see Section 6.5.3.1), the Moran's *I* scatter plot has four different component parts:

- Upper right quadrant. These are communities with above-average index termed "high–high" communities. These are communities having high average values but neighbors with high average values
- Lower left quadrant. These are communities with low average values and neighbors with low average values (low–low).
- Lower right quadrant. These are communities with higher average values surrounded by locations with lower average values (high–low).
- Upper left quadrant. Similar to the lower right quadrant, the upper left quadrant is the areas with low average values but surrounded by areas with higher average values (low–high) (Voss *et al.*, 2006).

The local Moran's *I* map shows how higher and lower conflict likely communities are grouped together and the diffusion of the hot spots and cold spots towards the coastal communities (see Appendix A.12.22 and A.12.23). The results of both SEFLAME-CM and SMCE-CM suggest that spatial explicit CVL Indices are not randomly distributed but rather follow a systematic pattern (Voss *et al.*, 2006, Rupasingha and Goetz, 2007). In 1986-2000, the local Morans '*I* shows that the inland communities such as Okrika and Khana dominate the areas of hot spots in both the SFLAME-CM and the SMCE-CM (see Appendix A.12.22). In contrast, in 2000-2016, the hot spot shifted coastward to communities such as Bonny, Finima and Opobo-Nkoro and Andoni (SEFLAME-CM) (see Appendix A.12.23).

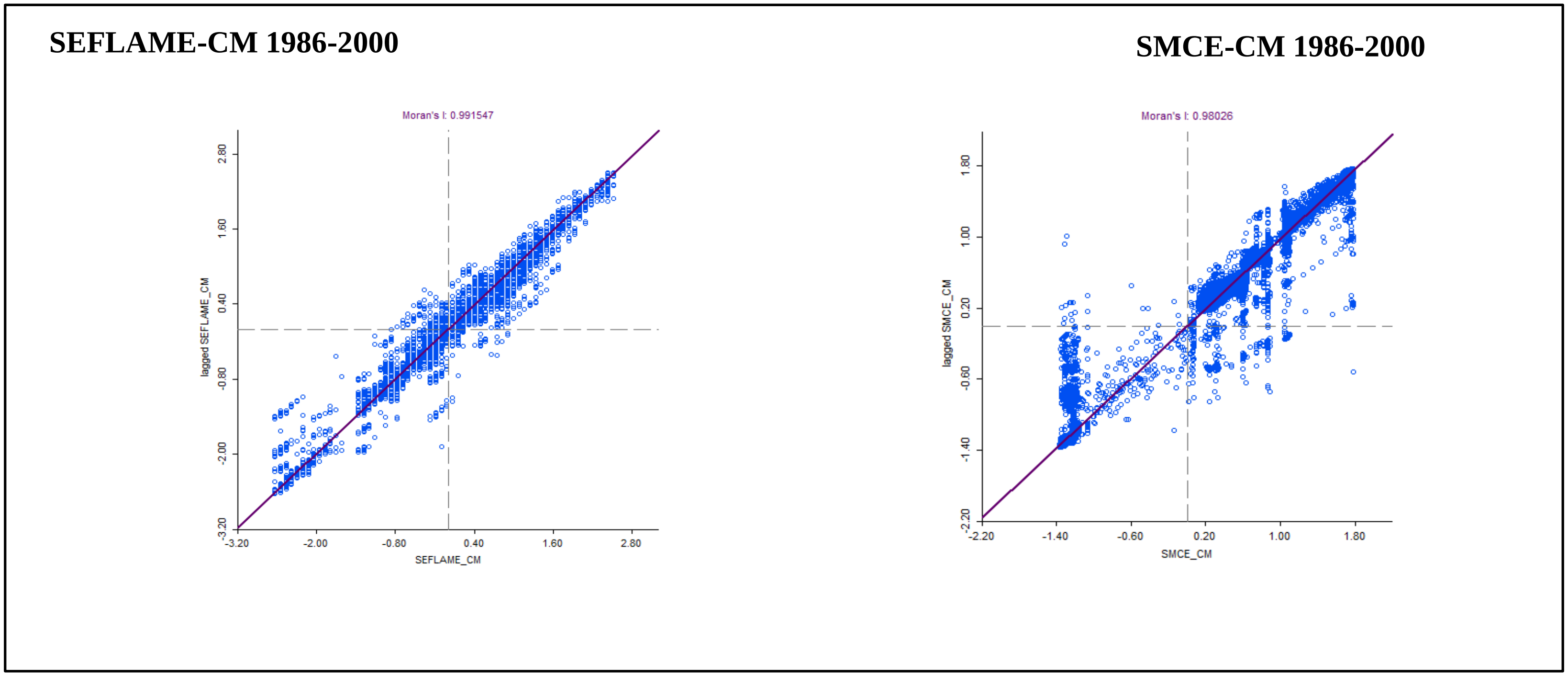


Figure 6.37: SEFLAME-CM (Left) vs SMCE–CM (right) for the CVL Index-1986-200. Moran's scatter plot with the *I* value displayed at the top.

Note: The x-axis is the value of *I* and the y-axis is the spatial lag (the weighted average of neighboring values). The slope of the line is Moran's *I*).

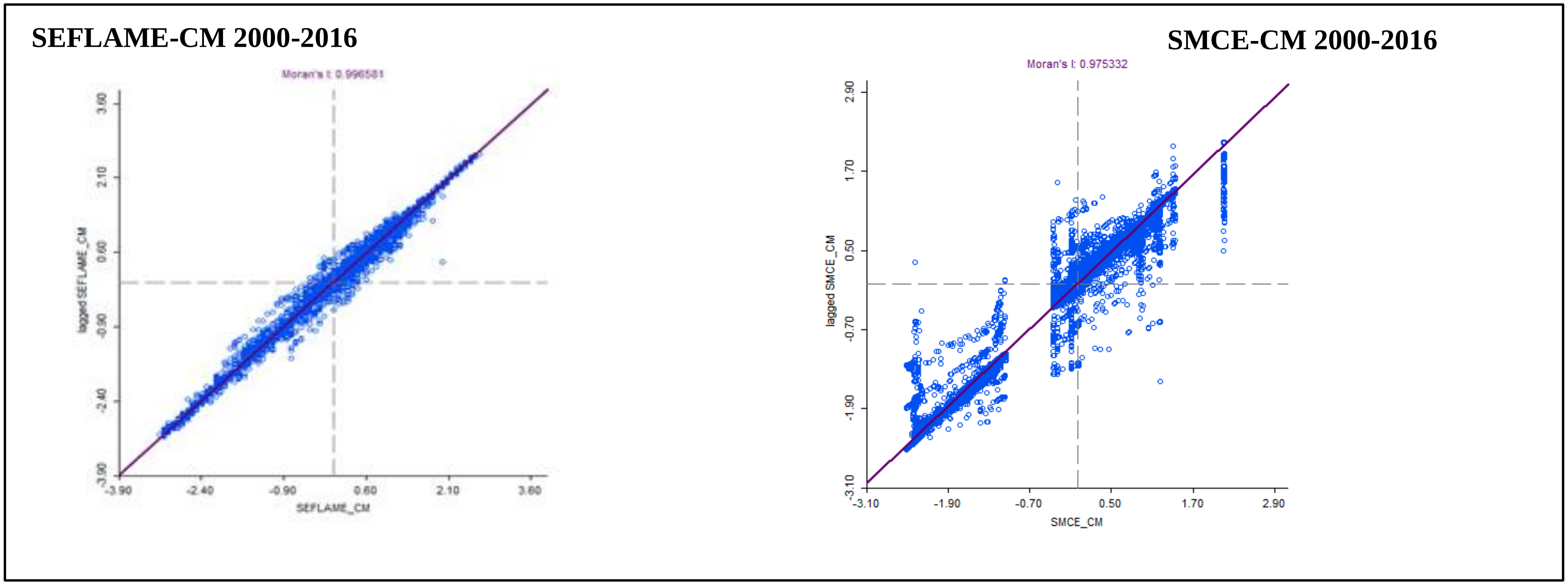


Figure 6.38: SEFLAME-CM (left) vs. SMCE–CM (right) for the CVL Index 2000-2016. Moran's scatter plot with the *I* value displayed at the top.

Note: The x-axis is the value of *I* and the y-axis is the spatial lag (the weighted average of neighboring values). The slope of the line is Moran's *I*).

It can be thus deduced from the above-presented results that with further improvement and availability of better data sets, SEFLAME-CM seems to be a good model for modeling NRBCs. The current design of SMCE has key challenges with its implementation. Many recent SMCE users for spatial decision making show that it requires custom design for better performance (Ferretti, 2016, Ferretti and Montibeller, 2016, Hua *et al.*, 2016, Moghadam *et al.*, 2016). Therefore SMCE will be useful in CM and negotiations but it will require stakeholder participation from the problem joint problem framing phase. An example is the recent use of *touch table* for interactive negotiation and spatial planning assisted with SMCE in land use planning (Arciniegas Lopez and Janssen, 2009). SEFLAME-CM compensates for this shortcomings. Particularly, the joint problem framing phase is a critical component of the functionality of the SEFLAME-CM. However, both SEFLAME-CM and SMCE-CM can be combined by harnessing the advantages of each other. The advantages of the use SEFLAME-CM as an innovative method for modeling NRBCs include but not limited to the following:

- Th actors participation from the problem structuring phase
- The weighting of drivers of conflict in order to generate the model inputs
- The transdisciplinary nature of the model because knowledge is derived from both the actors and from different disciplinary backgrounds.

The SEFLAME-CM has proved very useful in this work. Even though the improvement of the quality of the model remains to be investigated, the model has shown the capacity of modeling a complex real-world problem in a transparent manner. Besides the validation with the observed conflict data sets, the validation of the model with remote sensing data is further carried out.

6.5.3.2.4 SEFLAME-CM Validation using Remote Sensing Data

SEFLAME-CM is further validated using the environmental drivers of NRBCs derived from remote sensing. The environmental parameters derived are categorical variables. These are:

- Mangrove loss parameters (loss, gain, other land use and persistence),
- Farmland loss parameters (loss, gain, other land use and persistence),
- Distance to surface water pollution parameters (very near, near and far), and
- Proximity to oil infrastructure parameters (very near, near and far) (see Figure 6.39 and 6.40).

The spatially explicit CVL index produced using the SEFLAME-CM is used as the dependent variables. These are also the categorical type of variables (*most likely, very likely, likely, and unlikely*) (see Figures 6.35 and 6.36). Table 6.14 shows the coding of all the variables, the environmental parameters (independent variables) and spatial CVL Index categories (dependent variables). The validation is aimed at establishing the influence of specific environmental change variables on conflict likeliness between 1986-2016. This is implemented using Multinomial Logistic Regression (MNLR). MNLR is normally used to establish relationships in the memberships of more than two categorical variables (Bayaga, 2010).

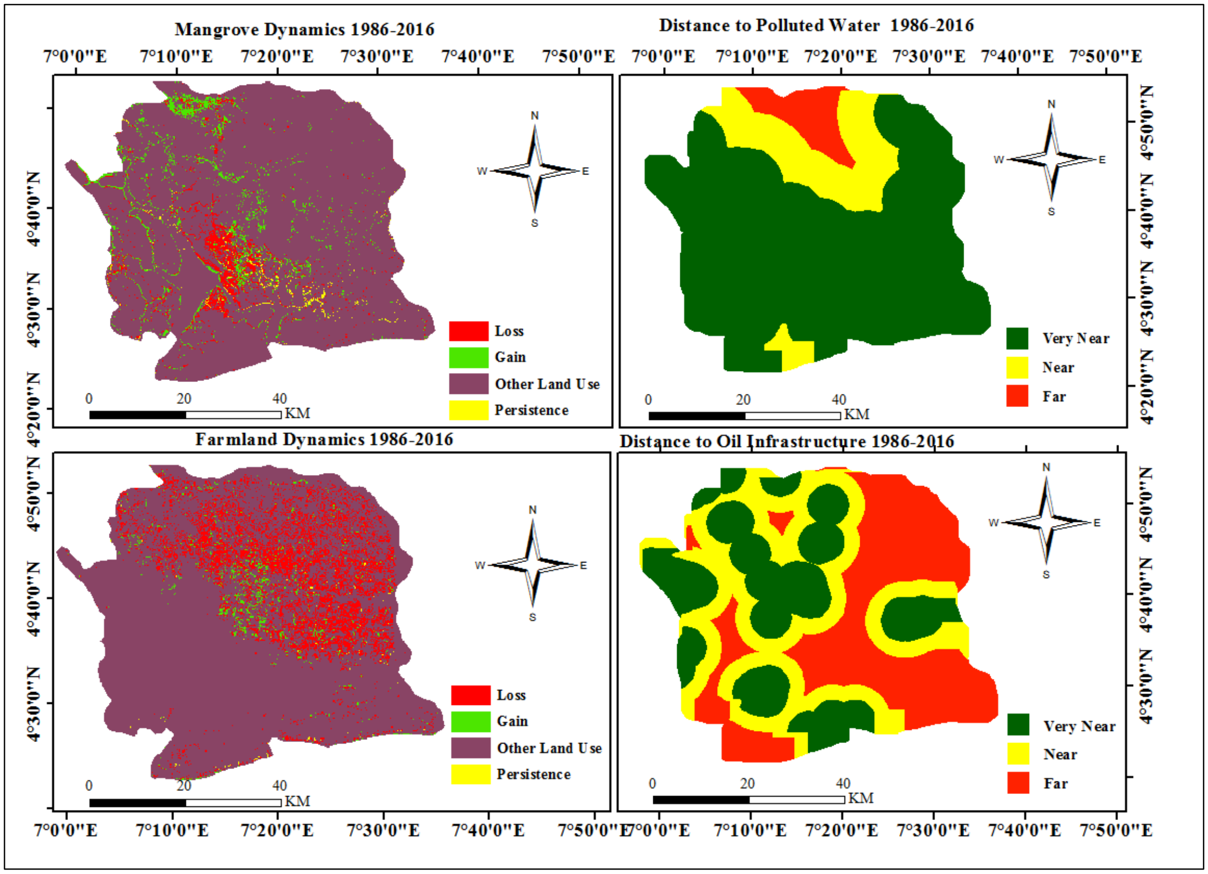


Figure 6.39: Remote sensing data: mangrove loss, farmland loss, water pollution level, and oil infrastructure parameters.

Environmental drivers for all year periods (1986-2016)	Parameters	Coding
Mangrove Loss	Persistence	1
	Gain	2
	Loss	3
	Other Uses	4 (reference category
Farmland	Persistence	1
	Gain	2
	Loss	3
	Other Uses	4 (reference category
Distance to polluted water	Very near	1
	Near	2
	Far	3 (reference category
Distance to oil Infrastructure	Very near	1
	Near	2
	Far	3 (reference category
CVL Index	Most Likely	1
	Very Likely	2
	Likely	3
	Unlikely	4 (reference category)

Table 6.14: Coding of data for model validation using remote sensing and MNLR.

MNLR has many similarities with multiple linear regression model (MLRM. As commonly stated, in MLRM, *Y* is predicted from a combination of each predictor variable multiplied by its respective regression coefficients (see *Equations 6.5 to 6.7*), where b_n is the regression coefficient of the corresponding variable X_n.

However, MNLR equations, instead of explaining the value of a variable *Y* from an explanatory variable X_1 or several explanatory variables *(Xs),* the probability of *Y* occurring is expressed given the known values of X_1 *(or Xs).* In its simplest form, when ther*e is only one predictor variable* X_1*, the MNLR equation gives a situation where the probability of* Y is predicted given by *Equation 6.12*

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_{1i})}} \qquad \textit{(Equation 6.12)}$$

where

P(Y)	=	*the probability of Y occurring*
Y	=	*CVL Index (unlikely, likely, very likely, most likely)*
e	=	*the base of natural logarithms*
b_0		*Intercept term*
$b_1, b_2\ldots, b_n$	=	*regression coefficient of the corresponding variable* $x_1, x_2, \ldots x_n$ *(see equation 6.14)*
x	=	*environmental drivers*
i	=	*the parameters under the drivers (such as very near, near and far)*

However, since we have several explanatory variables as parameters of conflict drivers as *(Xs)* and several values of the CVL Indices as (Ys), SEFLAME-CM is therefore validated using *Equation 6.13*. The values of the CVL index *(unlikely, likely, very likely, most likely)* are the probabilities of Ys occurring. *Equation 6.13* is therefore applied as an extension of that of the above (*Equation 6.12*). *Equation 6.13* is the same as the equation used when there is only one predictor except that the combination has been extended to include any number of explanatory variables (Field, 2009).

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_n X_{ni})}} \qquad \textit{(Equation 6.13)}$$

An important part of the interpretation of MNLR is the value of the odds ratio (Field, 2009). This is an indicator of the change in odds resulting from a unit change in the predictor. The odds of conflict occurring in a village is the probability of conflict occurring divided by the probability of conflict not occurring *(see Equation 6.14).* In the calculation of the odds ratio of conflicts, therefore, *Equation 6.14* is applied. For example, if the odds for a location with mangrove persistence, having *most likely* conflicts rather than *unlikely* conflicts is 0.64 times, this becomes 1 minus 0.64 (percent), ie 36% less than the odds of conflicts occurring in other land uses.

$$odds = \frac{P(Y)}{P(no\ conflct\ event} \qquad \textit{(Equation 6.14)}$$

where

$P(Y)$	=	*See Equation 6.14*
$P(no\ conflict\ event\ )$	=	$1 - P\ (conflict\ event)$

Table 6.14 shows the format of coding the variables. For example, the coding of the CVL Index includes *Most Likely=1, Very likely=2, Likely=3, Unlikely=4.* The *unlikely* parameter is taken as the reference category. In addition, at every level of analysis of the MNLR, each parameter of the explanatory variables is taken as a reference (Table 6.14). For instance, under the mangrove loss, another land use is taken as a reference category. In this case, all other parameters are compared with the reference category (Field, 2009).

All the data sets, both the explanatory remotely sensed data and spatial CVL Index were extracted and exported from GIS into SPSS for analysis. The boxplots shown in Figure 6.40 reveals the relationship between environmental drivers of conflicts and the spatial CVL Index derived from SEFLAME-CM. Table 6.15 shows the results of the comparisons (spatial CVL Index vs. environmental driver parameters in 1986-2016). In the interpretation of the results of the validation using MNLR, columns 1 to 4 are relevant here. These include the *parameters*, the *b value, significant value,* and the *odds ratio*. The results are explained below:

(1) Likely conflict vs. unlikely conflict

- *Mangrove Persistence (1):* Assessing whether the locations where mangrove persisted determine the locations that experienced *Likely* conflicts relative to the *unlikely* conflicts, b=-0.45, p<0.001. Holding other variables constant, the odds for a location with mangrove persistence, having *most likely* conflicts rather that *unlikely* conflicts are 0.64 times (36%) less than the odds for other land uses. This means conflicts are more *likely* in other land uses than where mangrove persisted i.e villages in such communities perceive conflicts to be relatively low.

- *Mangrove gain* (2): Assessing whether the locations where mangrove increased also determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b = 0.61, p < 0.001. Holding other variables constant, the odds for a location with *mangrove gain* having *likely* conflicts rather than *unlikely* conflicts is 1.84 times (84%) more than the odds for other land uses. This means that areas, where mangrove increased due to for example restoration projects, are also where conflicts increased for the period. Such conflict-prone locations may have attracted the attention of recent restoration projects by the government and the oil companies, such as Shell.

- *Mangrove loss (3):* Assessing whether the locations that experienced mangrove *loss* determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b

=- 0.55, p < 0.001. Holding other variables constant, the odds for a location with *mangrove loss* having *likely* conflicts rather that of *unlikely* conflicts are 0.58 times (42%) less than the odds for other land uses. This means that areas where mangrove experienced *loss* does not really have *likely* conflicts. However, this finding is only true for the *likely category*. This may not be true for the *very likely or most likely*

- *Very near polluted water (1)*: Assessing whether the locations that are *very near* to polluted surface water determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b = 2.75, p < 0.001. Holding other variables constant, the odds for a location *very near* polluted water having *likely* conflicts rather that *unlikely* conflicts are 0.064 times (6.4%) more than the odds for other land uses or locations *far* from polluted water.

- *Near polluted water (2):* Assessing whether the locations that are *near* the polluted water determine the locations that experience *likely* conflicts relative to the *unlikely* conflicts, b=0.89, p<0.001. Holding other variables constant, the odds for a location *near* the polluted water having *likely* conflicts rather than *unlikely* conflicts are 2.43 times (143%) more than the odds for other land uses or locations *far* from polluted water.

- *Farmland persistence (1):* Assessing whether the locations that experienced farmland *persistence* significantly determine the locations that experience *likely* conflicts relative to the *unlikely* conflicts, b = 1.14, p < 0.001. Holding other variables constant, the odds for a location with farmland *persistence,* having *likely* conflicts rather that *unlikely* conflicts are 3.11 times (211%) more than the odds for other land uses. This means that areas where farmland persisted also had *likely* conflict. This is maybe because of the increase in conflicts over the few remaining fertile agricultural lands.

- *Farmland gain (2):* Assessing if the locations that experienced farmland gain did not significantly determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b =-1.15, p > 0.05. Holding other variables constant, the odds for a location with *farmland gain,* having *likely* conflicts rather than *unlikely* conflicts is 0.04 times (4%) less than the odds for other land uses. This means that areas where farmland experienced *gain* had *unlikely* conflicts more than *likely* conflicts. But as it can be seen this not significant.

- *Farmland loss (3):* Assessing whether the locations that experienced farmland *loss* significantly determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b=1.38, p<0.001. Holding other variables constant, the odds for a location with farmland *loss,* having *likely* conflicts rather that unlikely conflicts are 3.31 times (231%) more than the odds for other land uses. This means that areas where farmland experienced loss had *likely* conflicts more than *unlikely* c*onflicts* compared to other land uses. But the *very likely* and *most likely* results suggest that farmland *loss* did not contribute to extreme conflicts.

- *Very near oil infrastructure (1):* Assessing whether the locations that are *very near* oil infrastructure significantly determined the locations that experience *likely* conflicts relative to the *unlikely* conflicts, b = 1.02, p < 0.001. Holding other variables constant, the odds for a location *very near* oil infrastructure having *likely* conflicts rather than *unlikely* conflicts is 2.77 times (177%) more than the odds for other land uses or locations *near* or *far* from oil infrastructure.

- *Near oil infrastructure (2):* Assessing whether the locations that are only *near* oil infrastructure does not significantly determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts, b=-1.15, p<0.001. Holding other variables constant, the odds for a location *near* oil infrastructure having *likely* conflicts rather than unlikely conflicts is 0.35 times (3.5%) more than the odds for other land uses or locations far from oil infrastructure.

(2) Very likely conflicts vs. unlikely conflicts

- *Mangrove Persistence (1).* Assessing whether the locations where mangrove persisted, do not significantly determine the areas that experienced *very likely* conflicts relative to the *unlikely* conflicts, b = 19.97, p > 0.05. Holding other variables constant, the odds for a location with mangrove persistence, having *most likely* conflicts rather than *unlikely* conflicts is several times more than the odds for other land uses. But this was not significant.

- *Mangrove gain (2)* Assessing whether the locations with mangrove *gain* determine the locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, b = 0.30, p < 0.001. Holding other variables constant, the odds for a location with mangrove *gain* having *most likely* conflicts rather than *unlikely* conflicts is 1.35 times (35%) more than the odds for other land uses. This means conflicts are *very likely* in other land uses than where mangrove was gained.

- *Mangrove loss* (3) Assessing whether locations that had mangrove *loss* significantly determine locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, b = 0.78, p < 0.001. Holding other variables constant, the odds for a location with mangrove loss having *most likely* conflicts rather that *unlikely* conflicts are 2.19 times (119%) more than the odds for other land uses. This means conflicts are *very likely* in mangrove loss locations than in *other land use*.

- *Very near polluted water (1)*: Assessing whether the locations that are *very near* the less polluted surface water determine the locations that experience *very likely* conflicts relative to the *unlikely* conflicts, b =- 0.10, p < 0.001. Holding other variables constant, the odds for a location *very near* to polluted water having *very likely* conflicts rather that unlikely conflicts are 0.80 times (80%) less than the odds for other land uses or the locations *far* from polluted water.

- *Near polluted water (2):* Assessing whether the locations that are *near* the polluted water determine the locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, $b = 0.046$, $p < 0.001$. Holding other variables constant, the odds for a location *near* to polluted water having *likely* conflicts rather than *unlikely* conflicts are 1.05 times (5%) more than the odds for other land uses or locations far from polluted water.

- *Farmland persistence (1)*: Assessing whether the locations that had farmland *persistence* determine the locations that experienced *very Likely* conflicts relative to the *unlikely* conflicts, $b = 0.21$, $p < 0.001$. Holding other variables constant, the odds for a location with farmland *persistence, having very likely* conflicts rather than *unlikely* conflicts is 1.23 times (23%) more than the odds for *other land use*.

- *Farmland gain (2):* Assessing whether the locations with farmland gain determine locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, $b = 0.91$, $p < 0.001$. Holding other variables constant, the odds for a location with farmland increase having *very likely* conflicts rather that *unlikely* conflicts are 2.48 times (23%) more than the odds for other land uses.

- *Farmland loss (3):* Assessing whether the locations that suffered farmland *loss* determine the locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, $b = 0.31$, $p < 0.001$. Holding other variables constant, the odds for a location with farmland *loss* having *very likely* conflicts rather that *unlikely* conflicts are 0.73 times (73%) less than the odds for other land uses. In fact, farmland *loss* does not contribute to *very likely* conflict when this misinterpreted literally.

- *Very near oil infrastructure (1):* Assessing whether the locations that are *very near* the oil infrastructure significantly determine the locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, $b =- 0.56$, $p < 0.01$. Holding other variables constant, the odds for a location *very near* to oil infrastructure having *very likely* conflicts rather that *unlikely* conflicts is 0.57 times (57%) less than the odds for other land uses or locations near or far from oil infrastructure. However, this was only significant at $p < 0.01$.

- *Near oil infrastructure (2):* Assessing whether the locations that are *near* the oil infrastructure significantly determine the locations that experienced *very likely* conflicts relative to the *unlikely* conflicts, $b= 0.73$, $p > 0.05$. Holding other variables constant, the odds for a location *very near* to oil infrastructure having *very likely* conflicts rather that *unlikely* conflicts is 0.497 times (49%) less than the odds for other land uses or locations near or far from oil infrastructure.

(3) Most likely conflict vs. unlikely conflicts

- *Mangrove persistence (1)* Assessing whether locations where mangrove persisted significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, $b=-0.72$, $p < 0.001$. Holding other variables constant, the odds for a location with mangrove *persistence, having* most *likely* conflicts rather than *unlikely* conflicts is 2.05 times (104%) less than the odds for other land uses. This means that conflicts are *most likely* in other land uses rather than where mangrove persisted.

- *Mangrove gain (2):* Assessing whether the *l*ocations where mangrove increased, do not significantly determine locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b = 0.08, p > 0.05. Holding other variables constant, the odds for a location with mangrove *gain* having *most likely* conflicts rather than unlikely conflicts is 0.92 times (92%) more than the odds for other land uses.

- *Mangrove loss (3):* Assessing whether the locations of mangrove loss significantly determine locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b = 0.99, p < 0.001. Holding other variables constant, the odds for a location with mangrove *loss* having *most likely* conflicts rather than *unlikely* conflicts is 2.60 times (160%) more than the odds for other land uses.

- *Very near polluted water (1):* Assessing whether the locations that are *very near* the polluted water significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b = 0.99, p < 0.001. Holding other variables constant, the odds for a location *very near* to polluted water having *most likely* conflicts rather than unlikely conflicts is 2.60 times (160%) more than the odds for other land uses or locations far from polluted water.

- *Near polluted water (2)*: Assessing whether the locations that are *near* the polluted water significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts. B = 0.50, p < 0.001. Holding other variables constant, the odds for a location *near* to less polluted having *most likely* conflicts rather that *unlikely* conflicts are 1.64 times (64%) more than the odds for other land uses or locations *far* from polluted water.

- *Farmland persistence (1)*: Assessing whether the locations that experienced farmland persistence significantly determine the locations that experience *most likely* conflicts relative to the *unlikely* conflicts, b= 0.21, p < 0.001. Holding other variables constant, the odds for a location with *farmland persistence,* having *most likely* conflicts rather than *unlikely* conflicts is 0.81 times (8.1%) less than the odds for other land uses. This means that areas, where farmland experienced persistence, had less *most likely* conflicts than *unlikely* conflicts.

- *Farmland gain (2):* Assessing whether the locations that experienced farmland increase significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b = 1.00, p < 0.05. Holding other variables constant, the odds for a location with farmland *gain,* having *most likely* conflicts rather than *unlikely* conflicts is 2.72 times (172%) more than the odds for other land uses. This means that farmland gain had *most* *likely* conflicts. In fact, locations, where farmlands increased, were also areas where conflicts persisted. Meaning that people may have moved to new locations where conflicts either already existed or they moved their conflicts there.

- *Farmland loss (3)*: Assessing whether the locations that experienced farmland loss significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b=-0.55, $p < 0.001$. Holding other variables constant, the odds for a location with farmland *loss, having most likely* conflicts rather that *unlikely* conflicts are 0.58 times (58%) more than the odds for other land uses. This means that areas where farmland experienced *loss* did not have *most likely* conflicts. Farmland loss did not lead to *most likely* conflicts.

- *Very near oil infrastructure (1):* Assessing whether the locations that are very *near* oil infrastructure significantly determine the locations that experienced *most likely* conflicts relative to the *unlikely* conflicts, b = 0.92, $p < 0.001$. Holding other variables constant, the odds for a location very *near* oil infrastructure having *most likely* conflicts rather than *unlikely* conflicts is 2.51 times (151%) more than the odds for other land uses or locations *very near* or *far* from oil infrastructure, meaning that the oil infrastructure is strongly connected to location with *most likely* conflicts

- *Near oil infrastructure (2):* Assessing whether the locations that are *near* the oil infrastructure significantly determine the locations that experienced *likely* conflicts relative to the *unlikely* conflicts. b= 0.31 $p <0.001$. Holding other variables constant, the odds for a location *very near* to oil infrastructure having *most likely* conflicts rather than *unlikely* conflicts is 1.37 times (37%) more than the odds for *other land use* or locations near or *far* from oil infrastructure.

The results presented above have proved the use of remote sensing in a systematic study of NRBCs, thereby supporting the "people and pixels" postulation (National Research Council, 1998). The model validation with remote sensing data confirms the interpretation of the FLAME-CM result reported in Section 6.5.1. The following main findings can be drawn regarding the four environmental drivers derived:

- The likeliness of mangrove loss leading to NRBCs is high. The probability of mangrove loss leading to *most likely* conflicts rather than *unlikely* conflicts is 160% more than the odds for other land uses.
- The areas very near the polluted water could also experience a high level of resource conflicts. The likeliness of conflicts becoming *more likely* rather than *unlikely* is (160%) more than the odds for *other land use.* This could be such settlements *very near* to polluted surfaces.
- Under farmland loss, it is also revealed that the likeliness of having *most likely* conflicts rather than *unlikely* conflicts is (58%) more than the odds for other land uses. This suggests that the actual locations where farmland *loss* occurred do not attract conflicts in the Niger Delta. This may be in line with the study by Ross (2004), who observed that there is perhaps a very little evidence supporting the link between agriculture with conflicts. However, it is

further revealed that the odds of farmland *gain* leading to *most likely* conflicts rather than *unlikely* conflicts is 172%. This value shows that the areas of farmland *gain,* experience *most likely* conflicts. This may be explained by the fact that people migrate from the polluted land to fertile land. In fact, better remote sensing data quality in terms of resolution and spatial extent could yield more insightful results.

- The nearness to oil infrastructure is critical to understanding NRBCs. As presented above, the probability of *very near* oil infrastructure leading to *most likely* conflicts rather than *unlikely* conflicts is (151%) more than the odds for locations *very near* or *far* from oil infrastructure. As revealed in the FLAME-CM validation result (see Section 6.5.1), oil infrastructure is strongly connected to the communities experiencing *most likely* conflicts.

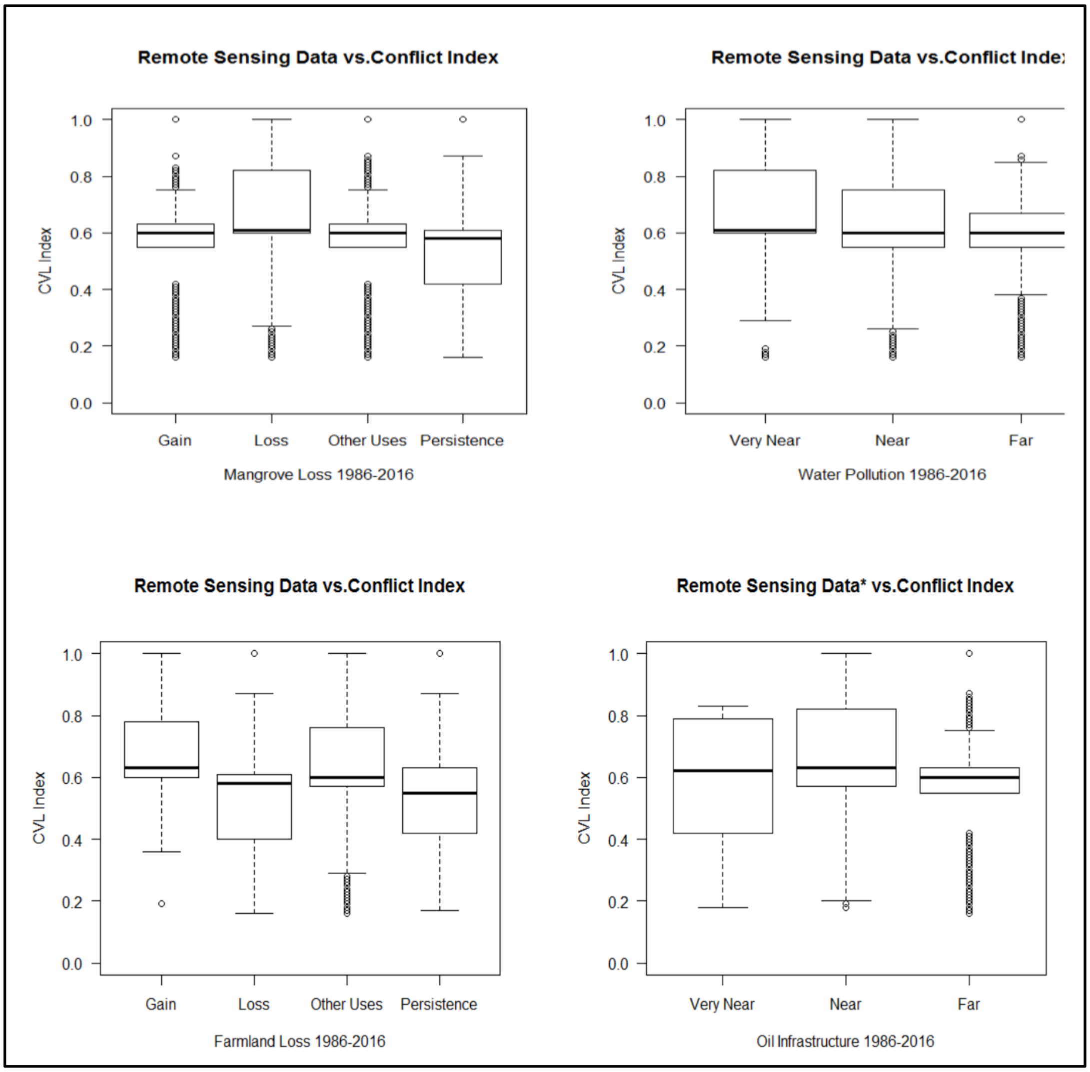


Figure 6.40: Summary of the distributions of the explanatory environmental variables (remote sensing data) and CVL Index (spatially explicit).

Table 6.15: Result of comparison of remote sensing data and the spatially explicit CVL Index 1986-2016

	B	Sig.	Odds Ratio	95% Confidence Interval for Odd Ratio Lower Bound	Upper Bound
Likely					
Mangrove 1986-2016=1	-0.45(0.08)		0.64	0.64	0.64
Mangrove 1986-2016=2	0.61 (0.08)***	0.000	1.85	1.57	2.17
Mangrove 1986-2016=3	-0.55 (0.09)***	0.000	0.58	0.48	0.69
Water 1986-2016=1	-2.75 (0.20)***	0.000	0.06	0.04	0.09
Water 1986-2016=2	0.89 (0.04)***	0.000	2.43	2.25	2.62
Farmland 1986-2016=1	1.14 (0.05)***	0.000	3.11	2.83	3.42
Farmland 1986-2016=2	-1.15 (1.08)	0.288	0.32	0.04	2.64
Farmland 1986-2016=3	1.37 (0.09)***	0.000	3.94	3.31	4.70
Oil 1986-2016=1	1.02 (0.24)***	0.000	2.77	1.73	4.45
Oil 1986-2016=2	-1.03 (0.05)***	0.000	0.36	0.33	0.39
Very Likely					
Mangrove 1986-2016=1	19.97 (7,004)	0.998	472,	0.00	.c
Mangrove 1986-2016=2	0.30 (0.07)***	0.000	1.35	1.18	1.54
Mangrove 1986-2016=3	0.78 (0.05)***	0.000	2.19	1.97	2.43
Water 1986-2016=1	-0.20 (0.04)***	0.000	0.82	0.76	0.89
Water 1986-2016=2	0.05 (0.03)	0.112	1.05	0.99	1.11

Farmland 1986-2016=1	0.21 (0.04)***	0.000	1.23	1.14	1.33
Farmland 1986-2016=2	0.91 (0.43)*	0.034	2.47	1.07	5.70
Farmland 1986-2016=3	-0.31 (0.08)***	0.000	0.73	0.63	0.86
Oil 1986-2016=1	-0.56 (0.22)**	0.011	0.57	0.37	0.88
Oil 1986-2016=2	-0.72 (0.03)***	0.000	0.48	0.46	0.51
Most Likely					
Mangrove 1986-2016=1	-0.72 (0.00)***	0.000	2.05	2.05	2.05
Mangrove 1986-2016=2	0.08 (0.08)	0.328	1.08	0.92	1.27
Mangrove 1986-2016=3	0.99 (0.06)***	0.000	2.60	2.40	3.02
Water 1986-2016=1	0.99 (0.06)***	0.000	2.60	2.40	3.02
Water 1986-2016=2	0.50 (0.03) ***	0.000	1.64	1.54	1.76
Farmland 1986-2016=1	-0.21(0.05)***	0.000	0.81	0.74	0.89
Farmland 1986-2016=2	1.00 (0.46)*	0.029	2.72	1.11	6.68
Farmland 1986-2016=3	-0.55 (0.11)***	0.000	0.58	0.47	0.71
Oil 1986-2016=1	0.92 (0.22)***	0.000	2.51	1.62	3.90
Oil 1986-2016=2	0.31 (0.03) ***	0.000	1.37	1.29	1.46

7. Outlook and Conclusion: Co-Creating Scenarios for Conflict Management

This section presents the conclusion and outlook of this thesis. It is concluded in this thesis that the model-SEFLAME-CM, developed and implemented under a transdisciplinary-based coupled approach improved the vulnerability assessment of NRBCs at a community scale. As a result, SEFLAME-CM fills the gap in the increasing need for developing sustainable peace strategies (Bruch et al., 2009, Ratner et al., 2013). Some strategies are presented for co-creating scenarios for the future integration of natural resource management (NRM) into conflict management (CM). There are limitations in this work which can be taken up by researchers in the future. Some recommendations are presented to address these limitations through future studies on Natural Resource-Based Conflict (NRBCs).

7.1 Towards Co-creating Scenarios for Future Natural Resource Conflict Management and Sustainable Peacebuilding

The co-dissemination/co-communication of results is the third and the last phase in the transdisciplinary research process for vulnerability assessment in the context of natural resource-based conflicts (NRBCs) (Mauser *et al.*, 2013). Thus this section presents the third phase of the approach (see Figure 1.4) and how this work contributes to future scientific investigations on NRBCs (see Sections 5, and 6 for the implementation of the approach).

7.1.1 Towards Policy Scenarios for Sustainable Peace

Following the joint problem framing and the co-production phases in the vulnerability assessments of NRBCs, the next step in this study is to co-create scenarios and develop strategies for managing future NRBCs. In the introductory section of the book, *Future Matters Action, Knowledge, Ethics, by Adam and Groves (2007),* the authors stated*:*

> "...futures are not merely imagined but they are also made. They are produced for months, years and even millennia hence, creating chain reactions that permeate matter"

This statement depicts the fact that while the historians or other humanities researchers can imagine the future, the natural scientists can quantitatively model the future, but the transdisciplinary-based researchers are able to both imagine and construct the future based on the combination of skills from different disciplines. Studies such as Rustad and Binningsbø (2012) thus observed that:

> "To disclose potential solutions to natural resource conflicts, there is a pressing need to evaluate post-conflict natural resource management policies that have been used and to explore new options for successful peacebuilding approaches" (: 544).

A number of findings in this thesis clearly inform the development of these new options for peacebuilding. These findings will support the co-creation of strategies for conflict management.

Firstly, it is shown in this thesis that the drivers that explain conflicts are dynamic; hence the future occurrence of NRBCs can be modeled given certain environmental, socio-economic and political conditions. The findings presented in Section 6 specifically show that the drivers of NRBCs are more explained at the community scale than at the Large-N scale. Although the future use of scenarios for conflict management requires information from the Large-N scale studies, such findings need not be taken *hook, line, and sinker*. Rather, they should be combined with that of the conflict studies at the community scale. In any case of contradiction, the local findings need to override the existing Large-N findings.

Secondly, apart from the drivers of NRBCs that are directly connected to resource conflict management policies, it is also revealed in this work that spatial assessment is a critical factor in the researches on the future management of NRBCs (see Section 6.5.3). The spatial dynamic relationships over NRBCs will advance the scientific studies and will help to better understand the knowledge of the conflict mechanisms and the spatial variations at the regional or the local levels (Chojnacki and Metternich, 2008). Rustad and Binningsbø (2012) showed that: "It seems plausible to assume that the success of natural resource management in creating sustainable post-conflict peace depends on knowledge about the mechanisms linking resources to the conflict" (:543).

Thirdly, it is established that the holistic vulnerability assessment concept plays a key role in the study of NRBCs at a local level (see Section 3). This work therefore supports the role of holistic vulnerability assessment in the co-construction of scenarios for future conflict management. As shown in the discussions in Section 1 and 3, it is important to state that most Large-N studies seem to support mainly the socio-economic and political drivers of conflicts with less attention given to environmental drivers. This is in contrast with the findings of this thesis. The holistic vulnerability assessment of NRBCs considers the different dimensions of vulnerability to NRBCs. The findings in Section 6 show that community-based resources and environmental services are critical to the occurrence of conflicts and local aggression. These findings are not obvious in Large-N studies of conflicts. For example, even the internationally renowned research projects such as the State Failure project have shown that environmental factors do not directly contribute to the risks of state failure (Gurr *et al.*, 1999). Such Large-N projects often ignore the role of contexts in scientific investigations of NRBCs. Basedau (2005) showed that context matters in terms of country-specific conditions. The resource-specific conditions (type, degree/level of abundance and dependence, resource revenue management and companies involved etc.) are critical to future holistic vulnerability assessment of NRBCs.

Fourthly, this thesis also supports the findings of past works which showed the importance of disaggregating the actors in conflict studies (Dewulf *et al.*, 2005, Gadjanova *et al.*, 2014). Disaggregation of NRBCs forms a strong basis for involving the actors in an attempt to co-create strategies for future management of NRBCs using scenarios. Disaggregating conflicts by space and time will also give an impetus to identifying the mechanisms and the emergent structures that will shape the attitudes and the behavior of actors in the future. These insights will, therefore, be useful when applied in the search for solutions for future NRBCs.

Given the above arguments, the scenario options for the future management of conflicts can be developed by considering certain conditions despite an absence of existing NRBCs scenarios in the public domain. Such scenarios may, for instance, consider the demands of natural resources, the findings of the previous Large N studies on NRBCs, the findings of the community-based studies and specifically the drivers developed in this thesis. In other words, the role of conflict drivers and how the local actors assess these local drivers for management of future conflicts will be critical to sustainable peace policies (see Buhaug and Rød (2006) for explicit discussions on the importance of local determinants of conflicts, e.g. democracy, and others). See also Ellingsen (2005) for local factors such as population. urbanization and other socio-economic issues.

The next sub-section discusses the implications of the concepts of vulnerability and resilience in this thesis and their relevance in the future investigations of NRBCs.

7.1.2 Implications of the Holistic Vulnerability Assessment and Resilience in Co-creating Scenarios for Sustainable Peace

As the entire thesis has shown, the goals of the holistic vulnerability assessment concept in co-creating for sustainable peace is to decrease the level of community vulnerabilities to NRBCs and increase the community resilience to NRBCs. This was achieved by using a transdisciplinary approach, using the knowledge from the scientists and that from the community actors.

In particular, the resilience concept as a flip side of vulnerability (see Section 3) in scenario development for the future CM shows that peace can be built by emphasizing on the ability of groups or communities to cope with external stresses, shocks or disturbances of environmental degradation, and the socio-economic and political dynamics (Gallopín, 2006, Yan and Xu, 2010). In this regard, it is, therefore, a major finding of this thesis that just by setting up democratic structures in post-conflict situations do not sustainably address the conflicts relating to natural resources. Rather the integration of NRM into CM is an integral part of sustainable peace.

Drawing on the implementation of the transdisciplinary approach, at the joint problem framing and the knowledge co-production phases in particular (see Sections 4 and 5, ad 6), this thesis gives insights on how the integration of actors' knowledge can be used in CM. It was specifically shown that the actors' knowledge on the vulnerabilities and the resilience of communities to NRBCs can be integrated into CM as a way of introducing new voices to the debate over the Niger Delta region's future (Acey, 2016). This is further supported by researches that focus on developing CM strategies in a long-term transition to peace (Brauch, 2016b, Oglethorpe *et al.*, 2016). However, as shown in Oglethorpe *et al.,* a key challenge in post-conflict recovery and peacebuilding is to shift the relevant time frame from the current and short-term situations (securing food and water, preventing tensions from reigniting and so on) to longer-term management. This is where the role of scenarios should be recognized by setting out visioning and future management strategies at a community or regional scale (Ratner *et al.*, 2013, Oglethorpe *et al.*, 2016). Such scenarios would include building institutional capacities regarding diverse policy issues such as environmental sustainability, land cover, agriculture, population, urbanization etc. It may also include building rural people's assets as an emerging awareness of the positive impacts that cooperation can create around NRM and how hybrid peace can help in reducing the risk of broader social conflicts (Ratner *et al.*, 2013, Oglethorpe *et al.*, 2016).

Despite the relevance of vulnerability and resilience concepts for the future studies of NRBCs, it is also a major observation in this study that the use of the concepts of vulnerability and resilience will not be a panacea to NRBCs. Caution is therefore required in their application. The contribution to resilience thinking for peacebuilding is not as a "template-style peace implementation" (Johansson, 2015). Peace will be built by strengthening the adaptive capacities of communities and their ability to manage NRBCs as a means of "advancing peacebuilding" (Johansson, 2015). In addition, in the use of the concepts of resilience and vulnerability, this thesis shows that peacebuilding should not only be based on adaptations to the current conditions in the short term but in long term.

7.1.3 A Shift from Liberal Peace to Hybrid Peace through Community Resilience in NRBCs

This thesis theoretically contributes (see Section 1 and Section 3) to the discussion that liberal democracies and liberal peace cannot successfully address the underlying causes and the dynamics that create NRBCs. Solutions to NRBCs should go beyond the policies derived from the dominance of Western states and the externally based institutions.

The thesis further gives insights on the need for a shift in CM strategies to more inclusive and cross-disciplinary strategies that permit a more nuanced analysis of conflicts, with explanations that account for changes over time and across spatial units, spanning the range from neighborhoods, villages, subnational administrative units on the incidence or intensity of conflicts (Chandler, 2014, Gadjanova *et al.*, 2014, Peek, 2016) (see the explanations of the spatiotemporal validation in Section 6.5). Such shift to a transdisciplinary approach as implemented in this thesis shows how the hybrid CM strategy is embraced as a community resilience thinking in peacebuilding (Tziarras, 2012).

7.2 The Co-creation Process and Proposed Scenarios in the Context of Natural Resource-Based Conflict Management

As mentioned in Section 7.1, this thesis argues that scenarios can be applied for future management of NRBCs. See Section 3.2.3 for detailed discussions on the typologies and the application of scenarios. This application of scenarios in the context of future CM gives insights into the use of knowledge co-creation to address a "wicked" problem such as the NRBCs. Scenarios in CM are understood as coherent and structured descriptions of what a desirable future would look like in a post-conflict community. This can be done by setting up alternative futures that explore management strategies with a combination of qualitative and quantitative methods (Carius and Maas, 2012). Unlike what obtains in the IPCC scenarios (e.g. where climate change scenarios exist in the public domain with quantifications and thresholds) the critical part of the CM scenario development is to develop and follow a systematic process in co-creating and implementing CM scenarios. It is, therefore, a major assumption in this thesis that the barrier of the absence of existing scenarios in the management of NRBCs can be overcome by combining quantitative and qualitative information. CM scenarios will thus be unique in their own rights.

CM scenarios will follow an iterative process and a constructive dialog among participants in the process (Mauser *et al.*, 2013, Kishita *et al.*, 2016). See Mauser *et al* and Section 5 for the third step of knowledge co-creation and the details of the research methodology respectively. One of the benefits of a co-created knowledge in scenario construction for NRBCs is that it enhances empowerment. Empowerment will lead to more acceptance of research outcome by communities (Carius and Maas, 2012). The CM scenarios do not eliminate uncertainties or envision an ideal world about the future, rather they provide a means of representing current knowledge embedded within the set of anticipated challenges of NRBCs (Carius and Maas, 2012). As mentioned in Section 7.1, this thesis revealed that NRBCs in communities are dynamic. Hence, the role of natural resources as a dynamic mitigating or contributing factor to violent conflict need to be recognized. In this case, it is important to identify the role of the dynamic demands of key natural resources such as oil and the environmental, socio-economic and political change drivers over time. Furthermore, while the international demand factors will need to be identified, at the local level, the trends need to also be addressed so that actors can make inputs into developing the scenarios that will help identify the communities that are vulnerable and those that are resilient to NRBCs.

It is therefore proposed that the overall scenario process of NRBCs will follow the story and simulation (SAS) approach (Alcamo and Ribeiro, 2001). This combines the exploratory and backcasting scenarios using qualitative and quantitative elements at the various process of the implementation (see Section 3.2.3 for scenario typologies). Similar methods were used in (Folhes et al., 2015, Aguiar et al., 2016, Gollnow et al., 2017). The proposed scenario approach is similar to the proposal by Kishita *et al.* (2016). Figure 7.1 shows the steps for implementing scenario co-creation. The steps will include:

(a) literature review/problem definition,
(b) idea integration/scenario descriptions, by using narratives and storylines from workshops and integrating them with existing numerical values,
(b) modeling and assessment and adapting SEFLAME-CM.

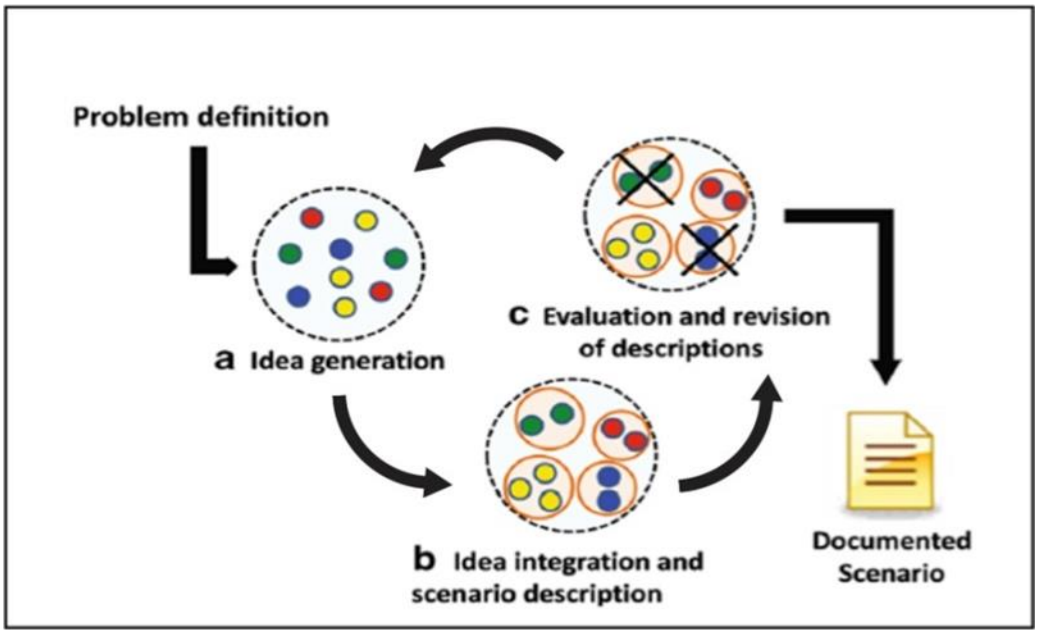


Figure 6.41: Conceptual scenario design, adapted from Kishita et al. (2016).

(a) **Problem definition and idea generation:** This step requires knowledge from different sources. Literature reviews need to be conducted on a wide variety of ideas. This will be combined with brainstorming, discussions, and interviews with the actors and use statistical data. This step will be similar to the joint problem framing phase (see Section 4).

(b) **Idea integration and scenario descriptions:** Narrative scenarios and storylines need to be generated from the workshops. Scenario descriptions can be added in an incremental manner with all the collated information. This will include describing the causal relationships between the scenario constituent elements. See Section 7.2 for details on scenario typologies, including the backcasting and the exploration methods.

(c) **Modeling and Assessment by Adapting SEFLAME-CM for modeling CM scenarios:** The contents of the scenarios can be quantified and modeled using the model set up of SEFLAME-CM. A key consideration will thus be given to a process of translation that is iterative, thoughtful, transparent, and reproducible (Mallampalli *et al.*, 2016). The co-creation process could itself be iteratively implemented following what may be referred to as co-framing, co-modeling, and co-validation of the results.

- Co-framing: This is the redefinition of the problem by the actors and developing the storylines during a modeling workshop (see Section 4.3.1.3, Appendix A.14.9). As implemented in the thesis, the actors could include the NGOs, community leaders, youths, farmers, and politicians in each of the LGAs/communities. This list could be expanded to include the oil companies, the regional and national political office holders or their representatives and any other stakeholders that have stakes in the development policies relating to natural resource management and CM.
- Co-modeling: The modeling and development of scenarios could consider the demands and drivers of conflicts identified by the actors and the scientists. This will include weighting of the drivers by the actors.
- Co-validation of scenarios: This will require validation of the results of the scenarios with the actors. All these processes will require desktop and fieldwork research and a collection of more data sets (see Section 7.3.1 for example).

7.3 The Implications of Adapting the SEFLAME-CM for Modelling Scenarios in Natural Resource-Based Conflict (NRBCs) Management

As presented in Sections 5 and 7.1-7.2, the model-SEFLAME-CM has a key advantage of accepting both qualitative and quantitative methods. These two types of data sets can complement each other. SEFLAME-CM can be adapted for scenario co-construction with more elaborated actors' involvement and a forward-thinking analysis. The scenarios for future management of NRBCs need to be developed based on the assumptions of future development of determinant variables of environmental, socio-economic and political forces. This may include climate change, technology, population, urbanization, governance, and development policies and actors behavioral patterns. A number of scenario families could be developed based on the demands of oil extraction and other drivers of NRBCs. In the absence of existing scenarios in the public domain, such as the IPCC, the conflict management scenarios are perceived as a combination of the knowledge of the actors and the existing temporal data sets in order to co-create between the scientists and the actors. The knowledge will reveal those communities/regions that are likely to be vulnerable to conflicts and those that resilient to conflicts i.e. areas of peace in the future. To account for the complexities involved in NRBCs as a social problem, the rigorous integration of qualitative and quantitative data sets will be a very useful approach (Alcamo and Ribeiro, 2001, Alcamo, 2008a, Alcamo, 2008b). According to (Alcamo, 2008a):

> "…the answer from recent international scenario exercises is that we do not need to decide. Rather, a combination of qualitative and quantitative scenarios can be the best answer to achieving the goals of a scenario analysis" (:126).

The important question to be addressed in adapting the SEFLAME-CM is: how can we identify the areas that are vulnerable or those that resilient to NRBCs in the future using the co-created scenarios?. The conceptualization of the plausible scenario families and groups with a combination of qualitative and quantitative analysis could be given thus:

- ***Scenario A****:* Socio-economic growth scenario (with sub-group scenarios). The socio-economic scenario family may include expansion of the oil industry, population growth and urbanization. Also, a consideration will be given to local or regional differences in per capita income.
- ***Scenario B:*** Political dimension scenarios (with sub-groups scenarios). This could involve the local, regional democracy and other political dimensions of NRBCs (see Section 5 for details on political drivers of NRBCs).
- ***Scenario C:*** Climate change scenario (with sub-groups scenarios). This may involve for example a qualitative and a quantitative assessment of climate change as drivers of environmental change and NRBCs.
- ***Scenario D:*** Environmental sustainability scenarios (with sub-groups scenarios). In this case, emphasis may be laid on technological development and more adherence to the environmental policies of the oil extractive companies or s shift away from the oil extraction as a mainstay of the economy.

These scenarios may also emphasize the wide involvement of all segments of society in decision making, and equal weights will be given to environmental and socio-economic policies. Regarding the storylines of the above-mentioned scenario families and groups, there will be emphasise on possible ecological, societal, economic, and political developments in the study region until 2060. The justification of the time scale is that in general, the global social science scenarios cover larger time horizons, 50–100 years, while the local scenarios focus on shorter periods, 20–30 years (Folhes et al., 2015). This scenario time frame is thus chosen to be relatively longer than 20–30 years because the study outcome is considered to be applicable to regional governance.

The story lines can be translated into their potential meaning for example into population change, agricultural development, urbanization, land-use policy, following a similar structure to the story and simulation approach (SAS) described by Alcamo (2008b). It has been recently shown that statements of storylines by actors on specific scenarios groups can be interpreted in terms of their potential meaning for modeling (Gollnow et al., 2018). The qualitative interpretations can then be translated and combined with numerical values for spatially explicit modeling.

Data will be required from various sources (see Section 7.3.1). In this context, the role of SEFLAME-CM is critical. Section 5 and 6 have shown how SEFLAME-CM can be implemented by using data from various sources. SEFLAME-CM also showed how linguistic statements can be converted into numbers inform of weighting of parameters and the drivers of conflicts by the actors.

To implement the co-created scenarios, therefore, the models of SEFLAME-CM and SMCE can be coupled (see Section 6). The spatial multicriteria evaluation (SMCE) module of ILWIS (ITC, 2005) is a suitable methodology for developing alternative scenarios (see Section 5.2.3.8.2). The spatially explicit results will reveal the likely vulnerable and the likely resilient communities to NRBCs. This information will help to support the spatial interventions policies on future CM. The use of vulnerability and resilience concepts for future assessment of NRBCs is in line with the consensus that they are strongly dependent (Folke, 2006, Berkes, 2007, Brand and Jax, 2007, Folke *et al.*, 2010, Miller *et al.*, 2010, Wilkinson, 2012) (see Section 3 for details on the link between resilience and vulnerability assessment).

7.3.1 Data for Proposed Scenarios

Detailed data and information will be required for co-creating the CM scenarios. For example, on the environmental changes, new satellite data sets will be required. Environmental data sets, though exist locally with the launching of Nigeria satellites by the National Space Research and Development Agency (NSRDA) and the Landsat data sets used for developing SEFLAME-CM (see Section 5), data sets with higher resolution are available. For example, multi-spectral data sets such as Sentinel 2 by European Space Agency (ESA) with a spatial resolution of 10 meters are very promising data sets for future studies on NRBCs. The social data sets will be derived from the secondary sources. SEFLAME-CM has proved to be able to accept data from various sources as provided in the preceding sections of the thesis. Many models such as land use models, econometric and social dynamic models will be crucial for computing the scenarios of future CM.

7.3.2 Outlook and Conclusion: Recommendations for Future Research on Natural Resource-Based Conflict using SEFLAME-CM

This thesis has clearly shown some limitations as in all studies. These limitations are mainly related to the time frame of the research and the cost of implementing co-created scenarios as mentioned in this section. Such research exercise would require more data sets (see Table 7.1) and more time of collection with its cost implications. It is therefore expected that the implementation of the co-creation of scenarios for management NRBCs will be carried out in the future.

Table 7.1 Data Sets and Specifications for Scenario Simulation using SEFLAME-CM

Data category	Data Description	Processing Mode	Source
Land use/cover suitability factors	Land use/land cover data from Remote sensing such as Sentinel -Agriculture e.g. Crop production(in tons/year and ha), Livestock units -Urbanization -Water quality - Normalized difference vegetation index (NDVI)	LULC Model/ SEFLAME-CM	ESA (www.esa.int) and (www.scihub.copernicus.eu)
GDP	National population	Econometric model/ SEFLAME-CM	National population commission/National Statistical Beaureu
Population	National population	SEFLAME-CM/GIS	National Population Commission/National Statistical Beaureu
Oil and Gas Infrastructure	High-Resolution Remote sensing data e.g. RapidEye to supplement temporal oil and gas infrastructure datasets	Object-Oriented image classification models/ SEFLAME-CM/GIS	RapidEye (http://eyefind.rapideye.com) Regional agencies such as the National Oil Spill and Detection and Response Agency (NOSDRA) (www.nosdra.gov.ng)
Political data sets	Local and regional political drivers. The local political institutions an governance	SEFLAME-CM/GIS	National Population Commission/National Statistical Bureau, international and local literature on national and regional political characteristics of Nigeria

Observed conflicts	Conflict typologies	SEFLAME-CM/GIS	See Section 5.2.1
Scenario quantification at a community, regional or macro level	The various conflict drivers as grouped under different scenario groups	SEFLAME-CM/SMCE and GIS	SEFLAME-CM/GIS

Given the successful application of a transdisciplinary-based coupled approach and an extended co-creation of scenarios for future conflict management, the following recommendations are derived from this thesis:

- First, in this work, all the actors' views were aggregated. Future research should establish the differences between the specific actors' views (e.g. farmers vs. youths, oil corporations vs. politicians, etc.) Future researchers interested in transdisciplinary approaches supported by the SEFLAME-CM should reveal the actors' disaggregation across the different communities and regions of study. This will be in terms of the actor' weighting of the parameters inputted into the SEFLAME-CM. This disaggregation will further address the actors' specific interactions and interests.

- Second, it is important to note that the fuzzy logic membership functions in this work were used to calibrate the model by comparing different membership functions (see Section 6.4). However, future research on NRBCs is expected to use information from the questionnaire surveys to directly develop a custom membership function (Zhao and Bose, 2002, Brennan and Martin, 2006). In addition, as social processes are complex and "wicked" in nature, a combination of fuzzy logic and agent-based modeling can help model the behavior of actors in the future.

- Third, regarding the application of remote sensing data, the scale of this study at the community level should naturally require less coarse resolution data sets. New and the available higher resolution data sets are expected to be used for the quantification of the environmental parameters, such as oil infrastructure, crop production, surface water, the normalized difference vegetation index (NDVI) etc. The outputs of remote sensing data from different sources and from different spatial resolution may also be compared in order to further reveal the data sets that are best suited for modeling NRBCs for sustainable peace.

- Fourth and importantly, an implementation of co-created scenarios in the future will reveal the areas of conflict and the areas of peace based on the different management scenarios across the scenario families and scenario groups in terms of the temporal and spatial contexts. Creating maps with GIS will reveal in a spatially explicit context the areas of future conflicts and the areas of future peace (2016-2060). The results of scenarios could also reveal the uncertainty of the co-created scenarios (2016-2060). An important question that could be addressed in the future study is: if there is no more oil extraction will there be conflicts or there will be another type of conflicts that are not related to oil?

- Fifth and finally, it is expected that the future use of the transdisciplinary-based coupled approach and the SEFLAME-CM will directly lead to policy recommendations and regional strategies on the management of the Niger Delta. Nigeria's return to multiparty democracy in 1999 and the subsequent geopolitical realignment has given the Niger Delta region a greater voice in public decision-making (Acey, 2016). The recently held 2015 national elections, in which the power of the presidency was successfully handed over to an opposition party without major violence or political strife for the first time in Nigeria's history also seems to reflect this slowly unfolding transition towards a more democratic society.

All in all, this thesis made a very important contribution to research on sustainable peace in terms of integrating NRM into CM and by demonstrating that environmental degradation, socio-economic and political drivers of NRBCs can be addressed holistically as well as being treated as separate drivers at a community scale. The results suggest that the community vulnerability to NRBCs can be addressed through the negotiation with the actors when supported with the SEFLAME-CM tool. The introduction of SEFLAME-CM is a first step towards realizing the use of science in managing and ultimately resolving intractable conflicts over natural resources in developing countries (Kwaku Kyem, 2004).

8. Summary

This thesis presents a new approach for investigating vulnerability assessment in the context of natural resource-based conflicts (NRBCs). It develops SEFLAME-CM (A Spatially Explicit Fuzzy Logic Adapted Modeling for Conflict Management). SEFLAME-CM is an innovative tool that improves the holistic vulnerability assessment (the external and the internal driver components) of NRBCs at a community scale towards co-creating scenarios for future conflict management (CM) strategies. It was perceived specifically that a methodology with the worldviews and the knowledge of the actors is capable of understanding conflicts better than the previous linear models such as the Multiple Linear Regression Model (MLRM) and the Multinomial Logistic Regression Models (MNLR). SEFLAME-CM, an adapted model proved to be a reliable modeling tool for capturing the non-linearity, uncertainty, and ambiguity characteristics of the vulnerability assessments of NRBCs.

The spatial extent of the study was limited to selected test sites within Ogoni and Okrika territories of the Niger Delta region of Nigeria. These comprise of LGAs/communities and villages. Despite the uncertainty involved in real-world problems such as the Socio-ecological Systems (SES), the NRBCs, the increase in the computational power in the last decades has enabled the modeling of the complexities involved. Issues that cut across social-economic and biophysical interfaces, such as NRBCs, require both the knowledge of the experts and that of the local actors. This is thus following the recommendation of Seidl et al. (2013) on science with social research in the Anthropocene:

> "A systems perspective on coupled human-environmental systems (HES) help to address the inherent complexities. Additionally, a thorough interaction between science and society (i.e., transdisciplinarity) is necessary, as sustainable transitions are sometimes contested and can cause conflicts. In order to navigate complexities regarding the delicate interaction of scientific research with societal decisions these processes must proceed in a structured and functional way" (: 5).

The main sections of the thesis after the introduction and the study area description began by reconceptualizing NRBCs. Current publications indicate that the study of NRBCs in the era of the Anthropocene needs to be reconceptualized to be able to explore strategies for conflict management which are beyond the hitherto military strategies often employed in the different international interventions on conflicts in the developing countries, particularly in Africa and Asia (Section 3). Multilateral agencies such as the United Nations, the North Atlantic Treaty Organization (NATO) and other peacekeeping international organizations, often embark on the use of military strategies which have proved to be unsustainable. This is because NRBCs are complex and "wicked" in nature (Brauch, 2003a, Spring et al., 2009, Brauch, 2010, Brauch, 2016b, Brauch, 2016a). By reconceptualizing NRBCs, the research firstly clarifies the concepts of risk, risk perception resilience, vulnerability assessment, and the "Vulnerability Cube". Secondly, the bridging of the gap between the concepts of a holistic vulnerability assessment (HVA) and the NRBCs was discussed. Thirdly, the integration of HVA of NRBCs into fuzzy logic theory was presented. This was implemented in Section 5. The main argument of this Section 3 is that the complex characteristics of vulnerability to NRBCs require the use of a non-linear theoretical model that is adaptable and capable of addressing the complexities of NRBCs research.

After the reconceptualization of NRBCs in Section 3, the thesis then followed the three phases of the transdisciplinary research approach proposed by Mauser et al. (2013) (see also Section 1.4 and Section 5.1). This phase dealt with a joint problem framing. This helped to operationalize NRBCs for simulation (see Section 4). The problem of NRBCs was framed by integrating the problem structuring methods (PSMs) (e.g GIS) with the qualitative method (e.g discourse analysis). The results of this joint problem framing showed the different drivers of NRBCs which were selected by the actors. With the aid of GIS, the actors' mental maps were presented based on the different dimensions of NRBCs vulnerability. The results also show the similarities in the interest of local actors. The joint problem framing equally helped to organize and operationalize the input variables that were used for the modeling phase of the research. Hence the operationalization of the conflict drivers/factors generated from the joint problem framing is seen as a critical step in the transdisciplinary-based coupled approach to NRBCs.

The second phase of the research after the joint problem phase is a co-production of knowledge for managing the NRBCs with the integration of knowledge from the actors. Here the overall research methodology and the algorithm of SEFLAME-CM were presented in Section 5. This was validated following a rigorous validation process (see Section 6). Prior to the validation of SEFLAME-CM, a non-spatially explicit model, Fuzzy Logic Adapted Modeling for Conflict Management (FLAME-CM) was developed, improved and validated following an iterative process using scores like R^2, p-values, RMSE. The results of the validated FLAME-CM was conducted at village scale as a test site, but this was transferred to a spatially explicit context using a resolution of 200 x 200m^2. The content of the FLAME-CM helped to establish a SEFLAME-CM. The validation of SEFLAME-CM is, therefore, an extension of FLAME-CM validation result (Figure 6.7). As seen in Figure 6.7, the result of the validated SEFLAME-CM is the final output of the model and the process does not have to go back to the FLAME-CM process. Figure 6.7 shows the schematics of the overall validation process. SEFLAME-CM was firstly validated by comparing outputs with spatial multi-criteria evaluation for conflict management (SMCE-CM) and secondly by using satellite remote sensing data. The result of the latter proved that the model result corresponds with the real world data (remote sensing). The result of the former shows that SEFLAME-CM performed better even when compared with the already established model of SMCE-CM. However, the advantage of SEFLAME-CM is that it accepts weighted inputs by the actors or stakeholders right from the problem framing phase. The entire methodological procedure of the research, therefore, shows a blend of methodology from the natural sciences and the social sciences, and integration of integration co-created knowledge with the actors.

The third and the last phase of the research process of this thesis is the outlook and conclusion (see Section 7). It dealt with the research proposal for co-construction of scenario pathways for long-term conflict management strategies. The scenario construction, when applied in the future, would address the positive potential of collective natural resource management for longer-term peacebuilding and sustainable peace (Bruch *et al.*, 2009, Ratner *et al.*, 2013). It was conceived that after developing and validating an innovative spatially explicit component of the simulation model, SEFLAME-CM, the next logical step of the thesis is to apply the methodology for future conflict management. The "scenario" proposal for future CM is a period from 2016 to

2060. The justification is that while global scenarios cover time horizons of say 50–100 years, local scenarios focus on shorter periods, 20–30 years (Folhes et al., 2015). The choice of a scenario time frame that is longer than 20–30 years is because the study outcome is considered to be applicable to regional or national governance. When the co-constructed scenarios are implemented, they would help to explore CM options and strategies that can influence policy and decision making over natural resource management (NRM). For example, in the Niger Delta, the investments in CM can be re-channeled from military strategies and the current unsustainable Presidential Amnesty Programmes to achieve both peacebuilding and sustainability. Since social resilience is a "naturally emergent" response to harm or disaster, it is argued that conflict management plans must recognize and build on community adaptive capacities, while the areas of high resilience in terms of peace should be priority areas for future NRM.

In a nutshell, the thesis enables the application of a transdisciplinary-based coupled approach that is based on co-creation of knowledge between the experts and the local actors in the management of NRBCs. Both the external and internal vulnerability drivers of NRBCs were assessed. The results demonstrate that environmental degradation, socio-economic and political drivers of resource conflict can be addressed holistically as well as being treated as separate drivers in the interplay of natural resources and conflicts at the community scale. Though there are limitations, relating to cost, time and the complex social processes involved in modeling a real-world process, the results at a fine-grained spatial and temporal scale proved to be very useful and form the basis for supporting integrated coastal zone management (ICZM) strategies for the future management and development of the Niger Delta region. The model remains very adaptable to other NRBCs cases in Africa and other regions of the world. This is especially where both natural resource extraction and conflicts intertwine, and particularly when there is either data scarcity or the available data sets are imprecise.

9. Zusammenfassung (German)

Diese Arbeit demonstriert eine neue Herangehensweise zur Analyse von Vulnerabilität gegenüber Konflikten, die auf natürlichen Resourcen beruhen (Natural Resource Based Conflicts: NRBCs). Gezeigt wird die Entwicklung von SEFLAME-CM-A, ein räumlich explizites Fuzzy Logic Modell für Konfliktmanagement. SEFLAME-CM-A ist ein innovatives Tool, welches an co-konstruierte Klimamodellszenarien unter verschiedenen Bedingungen anpassbar ist. Im Speziellen wurde festgestellt, dass eine Methode mit weltweitem Blick und Expertenwissen besser dazu in der Lage ist Konflikte zu erklären, als die bisherigen linearen Modelle, wie etwa multivariate lineare Regressionen (MLRM) oder multinomiale logistische Regressionen (MNLR). SEFLAME-CM zeigte sich als verlässliches Tool um die Nicht-Linearitäten, Unsicherheiten, fehlende Präzision und Mehrdeutigkeiten abzufangen, welche Vulnerabilitätsanalysen prinzipiell mit sich bringen.

Das räumliche Ausmaß der Studie ist auf ausgewählte Gebiete im Niger Delta begrenzt, die in LGAs/Communitys und Dörfer strukturiert sind. Trotz Unsicherheiten, welche bei realen Anwendung der NRBCs eine Rolle spielen, z.B. sozial-ökonomische Systeme, ermöglichte die zunehmende Leistungsstärke von Computern in den vergangenen Jahrzehnten auch Modellierungen von Sachverhalten höherer Komplexität. Probleme, die sozio-ökonomische und biophysikalische Räume spalten, schaffen eine Notwendigkeit sowohl für Expertenwissen, als auch für Mitwirken der lokal Beteiligten. Seidl et al. (2013) empfehlen für eine Wissenschaft mit Sozialforschung im Anthropozän, dass die Perspektive auf gekoppelte Mensch-Umwelt-Beziehungen dabei helfe, die damit einhergehende Komplixität besser berücksichtigen zu können. Zusätzlich sei eine gewissenhafte Interaktion zwischen Wissenschaft und Gesellschaft (also Interdisziplinarität) notwendig, da nachhaltige Umstellungen manchmal umstritten seien und Konflikte hervorrufen könnten. Um sich in der Komplexität zurechtzufinden, welche die heiklen Interaktionen zwischen wissenschaftlicher Forschung und gesellschaftlichen Entscheidungen mit sich bringen, müssten diese Prozesse auf strukturierte und funktionale Art und Weise ausgeführt werden.

Das Hauptkapitel dieser Arbeit, welches sich an die Einleitung und die Beschreibung des Untersuchungsgebiet anschließt, begann mit der Entwicklung eines neuen Denkansatzes bezüglich NRBCs. Aktuelle Veröffentlichungen zeigen, dass die Untersuchung dieser Konflikte neue Strategien des Konfliktmanagements erforderlich macht, die jenseits der bisherigen militärischen Lösungen liegen, wie sie derzeit in Entwicklungsländern vor allem in Afrika und Asien eingesetzt werden. Obwohl sie sich im Anthropozän als nicht nachhaltig erwiesen, da die Ursachen der Konflikte eindeutig in Umweltproblemen zu suchen sind, sind zahlreiche multilaterale Vertretungen wie die Vereinten Nationen, NATO oder internationale Organisationen zur Friedenswahrung auf die militärischen Strategien aufgesprungen (Brauch, 2003a, Spring et al., 2009, Brauch, 2010, Brauch, 2016b, Brauch, 2016a). Aus diesem Grund klärt diese Studie erstens die Konzepte von Risiko, Risikowahrnehmung, Resilienz, Vulnerabilitätsanalysen und Vulnerabilitätswürfel. Zweitens wurde eine Brücke zwischen dem Konzept der holistischen Vulnerabilitätsanalyse (holistic vulnerability assessment HVA) und NRBCs geschlagen. Drittens wurde die Integration der HVA von NRBCs in die Fuzzy Logic Theorie vorgestellt. Dies wurde in Section 5 eingebaut. Dessen Hauptargument war, dass die komplexen Eigenschaften der NRBCs einem nicht-linearen theoretischen Modell bedürfen, welches sowohl anpassungsfähig ist, als auch der Komplexität der NRBC-Forschung gerecht wird.

Nach der Neukonzeptionalisierung von NRBCs in Section 3, folgte die Arbeit schließlich dem Ansatz der drei Phasen transdisziplinärer Forschung von Mauser et al. (2013, siehe Section 1.4). Diese Phase verfolgte einen vereinten Problemlösungsansatz. Dieses Framework mit seiner Strukturierung ermöglichte die Operationalisierung von NRBCs für Computer-Simulationen. Dabei werden problemstrukturierende Methoden, wie beispielsweise GIS, mit qualitativen Methoden, z.B. einer Diskursanalyse, kombiniert. Die Ergebnisse der Implementierung von Problemabgrenzung und –strukturierung zeigt die unterschiedlichen Treiber von Konflikten über Naturresourcen, die von den Akteuren genannt wurden. Mithilfe von GIS wurden Mental Maps der Akteure basierend auf den verschiedenen Dimensionen des Konflikts und der Vulnerabilität visualisiert. Die Ergebnisse zeigen die Gemeinsamkeiten des Interesses lokaler Aktuere. Gleichwohl half die gemeinsame Problemabgrenzung dabei, die Eingangsvariablen zu organisieren, die in der Modellierungsphase genutzt wurden. Deshalb wird die Operationalisierung der Konfliktfaktoren, welche bei der gemeinsamen Problemabgrenzung erzeugt wurde, als kritischer Schritt im interdisziplinären Modellansatz naturresourcenbedinger Konflikte gesehen.

Die zweite Phase nach der gemeinsamen Problemphase war die Koproduktion zwischen Wissen über Konflikte über Naturresourcen und die Integration des Wissens der Akteure. Die Methodik und der Algorithmus von SEFLAME-CM wurde in Section 5 vorgestellt und anschließend einem strengen Validierungsprozess unterworfen (Section 6). Vor der Entwicklung des disziplinübergreifenden Modellansatzes SEFLAME-CM, welcher validiert und in dieser Arbeit angewandt wurde, wurde ein ähnliches, aber räumlich nicht explizites Modell – FLAME-CM – entwickelt, verbessert und einem iterativen Prozess folgend mit Methoden wie R^2, p-Values und RMSE getestet. Das Ergebnis des validierten FLAME-CM wurde auf lokaler Skala durchgeführt, aber dann auf räumlich expliziten Kontext mit einer Auflösung von 200x200 Metern übertragen. Wie in Abbildung 6.7 gezeigt, ist der Modell-Output von SEFLAME-CM final und der Prozess muss nicht länger auf FLAME-CM zurückgestuft werden. Abbildung 6.7 skizziert den übergreifenden Validierungsprozess. SEFLAME-CM wurde zunächst validiert, indem die Outputs mit einer räumlich multikriteriellen Evaluierung im Konfliktmanagement (Spatial Multi-Criteria Evaluation for Conflict Management, SMCE-CM) verglichen wurden. Die Ergebnisse des zuletztgenannten Verfahrens belegten, dass die Modellergebnisse korrekt mit echten Daten (Fernerkundung) übereinstimmen. Das Ergebnis des erstgenannten Verfahrens zeigt, dass SEFLAME-CM bessere Resultate erzielt, selbst wenn es mit dem existierenden Modell SMCE-CM verglichen wird. Der Vorteil von SEFLAME-CM ist jedoch, dass es ohne Weiteres gewichtete Inputs durch die Akteure und Stakeholder direkt in der Phase der Problemabgrenzung annimmt. Die gesamte methodologische Wissenschaftsprozedur zeigt daher einen Methodenmix aus Natur- und Sozialwissenschaften, wie beispielsweise eine integrative Kooperation der verschiedenen Akteure.

Die dritte und letzte Phase der Arbeit beinhaltet den Ausblick und die Schlussfolgerung (Section 7). Sie behandelt die Anwendung der gekoppelten Informationen. Diese finale Wissenschaftsphase umfasst eine gemeinschaftliche Erarbeitung von Szenarien und eine Simulation von Langzeitstrategien zum Konflikt-Management. Die Erstellung der Szenarien behandelt das Potential eines gemeinschaftlichen Management natürlicher Resourcen. Eine Verbesserung der Zusammenarbeit wird im Konflikt-Management zunehmend als wichtiger Bestandteil dauerhafter Friedensschließung angesehen (Bruch *et al.*, 2009, Ratner *et al.*, 2013). Nach Entwicklung und Validierung einer innovativen, räumlich expliziten Modell-Komponente, SEFRAME-CM, war der nächste logische Schritt dieser ArbAeit die Methoden auf zukünftiges Konflikt-Management anzuwenden, indem das Management natürlicher Resourcen in Klimamodelle integriert wurde. Der Vorschlag für ein „Szenario" für zukünftiges Konfliktmanagement beinhaltet die Zeitperiode von 2016 bis 2060. Dies liegt darin begründet, dass sich lokale Szenarien mit 20-30 Jahren (Folhes et al., 2015) auf kürzere Zeiträume konzentrieren, während globale Szenarien einen Horizont von 50-100 Jahren umspannen. Die Wahl fällt auf einen Zeitraum von 20-30 Jahren, da die Ergebnisse der Studie auf regionaler und nationaler Regierungsführung anwendbar sind. Eine Implementierung der gemeinschaftlich konstruierten Szenarien würde dabei helfen Optionen und Strategien des Konfliktmanagements zu erkunden, welche die Politik und deren Entscheidungsträger im Bezug auf Ressourcenmanagement beeinflussen. Eine Investition in Konflikt-Management, z.B. im Niger Delta, kann durch Neuausrichtung militärischer Strategien und das derzeit nicht-nachhaltige Presidential Armnesty Programm geschehen um Friedensbildung und Nachhaltigkeit zu erreichen. Da soziale Resilienz eine naturgemäße Antwort auf Unheil und Katastrophen darstellt, wird oft so argumentiert, dass Pläne zum Konflikt-Management die adaptiven Möglichkeiten der Communitys anerkennt und auf ihnen aufbaut, während Gebiete mit hohem Potential an Resilienz prioritär für Naturresourcen-Management der Zukunft angesehen wird

Zusammenfassend lässt sich sagen, dass die in dieser Arbeit dargestellte Herangehensweise die Anwendung eines interdisziplinären Modells ermöglicht, das auf gemeinsam entwickeltem Wissen von Experten und lokalen Akteuren im Management von NRBCs beruht. Sowohl die externen als auch internen Vulnerabilitätstreiber der NRBCs wurden bewertet. Die Ergebnisse zeigen, dass die Degradation der Umwelt sowie sozio-ökonomische als auch politische Treiber von Resourcenkonflikten jeweils holistisch, aber auch als separate Treiber im Zusammenspiel natürlicher Resourcen und Konflikten auf kommunaler Ebene behandelt werden können. Trotz allem gibt es Limitierungen, die hauptsächlich auf den komplexen sozialen Prozessen der realen globalen Prozesse beruhen. Die Ergebnisse aus räumlich und zeitlich hoch aufgelösten Daten zeigte sich als sehr nützlich und stellt die Basis für die Unterstützung der Strategien des integrierte Management von Küstenzonen dar, wie sie für ein zukünftiges Management in der Region des Niger Deltas Anwendung finden soll. Das Modell bleibt dabei stark anpassungsfähig für ähnliche Fälle von NRBCs in Afrika und anderen Regionen der Welt, bei denen biophysikalische, sozio-ökonomische und politische Verbindungen entzweit werden. Dies gilt besonders dann, wenn die Datengrundlage knapp und die verfügbaren Datensätze unpräzise.

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A Transdisciplinary-Based Coupled Model Approach
For Vulnerability Assessment in the Context of Natural Resource Based Conflicts
Using Remote Sensing, Spatial Statistics and Fuzzy Logic Adapted Models

APPENDIX

Dissertation der Fakultät für Geowissenschaften

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Communities Involved		Causes/Types of Conflicts	Year
1	Andoni and Ogoni	Territorial/land dispute	1970
2	Andoni and Ogoni	Territorial/land dispute	1974
3	Gbarain versus SPDC	Social amenities	1992
4	Gbarain community versus SPDC	EIA	1992
5	Oluasiri (Nembe) and Orusangama(Kalabiri)	Territorial/land dispute	1994
6	Gbarain Oil Field owner versus SPDC	Environmental Impact Assessment(EIA)	1994
7	Oluasiri (Nembe) and Orusangama(Kalabiri)	Territorial/land dispute	1995
8	Bassambiri and Ogbolomabiri	Problem of Location ofL.G.A. Headquarters	1997
9	Okuruama versus Abuloma	Social amenities	1997
10	Ilajes and Ijaws	Territorial/land dispute	1998
11	Andoni and Ogoni	erritorial/land dispute	1998
12	Okpoama and Ewoam	Chieftaincy	1998
13	Ikebiri versus Agip	Social responsibilities	1998
14	Ojobo versus shell SPDC	Violation of MOU. Social responsibilities	1998
15	Ilajes and Ijaws	Territorial/land dispute	1999
16	Epebu Versus Emadike	Land	1999
17	Okpoama and Twon-Brass	Land	1999
18	Oleh versus Olomoro	Oil field dispute	1999
19	Ogu and Bolou	Territorial/land dispute	2000
20	Ijaws and Itsekiri's	LGA Creation/ward creation/Territorial/land disp	2000
21	Akassa and Egweama	erritorial/land dispute	2000
22	Epebu Versus Emadike	Land	2000
23	Choba Youths versus Wibros	Social amenities	2000
24	Egi Youths versus Agip	Social amenities	2000

A. 12.1 Cases of Inter-and Intra Community Natural Resource-Based Conflicts in the Case Studies (Continued).

25	Okpoama –Tubu versus Agip	Social responsibilities	2000
26	Tebidaba versus Agip	Social responsibilities	2000
27	Elekahia Youths versus Nkpogu Youths	Social responsibility	2000
28	Opuoma and Oforibiri	Land dispute	2000
29	Ke and Bille	The territorial/land dispute	2001
30	Eleme and Okirika	The Territorial/land dispute	2001
31	Okirika and Ikwerre	The Territorial/land dispute	2001
32	Amabolou and Ayama	The territorial/land dispute	2001
33	Biogbolo and Yeneizue	Land	2001
34	Akassa and Koluama	Land dispute	2002
35	Biseni and Okordia	Land/Oil field	2002
36	Olugbobiri vs Ologboro	Oil well field	2002
37	Apoi versus Agip	Social amenities	2003
38	Epie communities versus SPDC	Oil spillage	2003
39	Ijaws and Itsekiri's	LGA Creation/ward creation/Territorial/land disput	2004
40	Ekeremor and Ogbodobiri	Piracy Issue	2004
41	Rukpokwu versus SPDC	Oil Spillage	2004
42	Niger Delta Peoples Volunteer	Resources control, self-determination,	2004
43	Niger Delta vigilantee versus Niger Delta Peoples Volunteer Force	Protection of rights	2004

A. 12.2 A List of Selected Scientific Papers on Conflict Management in the Niger Delta (2000-2017).

Year		Author	Short Title	Approach	Research Type e.g Review, Qulitative, Quantitatve	Method of Data Collection	**Participatory Method: (No: Not used or recommended Yes: used or recommended**
1	2008	Watts, M.J	Blood Oil: The Anatomy of a Petro-Insurgency	Resource Curse	Theoretical	Literature and Secondary Sources	No
2	2008	Oyefusi, A	Oil and the Probabaility of Rebel Participation	Resource Curse	Quantitative	Survey	Yes
3	2009	Obi, C	Understanding the Complex Drivers	Resource Curse	Theoretical	Literature	Yes
4	2009	Agbonifo, J	Territorialising conflicts	Resource Curse	Review	Literature	Yes
5	2009	Ogundiya, S	Domestic Terrorism Threats	Terrorism	Review	Secondary sources	No
6	2009	Watts, M.J	Life & Death on the Nigerian Oil Fields	Resource Curse	Theoretical	Literature and Secondary sources	No
7	2009	Babatunde, A	Oil Exploration and Conflict	Resource Curse	Quantitative	Survey	Yes
8	2009	Ako, R	Nigeria's Land use Act: Environmental Justice	Law	Theoretical	Literature/Secondary sources	Yes
9	2010	Obi, C	Oil as the 'curse' of conflict	Resource Curse	Review	Literature	No
100	2010	Ibaba, I .S	Violent Conflicts and Sustainable Dev	Sustainable Development/institutional analysis	Qualitative	Interview	Yes
11	2011	Ogundiya, S	Beyond the Geography of Terrorism and Terror of Geography	Terrorism	Review	Literature /Secondary sources	No
12	2011	Oluwaniyi, O	Post-Amnesty Programme: Challenges and Prospects	Post-Conflict Amnesty	Review	Literature	Yes
13	2012	Aghedo, I	Winning the War, Losing the Peace: Amnesty Challenges of Post-Conflict	Post-Conflict Amnesty	Review	Literature	No

A.12.2 A List of Selected Scientific Papers on Conflict Management in the Niger Delta (2000-2017) (Continued).

14	2012	Mähler,A	An inescapable curse? Resource management, violent conflict, and peacebuilding i	Resource Curse	Review	Literature	Yes
15	2013	Austine E and Sunday E. C	A Critical Appraisal of the Amnesty Programme	Post-Conflict Armensty	Review	Literature	Yes
16	2014	Obi, C	Oil and the Post-Amnesty Programm(PAP):Sustainable Dev	Post-Conflict Armensty	Review	Literature	Yes
17	2015	Aibola, Iyabobola O	The Role of Enpowerment in Achieving Peace & Development	Empowerment and Development	Review	Literature	Yes
18	2015	Nwankwo, B. O	The Politics of Conflict over Oil	corporate social responsibility	Review	Literature and Secondary sources	Yes
19	2016	Charisma, A	Managing Wickedness	Wicked Problem approach	Qualitative/Content analysis	Secondary sources	Yes
20	2016	Pierskalla, J and K Carlo	Effects of Oil Production on Violent Conflicts	Terrorism	Mixed Methods	Survey	No
21	2016	Rustad, Sri, A	Socioeconomic Inequalities and Attitudes Toward Violence	Inequalities	Quantitative	Survey	Yes
22	2016	Ahmed, Iqbal	Natural Resources, C conflict, & Sustainable Development	Sustainable Development	Theoretical/mixed method	Literature	Yes
23	2016	Idemudia, U and Osayande, N	Effect of corporate social responsibility on community development	Corporate Social Responsibility	Theoretical	Literature	Yes
24	2017	Idemudia, Uwafiokun	Business and peace in the Niger Delta	Corporate Social Responsibility	Theoretical	Literature	Yes

A..12.3 List of Equations used for Deriving the Conflict Driver Parameters.

CD	*Equations*	*Definition of functions*		
		CD	=	*Conflict Drivers*
WP	$RatingVery_{near} = \frac{\sum_{i=1}^{N} r(Very\ near, Acrtor_i)}{N}$	*r*	=	*See Equations 4.1 and 4.2 for definition*
	$Ratinnear_r = \frac{\sum_{i=1}^{N} r(Near, Acrtor_i)}{N}$	*N*	=	*See Equations 4.1 and 4.2 for definition*
	$Rating_{Far} = \frac{\sum_{i=1}^{N} r(Far, Acrtor_i)}{N}$	*WPdist1*	=	*Water Pollution distance (fuzzy parameter category 1*
	$Weight_{WPdist} = r(Rating_{Very\ near}, WPdist1\%) + r(Rating_{Near}, WPdist2\%)$	*WPdist1*	=	*Water Pollution distance (fuzzy parameter category 2)*
	$+r(Rating_{Far}, MLdist3\ \%)$	*WPdist1*	=	*Water Pollution distance (fuzzy parameter category 3)*
FL	$Weight_{FLdist} = r(Rating_{Very\ near}, FLdist1\%) + r(Rating_{Near}, FLdist2\%)$	*r*	=	*See Equations 4.1 and 4.2 for definition*
	$+r(Rating_{Far}, FLdist3\ \%)$	*N*	=	*See Equations 4.1 and 4.2 for definition*
		FLdist1	=	*Farmland loss distance (fuzzy parameter category 1)*
		FLdist2		*Farmland loss distance (fuzzy parameter category 2)*
		FLdist3	=	*Farmland loss distance (fuzzy parameter category 3)*
OI	$Weight_{OIdist} = r(Rating_{Very\ near}, OIdist1\%) + r(Rating_{Near}, OIdist2\%)$	*n*	=	*See Equations 4.1 and 4.2 for definition*
	$+r(Rating_{Far}, OIdist3\ \%)$	*N*	=	*See Equations 4.1 and 4.2 for definition*
		FLdist1	=	*OilInfrastructure distance (fuzzy parameter category 1)*
		FLdist2	=	*OilInfrastructure distance (fuzzy parameter category 2)*
		FLdist3	=	*OilInfrastructure distance (fuzzy parameter category 3)*
POV	$Rating_{Hight} = \frac{\sum_{i=1}^{N} r(High, Acrtor_i)}{N}$	*n*	=	*See Equations 4.1 and 4.2 for definition*
	$Rating_{Medium} = \frac{\sum_{i=1}^{N} r(Medium, Acrtor_i)}{N}$	*N*	=	*See Equations 4.1 and 4.2 vfor definition*
	$Rating_{Low} = \frac{\sum_{i=1}^{N} r(Low, Acrtor_i)}{N}$	*POV_Level1*	=	*Poverty level (fuzzy parameter category 1)*
		POV_Level2	=	*Poverty level (fuzzy parameter category 2)*
	$Weight_{Pov\_Level} = r(Rating_{High}, Pov\_Level1\%) + r(Rating_{Medium}, Pov\_Level2\%) + r(Rating_{Low},$	*POV_Level3*	=	*Poverty level (fuzzy parameter category 3)*

A. 6.3 List of Equations used for Deriving the Conflict Driver Parameters (Continued).

Parameter	Equation	Definitions
ED	$Rating_{LTertiary} = \frac{\sum_{i=1}^{N} r(High, Acrtor_i)}{N}$ $Rating_{LSecondary} = \frac{\sum_{i=1}^{N} r(Medium, Acrtor_i)}{N}$ $Rating_{LPrimary} = \frac{\sum_{i=1}^{N} r(Low, Acrtor_i)}{N}$ $Weight_{ED_{Level}} = r\left(Rating_{Tertiary}, ED_{Level1}\%\right) + r\left(Rating_{Secondary}, ED\_Level2\%\right)$ $+r(Rating_{Primary}, ED\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *ED_Level1* = *Educational level (fuzzy parameter category 1)* *ED_Level2* = *Educational level (fuzzy parameter category 2)* *ED_Level3* = *Educational level (fuzzy parameter category 3)*
MG	$Weight_{MG} = r\left(Rating_{High}, MG\_Level1\%\ \right) + r(Rating_{Medium}, MG\_Level2\%\ )$ $+r(Rating_{Low}, MG\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *MG_Level1* = *Migration level (fuzzy parameter category 1)* *MG_Level2* = *Migration level(fuzzy parameter category 2)* *MG_Level3* = *Migration level (fuzzy parameter category 3)*
OB	$Weight_{OB} = r\left(Rating_{High}, OB\_Level1\ \%)\right) + r(Rating_{Medium}, OB\_Level2\ \%)$ $+r(Rating_{Low}, OB\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *OB_Level1* = *Oill Benefits level (fuzzy parameter category 1)* *OB_Level2* = *Oill Benefits level (fuzzy parameter category 2)* *OB_Level3* = *Oill Benefits level (fuzzy parameter category 3)*
PR	$Weight_{MG} = r\left(Rating_{High}, PR\_Level1\ \%)\right) + r(Rating_{Medium}, PR\_Level2\ \%))$ $+r(Rating_{Low}, PR\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *PR_Level1* = *Political repression level (fuzzy parameter category 1)* *PR_Level1* = *Political repression level (fuzzy parameter category 2)* *PR_Level1* = *Political repression level (fuzzy parameter category 3)*
PE	$Weight_{MG} = r\left(Rating_{High}, PE\_Level1\ \%\right) + r(Rating_{Medium}, PE\_Level2\ \%)$ $+r(Rating_{Low}, PE\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *PE_level1* = *Political repression level (fuzzy parameter category 1)* *PR_Level2* = *Political repression level (fuzzy parameter category 2)* *PR_Level3* = *Political repression level(fuzzy parameter category 3)*
ETLF	$Weight_{ETLF} = r\left(Rating_{High}, ETLF\_Level1\ \right) + r(Rating_{Medium}, ETLF\_Level2\ )$ $+r(Rating_{Low}, ETLF\_Level3\ \%)$	*n* = *See Equations 4.1 and 4.2 for definition* *N* = *See Equations 4.1 and 4.2 for definition* *ETLF_level1* = *Political repression level (fuzzy parameter category 1)* *ETLF _level1* = *Political repression level (fuzzy parameter category 2)*

A. 6.3 List of Equations used for Deriving the Conflict Driver Parameters (Continued).

YB	$Weight_{YB} = r\left(Rating_{High}, YB_{Level1}\%\right) + r(Rating_{Medium}, YB_{Level2}\%)$ $+r(Rating_{Low}, YB\_Level3\ \%)$	*n*	=	*See Equations 4.1 and 4.2*
		N	=	*See Equations 4.1 and 4.2*
		YB_level1	=	*Youth-bulge level (fuzzy parameter category 1)*
		YB_level1	=	*Youth-bulge level (fuzzy parameter n category 2)*
		YB_level1	=	*Youth-bulge level (fuzzy parameter category 3)*

A. 6.4 A Picture of Research Team Members Taken During a Field trip to the Niger Delta Creeks.

A. 6.5 Pictures of some Examples of Land use Types Mapped with Remote Sensing Method.

A. 6.6 Picture of an Abandoned Oil well in the Niger Delta.

A. 6.7 Pictures of Water Surface Polluted with Oil Spills in the Case Studies.

A. 6.8 Sample A Letter of Introduction from the Geography Department, LMU and Letters from Department of Petroleum Resources (DPR) to Multinational Oil Corporations (MNOCs).

LMU | LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN | DEPARTMENT OF GEOGRAPHY CHAIR FOR GEOGRAPHY AND REMOTE SENSING

Chair for Geography and Remote Sensing

Prof. Dr. Wolfram Mauser

Telefon +49 (0)89 2180-6674
Telefax +49 (0)89 2180-6675
w.mauser@lmu.de
www.geographie.uni-muenchen.de
Mail address:
Luisenstraße 37
D-80333 Munich
Germany

The Director
Department of Petroleum Resources
7, Kofo Abayomi,
Victoria Island
Lagos.

Your Correspondence

Our Correspondence
Ma-2013/27

Munich, 2.Feb.2013

LETTER OF INTRODUCTION

DPR ... Director's Office 22 ... 2013

PhD Research Student IBEH, Lawrence
Request for Research Data

Dear Sir/ Madam,

Mr. Lawrence Ibeh is a Nigerian citizen and a PhD student registered at the doctoral programme of the Rachel Carson Center for Environment and Society and the Faculty of the Geosciences, Department of Geography and Remote Sensing, Ludwig-Maximilian University (LMU), Munich Germany. He is carrying out his PhD Dissertation with the title:

Risk of Violent Resource Conflict in the Niger Delta of Nigeria using Remote Sensing, Fuzzy Logic and Geospatial Methods

Mr. Ibeh is currently embarking on a field research and data collection in Nigeria. We kindly request for your support in providing us any of the following data and information for the success of this research:

- **Data on oil infrastructure location in the Niger Delta, particularly Rivers, Bayelsa and Delta states.**
- **Past Oil spill data.**
- **Access to Oil field location premises.**
- **Other data that can enhance this research.**

We confirm that the data to be provided will only be used for the purposes of this project. Only the result of the research will be published but not the data in its raw state. We will also protect the data from getting into the hands of any third party.

Thank you very much for your anticipated support.

W. Mauser
Prof. Dr. Wolfram Mauser

Dienstgebäude
Luisenstr. 37, Room 440
D-80333 Munich

Public Transport
Bus Line 100
Subway Line 2 –Station Königsplatz

Bayerische Landesbank München
Acc.No. 24 868 Bank-No. 700 500 00
USt-IdNr. DE 811 205 325

A. 6.8 Sample Letters of Introduction (Continued)- A Letter of Introduction to Shell from DPR.

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND LAGOS

P.M.B. No:.........12560.........................
Telephone:........2790000, 4611777.....
Website: www.dprnigeria.com

Ref. No:..............DPR/SE/7118/Vol.8T/109
Date:...................25th February, 2013........

The Managing Director
Shell Petroleum Development Company
Freeman House
21/22 Marina
Lagos.

Dear Sir,

LETTER OF INTRODUCTION: IBEH LAWRENCE

The bearer, Mr. Lawrence Ibeh is a PhD Research student of the Ludwig – Maximilian University (LMU), Munich Germany. He is registered at the doctoral programme of the Rachel Carson Center for Environment and Society and the Faculty of the Geosciences, Department of Geography and Remote Sensing.

2. He is currently carrying out his PhD dissertation with the title: **"RISK OF VIOLENT RESOURCE CONFLICT IN THE NIGER DELTA OIL EXTRACTIVE ENVIRONMENT USING REMOTE SENSING, FUZZY LOGIC AND GEOSPATIAL METHODS"** and requires the following to complete the research:

i. Data on your key oil infrastructure locations in the Niger Delta, Particularly Rivers, Bayelsa and Delta States including high resolution spatial imageries if available.

ii. Past Oil Spill Data (1990s till date as available).

iii. Formal and informal interviews with your key staff involved in Community Relations including the permission to administer questionnaires and other survey tools in furtherance of the research effort.

iv. Access to selected Oil field locations to groundtruth the location information.

v. Any other information or publications on environment & conflict as available.

3. Kindly afford him all the necessary assistance.

Yours faithfully,

Ms. Dorothy Bassey
for: Director of Petroleum Resources

A. 6.8 Sample Letters of Introduction (Continued)- A Letter of Introduction to Total from DPR.

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND LAGOS

P.M.B. No: 12560
Telephone: 2790000, 4611777
Website: www.dprnigeria.com

Ref. No: DPR/SE/7118/Vol.8T/110
Date: 25th February, 2013

The Managing Director
Total Exploration & Production Nigeria
35 Kofo Abayomi Street
Victoria Island
Lagos.

Dear Sir,

LETTER OF INTRODUCTION: IBEH LAWRENCE

The bearer, Mr. Lawrence Ibeh is a PhD Research student of the Ludwig – Maximilian University (LMU), Munich Germany. He is registered at the doctoral programme of the Rachel Carson Center for Environment and Society and the Faculty of the Geosciences, Department of Geography and Remote Sensing.

2. He is currently carrying out his PhD dissertation with the title: **"RISK OF VIOLENT RESOURCE CONFLICT IN THE NIGER DELTA OIL EXTRACTIVE ENVIRONMENT USING REMOTE SENSING, FUZZY LOGIC AND GEOSPATIAL METHODS"** and requires the following to complete the research:

i. Data on your key oil infrastructure locations in the Niger Delta, Particularly Rivers, Bayelsa and Delta States including high resolution spatial imageries if available.

ii. Past Oil Spill Data (1990s till date as available).

iii. Formal and informal interviews with your key staff involved in Community Relations including the permission to administer questionnaires and other survey tools in furtherance of the research effort.

iv. Access to selected Oil field locations to groundtruth the location information.

v. Any other information or publications on environment & conflict as available.

3. Kindly afford him all the necessary assistance.

Yours faithfully,

Ms. Dorothy Bassey
for: Director of Petroleum Resources

A. 6.8 Sample Letters of Introduction (Continued)- A Letter of Introduction to Agip from DPR.

MINISTRY OF PETROLEUM RESOURCES

DEPARTMENT OF PETROLEUM RESOURCES

7 KOFO ABAYOMI STREET, VICTORIA ISLAND LAGOS

P.M.B. No: 12560
Telephone: 2790000, 4611777
Website: www.dprnigeria.com

Ref. No: DPR/SE/7118/Vol.8T/111
Date: 25th February, 2013

The Managing Director
Nigerian Agip Oil Company
Mile 4, Ikwerre Road
Port Harcourt
Rivers State.

Dear Sir,

LETTER OF INTRODUCTION: IBEH LAWRENCE

The bearer, Mr. Lawrence Ibeh is a PhD Research student of the Ludwig – Maximilian University (LMU), Munich Germany. He is registered at the doctoral programme of the Rachel Carson Center for Environment and Society and the Faculty of the Geosciences, Department of Geography and Remote Sensing.

2. He is currently carrying out his PhD dissertation with the title: **"RISK OF VIOLENT RESOURCE CONFLICT IN THE NIGER DELTA OIL EXTRACTIVE ENVIRONMENT USING REMOTE SENSING, FUZZY LOGIC AND GEOSPATIAL METHODS"** and requires the following to complete the research:

i. Data on your key oil infrastructure locations in the Niger Delta, Particularly Rivers, Bayelsa and Delta States including high resolution spatial imageries if available.

ii. Past Oil Spill Data (1990s till date as available).

iii. Formal and informal interviews with your key staff involved in Community Relations including the permission to administer questionnaires and other survey tools in furtherance of the research effort.

iv. Access to selected Oil field locations to groundtruth the location information.

v. Any other information or publications on environment & conflict as available.

3. Kindly afford him all the necessary assistance.

Yours faithfully,

Ms. Dorothy Bassey
for: Director of Petroleum Resources

A. 6.9 Sample Research Questionaire.

A Questionnaire Survey on the Perception and Assessment of the Risk of Natural Resource related Conflicts in River State, Niger Delta of Nigeria

LGA..............VILLAGE................ DATE...............Name of Interviewer...

Start Interview time .... End Interview Time....................

SECTION A.

Personal Information

Respondent: Household head.........................wife as household head...........

Others (please specify)................................

A1 Gender: Male ☐ Female ☐

A2 Age and Resource use periods. Please tick the age bracket that applies to you below

Age	Period of resource use	Please tick
70 years and above	Use of resources(land, water, forest) before 1990s	
40-69years	Use of resources(land, water, forest) between 1991-2000	
20-39years	Use of resources(land, water, forest) between 2001 and today	

A3 Gender: male ☐ female ☐

A4 level of education

1. Non ☐
2. Adult literacy ☐
3. Primary ☐
4. Secondary ☐
5. Post secondary: Diploma, certificate, ☐
6. Vocationally ☐
7. University degree

A3 Household size (number of people in your family).......................

A4 Are you from an oil producing village/Community? Yes ☐ No ☐

A5 What type of oil infrastructure do you have in your village?..

A6 Employment Status

01) Unemployed ☐
02) Public Service ☐
03) Private Sector ☐
04) Self- employed ☐

A7 Occupational/Professional Status

01) Politician ☐
02) Professional ☐
03) Oil Company worker ☐
04) Student ☐
05) Trader/Businessman ☐
06) Farming ☐
07) Fishing ☐

A. 6.9 Sample Research Questionaire (Continued)

08) Wine tapping ☐
09) Others (please specify) ……………………

SECTION B.

Use of environmental resources

B1.How are the environmental resources such as land, water (rivers), forest e.g. mangrove used in your area?

Land……
……

Water(rivers)…………………………………………………………………………………………………
……

Forest……
……

B2. Has the use of the above resources changed since the past 20 to 30 years? Yes ☐ No ☐

B3 If yes, what is responsible for these changes?……………………………………………………
……
……
……

B4 Does the changes in the use or scarcity of the environmental resources led to conflicts in your area?

Yes ☐ No ☐

B5 If yes how has these changes or scarcity led to violent conflicts?……………………………………
……
……
……
……
……

B6What are other causes of violent conflicts in your area?…………………………………………
……
……
……
……
……

SECTION C.

Perception of the effects of environmental changes and the causes

Very most unlikely (0-1)
Most unlikely (2-3)
Likely (4-5)
Most likely (6-7)
Very most likely (8-10)

C1. Please rank the effects of environmental changes in your village and the causes of the changes (from 1 to 10)

	Effects of environmental Changes		Causes of the changes							
		Gas flaring	Oil spill	Climate change	New agric policy	Animal disease	Wish to increase income	Flooding and erosion	Any other ………	Total dont write here)
1	Reduced yield									
2	Use of fertilizer									
3	Lack of Food & food habits change									
4	Buying of food e.g. rice									

A. 6.9 Sample Research Questionaire (Continued).

5	Buying of firewood									
6	Traveling far for firewood									
7	Fishing has reduced totally									
8	Water scarcity									
9	No more livestock									
10	Poor health									
11	Migration to nearby village or city									
12	Any other……………….									
	Total (please don't write here)									

C2. Please state the remedies to the following environmental problems

Water scarcity………

Loss of farmland……

Change of forest……

Any other (specify)(…………)…………………………………………………………………………………………

SECTION D.
The types of conflicts

D. What types of conflicts do you experience in your village?

Please rank the following in the order of the most likely conflict type that your village has experienced in the last five years

	High	Medium	Low
D1) Conflict over claiming of Land			
D2) Village based or communal conflicts			
D3) Conflict over oil related issues e.g. environmental disasters e.g. relating to oil extraction, oil spill, oil blowout			
D4) Chieftaincy			
D5) Militancy-youth disturbances over resources such as…………………………			
D6) Others specify……………………………			
……………………………………………………			

Please give reasons for your answers…………………………………………………………………………………

………

SECTION E. (Part one)
Understanding resource conflicts
(Environment)

1. Oil infrastructure

E1. Does the location or closeness of your village to oil infrastructure affect the environmental degradation in your village? Yes☐ No☐

A. 6.9 Sample Research Questionaire (Continued).

E2. Does the location or closeness of oil infrastructure in your affect conflict likeliness in your village?
Yes☐ No☐

E3. How does the closeness of your village to oil infrastructure affect conflict likeliness in your village?

Distance to oil location	what do you think about the distance of oil location in your village	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very near	0 Low	
	0.5 Medium	
	1 High	
Near	.5 Low	
	2.5 Medium	
	3 High	
Far	2.5 Low	
	3.5 Medium	
	5 High	

Please give reasons for your answers...

....

2. Farmland

E4. Has the distance you travel for farming changed over time? Yes ☐ No ☐

E5 How does the distance you travel for farming in your village affect occurrence of conflicts in the village?

Distance to Farmland Location	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very Near	0 Low	
	0.5 Medium	
	1 High	
Near	. 5 Low	
	2.5 Medium	
	3 High	
Far	2.5 Low	
	3.5 Medium	
	5 High	

Please give reasons for your answers...

....

3. Mangrove Forest

E6 Has the distance you travel to fetch firewood changed over time? Yes ☐ No ☐

E7 How does the distance you travel to fetch firewood affect occurrence of conflicts in the village?

Distance to mangrove forest	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very near	0 Low	
	0.5 Medium	
	1 High	

A. 6.9 Sample Research Questionaire (Continued).

Naer	. 5 Low	
	2.5 Medium	
	3 High	
Far	2.5 Low	
	3.5 Medium	
	5 High	

Please give reasons for your answers...

....

4. Water

E8 Has the location you go for domestic water changed over time? Yes ☐ No ☐

E9 How does the location you go to fetch water affect occurrence of conflicts in the village?

Distance to water	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very Near	0 Low	
	0.5 Medium	
	1 High	
Near	. 5 Low	
	2.5 Medium	
	3 High	
Far	2.5 Low	
	3.5 Medium	
	5 High	

Please give reasons for your answers...

....

SECTION E (Part Two)

Understanding resource conflicts

(Socio-economic factors)

1. Poverty

E10 Please tick the income group you belong per annum in (Naira unit).

800,000-above	Very High Income	
500,000-799,000	High Income	
200,000-499,000	Medium Income	
199,000-300,000	Low income	

E11. How does Income poverty affect conflicts likeliness in your village?

Income poverty	Input space values	**Ranking (weight from 1 to 10) Very most**

A. 6.9 Sample Research Questionaire (Continued).

		unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Not much at all	Do not agree	
	Agree	
	Strongly agree	
Just a little	Do not agree	
	Agree	
	Strongly agree	
Very much	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

2. Education

E12. How does education level of people affect their participation in conflicts in your village?

Education	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Primary education	Do not agree	
	Agree	
	Strongly agree	
Secondary education	Do not agree	
	Agree	
	Strongly agree	
Tertiary education	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

3. Oil Migration

E13. When people migrate to other villages or the city, how does this affect conflicts likeliness in your village?

Oil Migration	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
High level of migration	Do not agree	
	Agree	
	Strongly agree	
Medium level of migration	Do not agree	
	Agree	
	Strongly agree	
Low level of migration	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

A. 6.9 Sample Research Questionaire (Continued).

....

E14 How does presence of a lot of youths affect conflicts?

4. Youth-Bulge

Youth Bulge	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very many youths	Do not agree	
	Agree	
	Strongly agree	
Not so many	Do not agree	
	Agree	
	Strongly agree	
Very few youths	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

SECTION E (Part Three)

Understanding resource conflicts

(Political factors)

1. Political repression

E15 How does political repression (a situation where individuals are not allowed to air their views of resource management e.g. on oil, land, forest) affect conflicts?

Political repression	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very serious abuse of individuals	Do not agree	
	Agree	
	Strongly agree	
Not very serious	Do not agree	
	Agree	
	Strongly agree	
Not serious abuse at all	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

2. Political exclusion

E16. How does political exclusion (a situation where your community or village is neglected in decision making concerning resource management) affect conflicts?

Political exclusion	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very much excluded	Do not agree	
	Agree	
	Strongly agree	
Averagely excluded	Do not agree	

A. 6.9 Sample Research Questionaire (Continued).

	Agree	
	Strongly agree	
Not excluded at all	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

3. Oil Benefits

E17 How does the benefits your village derive from oil extraction affect conflicts in your village?

Oil Benefits	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very High level of benefits	Do not agree	
	Agree	
	Strongly agree	
Medium level of benefits	Do not agree	
	Agree	
	Strongly agree	
Low level of benefits	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

4. Ethnic Fractionalization

E18 Ethnic Fractionalization (the number of ethnic groups).?

a. How many languages do you speak in your village?. 1-2[ ] 3-4[ ] 5-6 [ ] 7 and above[ ]

b. Are you willing to support your group to fight other groups over land or any natural resource?

Yes[ ] No[ ]

E19. How do you think ethnicity affect likeliness of resource violence in your village?

Ethnic Fractionalization	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very high	Do not agree	
	Agree	
	Strongly agree	
average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

A. 6.9 Sample Research Questionaire (Continued).

SECTION F

Environments, Socio-economic and Political factors

1. All Environmental factors

F1. Please rate how all the Environmental factors (e.g. oil spill, reduction of yield, loss of forest and water pollution) affect likeliness of resource conflicts in your village?

Environmental factors and violence	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

2. All Socio-economic factors

F2. Please rate how all socio-economic livelihoods affect likeliness of resource conflicts in your village?

Socio-economic livelihoods Of conflicts	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

3. All Political Factors

F3 Please rate how all the political factors together affect conflicts in your village or community?

Political factors of conflicts conflicts	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	

A. 6.9 Sample Research Questionaire (Continued).

Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

SECTION G

Relationship between Environments and Other Factors Of Conflicts

1. Environmental resource access and Poverty

G1. Please rate how your lack of access to environmental goods and poverty can cause conflicts in your village?

Resource access and poverty, and conflict relationship	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

2. Environmental resource access and Education

G 2. Please rate how your lack of access to environmental resources and education and conflict likeliness?

Resource access , education and conflict relationship	Input space values	Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

A. 6.9 Sample Research Questionaire (Continued).

3. Environmental resource access and oil migration

G3. Please rate how your lack of access to environmental resources and oil migration and conflicts likeliness

Resource access, oil migration and conflict relationship	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers……………………………………………………………………………………

………

4. Environmental resource access and Youth-Bulge

G4. Please rate how your lack of access to environmental resources and presence of lot of youth affect conflicts likeliness

Resource access, youth-bulge and conflict relationship	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers……………………………………………………………………………………

………

5. Environmental resource access and Political Repression

G5 Please rate how lack of access to environmental resources and political repression affect conflicts likeliness in your village

Resource access, political ssion and conflict relationship	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	

A. 6.9 Sample Research Questionaire (Continued).

	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

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6. Environmental resource access and Political Exclusion

G6 Please rate how lack of access to environmental resources and political exclusion affect conflicts likeliness in your village

Resource access, political exclusion conflict relationship	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

7. Environmental resource access and Political Exclusion

G7 Please rate how lack of access to environmental resources and oil benefits affect conflicts likeliness in your village

Resource access, oil benefits and ct relationship	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers...

....

8. Environmental resource access and Political Exclusion

G8 Please rate how lack of access to environmental resources and ethnic fractionalization affect conflicts likeliness in your village

A. 6.9 Sample Research Questionaire (Continued).

Resource access, ethnic group fractionalization and conflict	Input space values	**Ranking (weight from 1 to 10) Very most unlikely (0-1) Most unlikely (2-3) Likely(4-5) Most-likely(6-7) Very- most likely(8-10)**
Very high	Do not agree	
	Agree	
	Strongly agree	
Average	Do not agree	
	Agree	
	Strongly agree	
Very low	Do not agree	
	Agree	
	Strongly agree	

Please give reasons for your answers……………………………………………………………………………………

………

SECTION H

INTENSITY OF CONFLICTS

H. In the common conflicts that occur in your village, please state the degrees of conflict intensity?

Degree of Conflicts	High	Medium	Low
H1 Number of Deaths……………..			
H2Duration of Conflicts…………………..			
H3 Number of People involved…………………..			
H4 Armed or non armed …………………….			
H5 Others specify…………………………… …………………………………………………			

Please give reasons for your answers……………………………………………………………………………………

………

SECTION H

RESOURCE CONFLICT MANAGEMENT

H Resource conflict Management strategies

Please explain what you think will be a solution to the problems of environmental degradation and violent conflicts in the Niger Delta

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A. 6.10 Pictures taken During Workshops, FGDs, and Interview with the Local Actors.

A. 6.11 Sample IF THEN RULES: Environmental Dimension.

IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	FAR	"Oil Infrastructure Distance" IS	VERY NEAR	THEN	"Environmental Risk-Conflict" IS	VERY LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	FAR	"Oil Infrastructure Distance" IS	NEAR	THEN	"Environmental Risk-Conflict" IS	VERY LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	FAR	"Oil Infrastructure Distance" IS	FAR	THEN	"Environmental Risk-Conflict" IS	UNLIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	NEAR	"Oil Infrastructure Distance" IS	VERY NEAR	THEN	"Environmental Risk-Conflict" IS	VERY LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	NEAR	"Oil Infrastructure Distance" IS	NEAR	THEN	"Environmental Risk-Conflict" IS	VERY LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	NEAR	"Oil Infrastructure Distance" IS	FAR	THEN	"Environmental Risk-Conflict" IS	UNLIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	VERY NEAR	"Oil Infrastructure Distance" IS	VERY NEAR	THEN	"Environmental Risk-Conflict" IS	LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	VERY NEAR	"Oil Infrastructure Distance" IS	NEAR	THEN	"Environmental Risk-Conflict" IS	LIKELY	"AND or OR"
IF	"Mangrove Distance" IS	FAR	"Less Turbid water" IS	FAR	"Farmland Distance IS	VERY NEAR	"Oil Infrastructure Distance" IS	FAR	THEN	"Environmental Risk-Conflict" IS	UNLIKELY	"AND or OR"

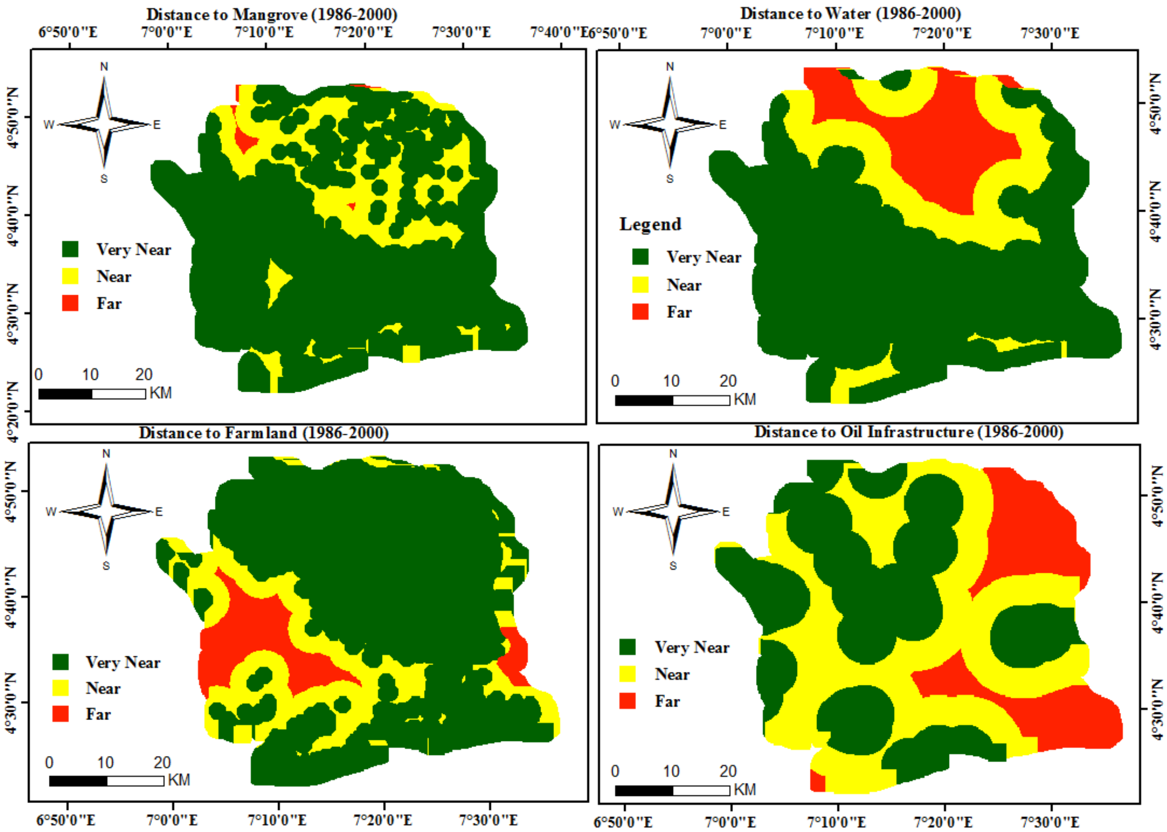
A. 6.12 Sample IF THEN RULES: Socio-economic Dimension.

IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	HIGH	"Oil Benefits	LOW	THEN	"Socio-economic Vulnerability-Con IS	VERY LIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	HIGH	"Oil Benefits	MEDIUM	THEN	"Socio-economic Vulnerability-Con IS	VERY LIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	HIGH	"Oil Benefits	HIGH	THEN	"Socio-economic Vulnerability-Con IS	UNLIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	MEDIUM	"Oil Benefits	LOW	THEN	"Socio-economic Vulnerability-Con IS	VERY LIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	MEDIUM	"Oil Benefits	MEDIUM	THEN	"Socio-economic Vulnerability-Con IS	VERY LIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	MEDIUM	"Oil Benefits	HIGH	THEN	"Socio-economic Vulnerability-Con IS	UNLIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	LOW	"Oil Benefits	LOW	THEN	"Socio-economic Vulnerability-Con IS	LIKELY	"AND or OR"
IF	"Poverty" IS	HIGH	"Educational Attainment" IS	TERTIARY	" Migration" IS	LOW	"Oil Benefits	MEDIUM	THEN	"Socio-economic Vulnerability-Con IS	LIKELY	"AND or OR"

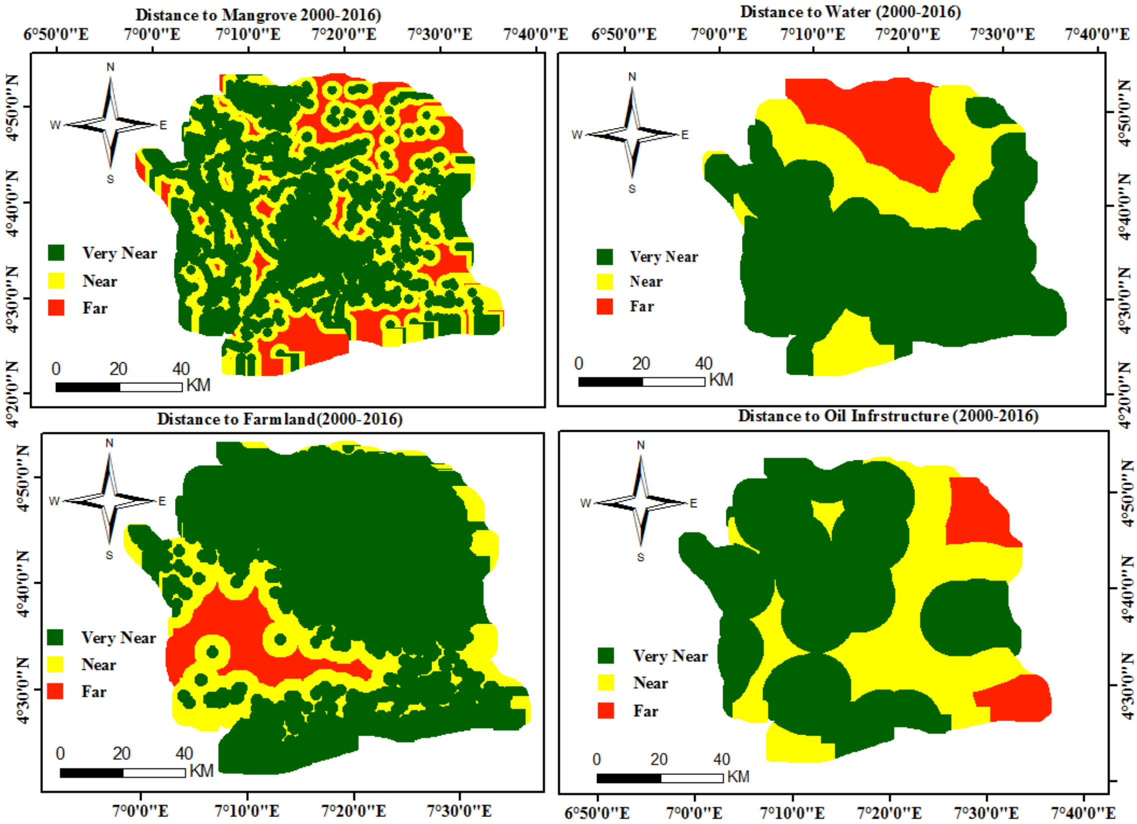
A. 6.13 Sample IF THEN RULES: Political Dimension.

IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	HIGH	"Youth- IS"	FEW	THEN	"Political Vulnerability-C IS	LIKELY	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"Ethnic Linguistic Fractionlization" IS	HIGH	"Youth- IS"	MANY	THEN	"Political Vulnerability-C IS	VERY LIK	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"Ethnic Linguistc Fractionalization" IS	HIGH	"Youth- IS"	VERY MANY	THEN	"Political Vulnerability-C IS	VERY LIK	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	MEDIUM	"Youth- IS"	FEW	THEN	"Political Vulnerability-C IS	UNLIKEL	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	MEDIUM	"Youth- IS"	MANY	THEN	"Political Vulnerability-C IS	LIKELY	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	MEDIUM	"Youth- IS"	VERY MANY	THEN	"Political Vulnerability-C IS	VERY LIK	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionlization" IS	LOW	"Youth- IS"	FEW	THEN	"Political Vulnerability-C IS	UNLIKEL	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	LOW	"Youth- IS"	MANY	THEN	"Political Vulnerability-C IS	LIKELY	"AND or OR"
IF	"Political Repression IS"	HIGH	"Political Exclusion IS"	HIGH	"EthnicLinguistc Fractionalization" IS	LOW	"Youth- IS"	VERY MANY	THEN	"Political Vulnerability-C IS	VE LII	"AND or OR"

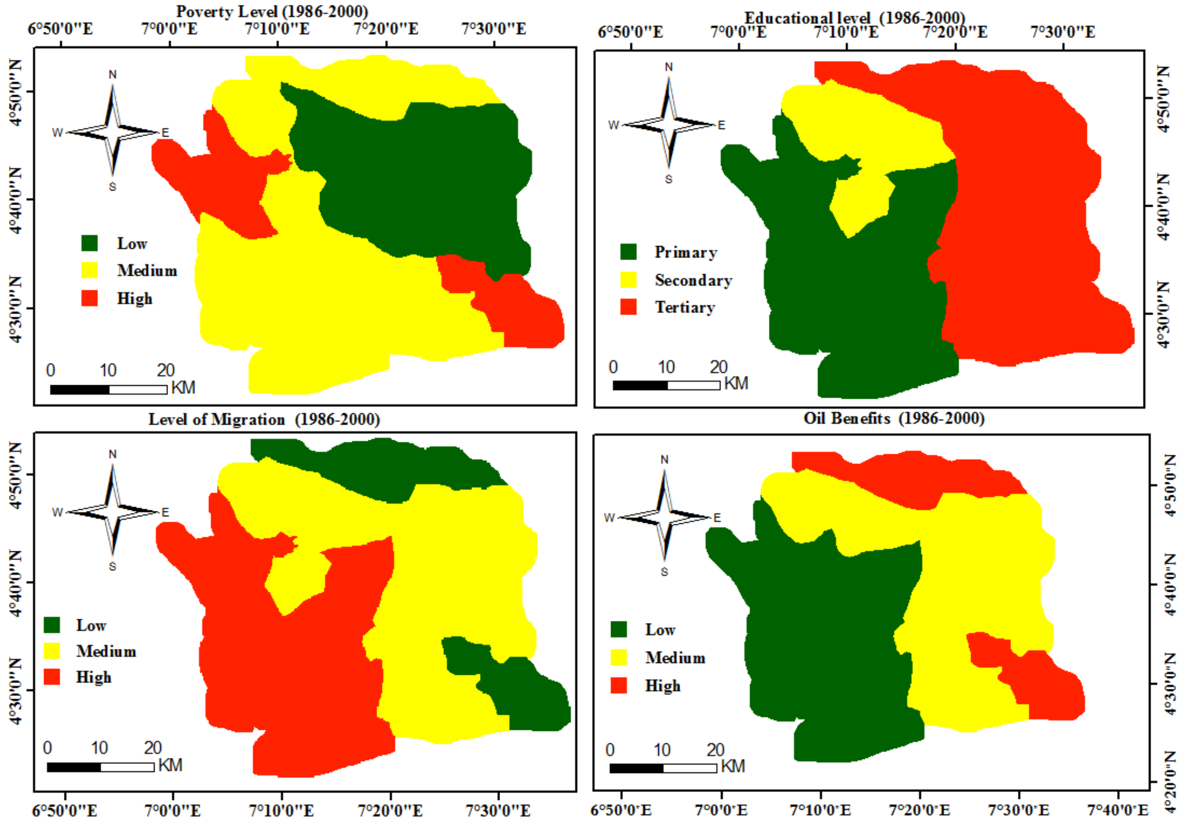
A. 6.14 Maps of Environmental Drivers and Parameters of Natural Resource-Based Conflicts, 1986-2000.



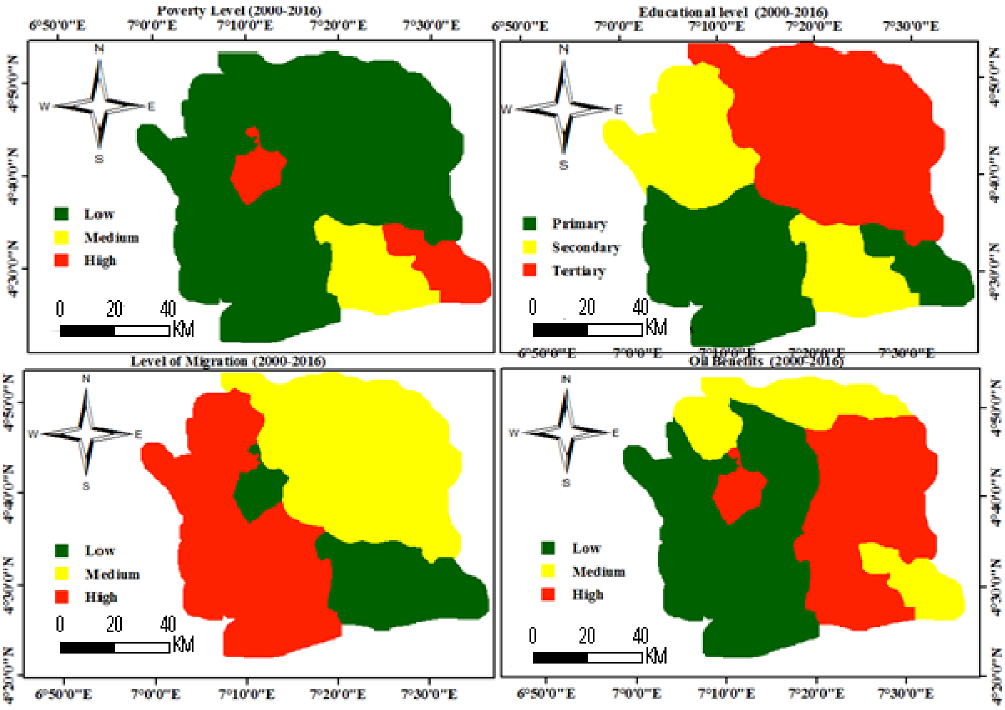
A. 6.15 Maps of Environmental Drivers and Parameters of Natural Resource-Based Conflicts, 2000-2016.



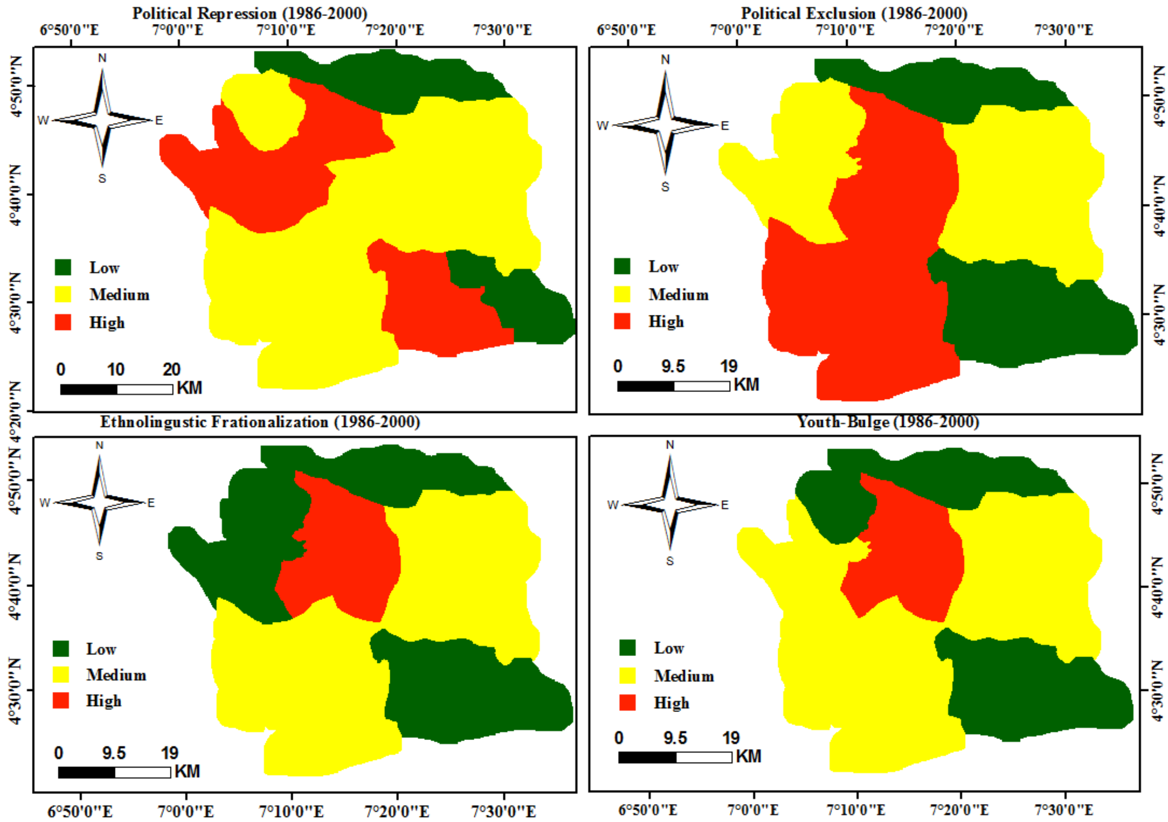
A. 6.16 Maps of Socio-economic Drivers and Parameters of Natural Resource-Based Conflicts, 1986-2000.



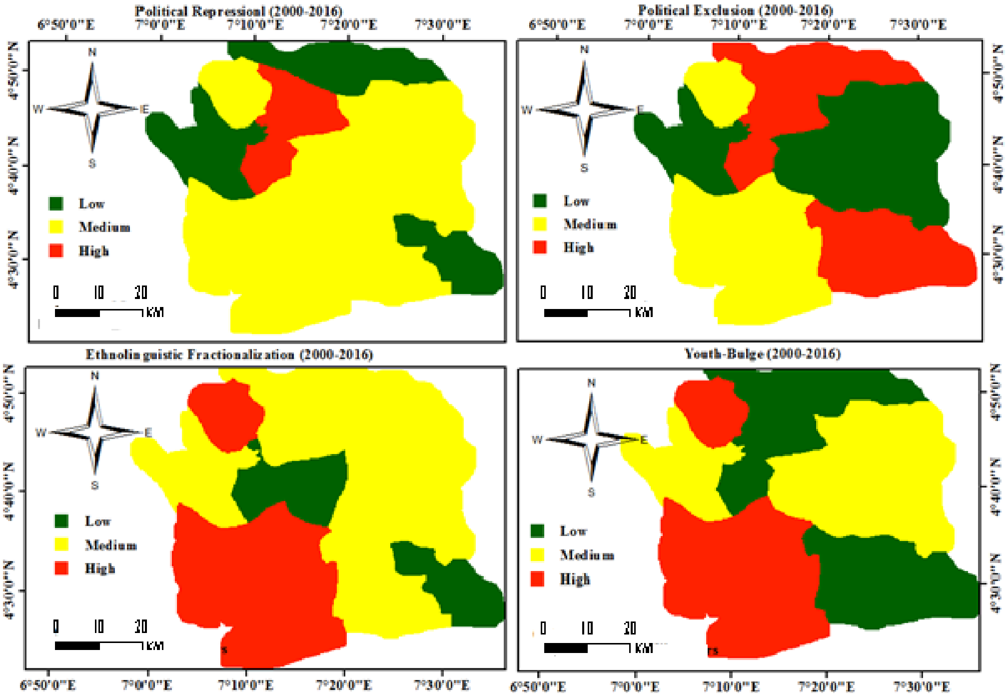
A. 6.17 Maps of Socio-economic Drivers and Parameters of Natural Resource-Based Conflicts, 2000-2016.



A. 6.18 Maps of Political Drivers and Parameters of Natural Resource-Based Conflicts 1986-2000.



A. 6.19 Maps of Political Drivers and Parameters of Natural Resource-Based Conflicts 2000-2016



A. 6.20 Sample Points for Remote Sensing Data Validation.

ID	Village	Land use Type	Longitude(M)	Latitude(M)
1	Eleme	Built up	291009.6087	529296.7013
2	Ogale	Built-up	292108.3101	529472.9016
3	Tai	Built up	303476.9438	524149.6056
4	Beree	Built-up	325090.0704	518745.794
5	Wiiyaakara	Built up	324672.4689	515894.6689
6	Bori	Built up	319146.5541	517277.764
7	Yeghe	Built-up	317366.1014	517476.8577
8	Beera	Built up	312085.7845	515907.9509
9	Mogho	Built up	308991.5698	513673.3395
10	Biara	Built up	312009.2364	517105.93
11	Ogu	Built-up	300993.7634	522142.6367
12	Refinaery	Built up	288924.6935	526875.657
13	Okrika	Built up	289182.8201	525950.9425
14	Finima	Built-up	296837.9373	490435.0548
15	Andoni	Built-up	324224.2125	495732.7277
16	Opobo	Built up	328534.1837	504442.4611
17	Oyigbo	Built-up	306176.2082	535510.17
18	Oyigbo	Built-up	309498.4777	533444.9755
19	Gokana	Built up	308331.1938	511984.9107
20	Gokana	Built up	308241.4027	516294.8818
21	Ogu	Built-up	302494.7745	516294.8818
22	Beree	Mangrove forest	324930.2836	516755.8746
23	Bonny	Mangrove forest	304200.8048	509470.7608
24	Polluted	Mangrove forest	307217.9595	511242.8026
25	Okrika bridge	Mangrove forest	288652.4039	524685.5892
26	Bonny	Mangrove forest	290732.1448	514948.0159
27	Bonny	Mangrove forest	303123.312	498695.8329
28	Finima	Mangrove forest	294593.1607	496720.4294

A.12.20 Sample Points for Remote Sensing Data Validation (Continued).

29	Bonny	Mangrove forest	305996.6261	504262.879
30	Tai	Mangrove forest	304470.178	530661.4524
31	Oyigbo	Mangrove forest	309408.6866	535959.1254
32	Oyigbo	Mangrove forest	313269.7024	531738.9452
33	Andoni	Mangrove forest	319106.1218	502556.8487
34	Andoni	Mangrove forest	316143.0166	499324.3703
35	Bonny	Mangrove forest	301956.0281	497797.9222
36	Bonny	Mangrove forest	304200.8048	511715.5375
37	Gokana	Mangrove forest	312282.0007	519706.9424
38	Bonny	Mangrove forest	287320.0843	505968.9092
39	Bonny	Mangrove forest	305098.7154	500042.6988
40	Bonny	Mangrove forest	307523.0742	502377.2666
41	Bonny	Mangrove forest	305727.2529	502107.8934
42	Ogu bolo	Mangrove forest	303572.2673	514858.2248
43	Bonny	Mangrove forest	310575.9705	507046.402
44	Tai	Mixed farmland	301585.2331	525418.5335
45	Tai	Mixed farmland	309041.3108	521984.875
46	Banana Plantation	Mixed farmland	315188.2301	522912.856
47	Farmland	Mixed farmland	322494.5996	516513.7644
48	Beera	Mixed farmland	313712.7751	517380.927
49	Mogho	Mixed farmland	308986.1293	513670.4701
50	Bodo	Mixed farmland	308793.913	512908.0712
51	Opobo	Mixed farmland	328085.2284	500581.4452
52	Opobo	Mixed farmland	327456.6909	503275.1772
53	Andoni	Mixed farmland	329252.5122	496810.2205
54	Opobo	Mixed farmland	333472.6924	500491.6542
55	Khana	Mixed farmland	330509.5872	508213.6859
56	Khana	Mixed farmland	323416.0929	507764.7305
57	Eleme	Mixed farmland	299352.0872	533624.5576
58	Oyigbo	Mixed farmland	297107.3105	534342.8862
59	Oyigbo	Mixed farmland	315783.8523	530751.2435

A.12.20 Sample Points for Remote Sensing Data Validation (Continued).

60	Oyigbo	Mixed farmland	317400.0915	536587.6628
61	Oyigbo	Mixed farmland	321261.1073	536587.6628
62	Oyigbo	Mixed farmland	301417.2817	535151.0058
63	Oyigbo	Mixed farmland	296478.7731	537575.3646
64	Eleme	Mixed farmland	290283.1895	532816.438
65	Khana	Mixed farmland	323865.0483	511805.3285
66	Khana	Mixed farmland	316502.1808	512613.4481
67	Khana	Mixed farmland	318657.1664	515127.598
68	Khana	Mixed farmland	325571.0785	513690.9409
69	Tai	Mixed farmland	310935.1347	525184.1974
70	Tai	Mixed farmland	309229.1045	528057.5115
71	Khana	Mixed farmland	321979.4359	530751.2435
72	Khana	Mixed farmland	330150.4229	522490.4654
73	Gokana	Mixed farmland	311294.299	510817.6268
74	Ogu boundary	Mixed farmland	304650.2178	519635.7912
75	Eleme	Secondary rainforest	296478.4173	527629.8977
76	Eleme	Secondary rainforest	296592.3106	527585.7401
77	Tai	Secondary rainforest	305736.7931	521688.777
78	Tai	Secondary rainforest	306761.892	521566.8197
79	Taabaa	Secondary rainforest	322802.1001	523050.2024
80	Beere	Secondary rainforest	324934.2384	520536.4972
81	Beree	Secondary rainforest	325283.1907	517487.4327
82	Beera	Secondary rainforest	315705.6717	517761.5244
83	Saakpenwa	Secondary rainforest	310370.3953	519036.6394
84	Saakpenwa	Secondary rainforest	303897.4015	520201.1124
85	Eteo eleme	Secondary rainforest	299097.2051	524462.6092
86	Eteo eleme	Secondary rainforest	300243.3244	523422.9518
87	Andoni	Secondary rainforest	330778.9604	495014.3991
88	Eleme	Secondary rainforest	294323.7875	533804.1398
89	Khana	Secondary rainforest	321440.6895	515217.389
90	Khana	Secondary rainforest	319106.1218	512972.6124

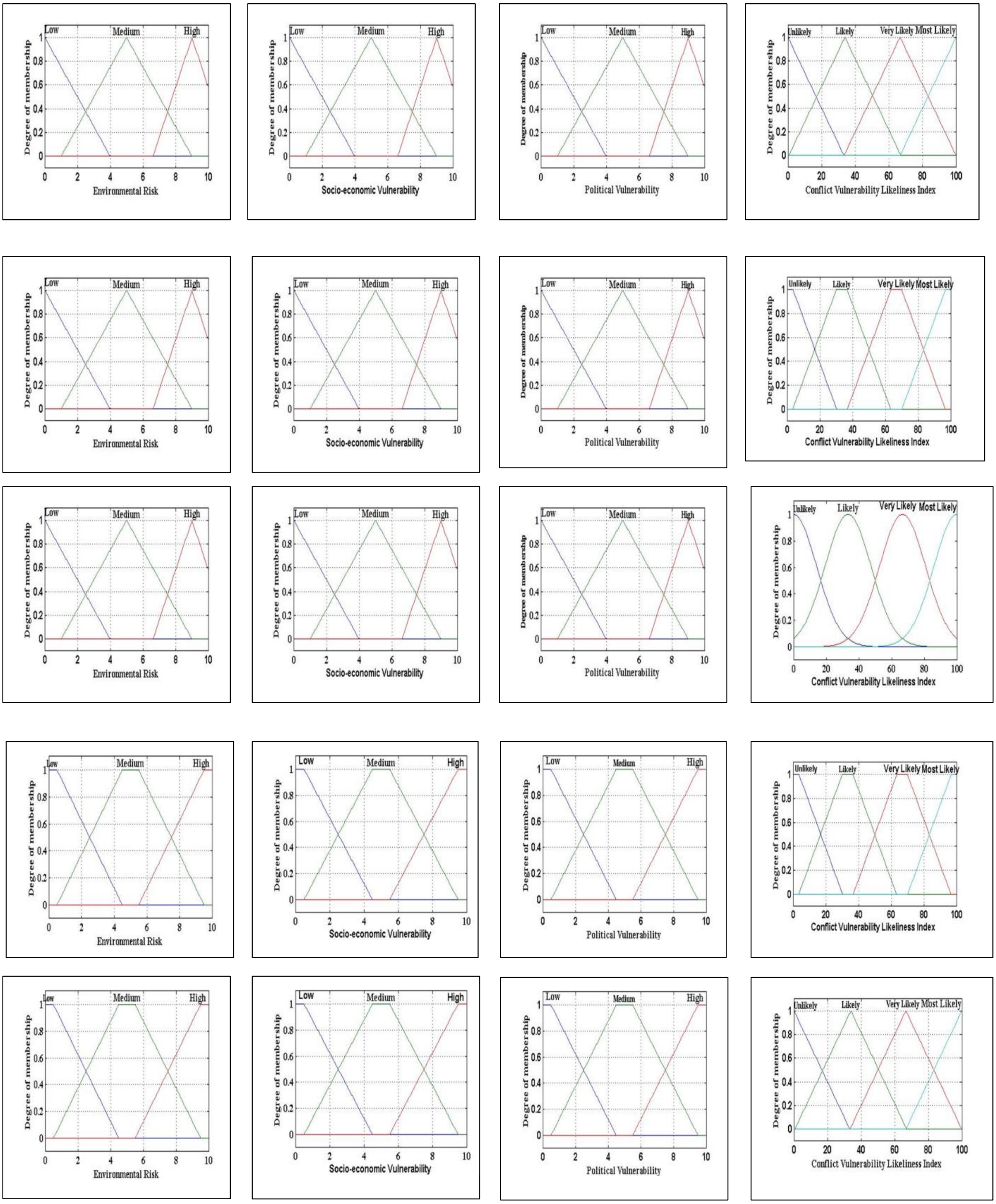
A.12.20 Sample Points for Remote Sensing Data Validation (Continued).

91	Khana	Secondary rainforest	323146.7197	513960.3141
92	Khana	Secondary rainforest	328534.1837	513780.732
93	Bonny	Secondary rainforest	310935.1347	499234.5793
94	Khana	Secondary rainforest	326379.1981	529673.7507
95	Khana	Secondary rainforest	334011.4388	528237.0937
96	Gokana	Secondary rainforest	313628.8667	520874.2262
97	Khana	Secondary rainforest	334101.2298	513152.1945
98	Finima	Secondary rainforest	303392.6852	490704.428
99	Finima	Secondary rainforest	305996.6261	492949.2046
100	Khana	Secondary rainforest	315155.3148	508932.0144
101	Ogu bolo	Secondary rainforest	300698.9532	516564.255
102	Beera	Thick forest	313707.759	517363.5145
103	Eteo eleme	Thick forest	301262.7731	523405.1956
104	Okrika bridge	Thick forest	286152.8004	517911.121
105	Bonny	Thick forest	303302.8941	494924.6081
106	Finima	Thick forest	303751.8494	493577.7421
107	Opobo	Thick forest	329432.0944	501658.938
108	Andoni	Thick forest	329521.8854	495553.1455
109	Opobo	Thick forest	337962.2457	495283.7723
110	Oyigbo	Thick forest	319375.495	534522.4683
111	Oyigbo	Thick forest	316412.3898	533804.1398
112	Oyigbo	Thick forest	313808.4488	537126.4092
113	Oygbo	Thick forest	325122.1232	535689.7522
114	Khana	Thick forest	326468.9892	510099.2983
115	Andoni	Thick forest	323416.0929	502736.4308
116	Andoni	Thick forest	319106.1218	498606.0418
117	Bonny	Thick forest	310037.2241	490973.8012
118	Khana	Thick forest	334191.0209	518000.9121
119	Finima	Thick forest	291809.6376	497348.9669
120	Finima	Thick forest	289564.861	499414.1614
121	Finima	Thick forest	300160.2068	491871.7118

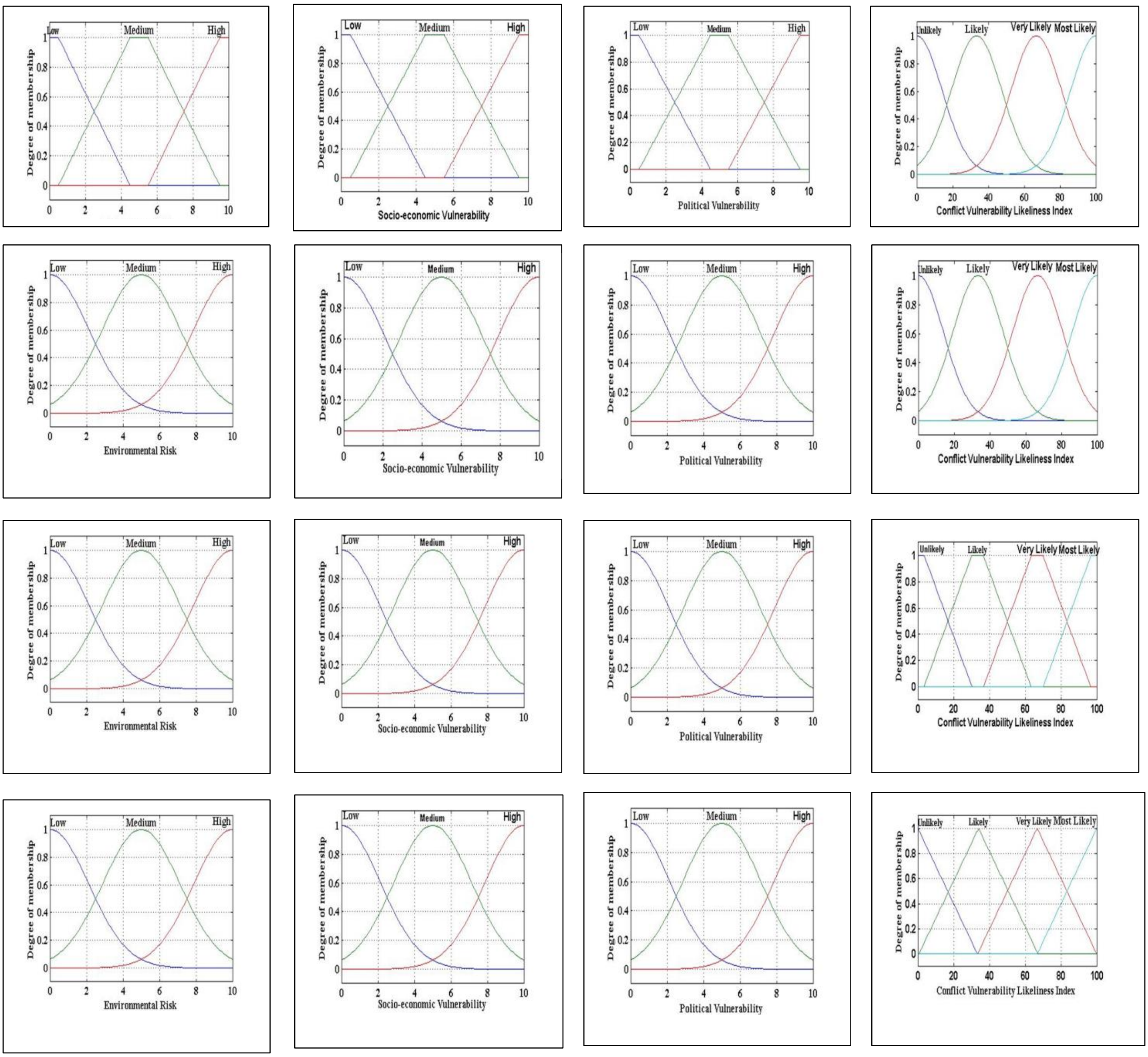
A.12.20 Sample Points for Remote Sensing Data Validation (Continued).

122	Ogu	Thick forest	300609.1621	512793.0303
123	Ogu bolo	Thick forest	301237.6996	518988.6138
124	Ogu bolo	Thick forest	303841.6405	515845.9265
125	Ogu bolo	Thick forest	299711.2514	517821.33
126	Okrika	Waterbody	294106.3588	514640.7961
127	Opobo	Waterbody	337922.2572	500090.8246
128	Bonny	Waterbody	305368.0886	497438.7579
129	Bonny	Waterbody	307523.0742	508213.6859
130	Andoni	Waterbody	314257.4042	504801.6254

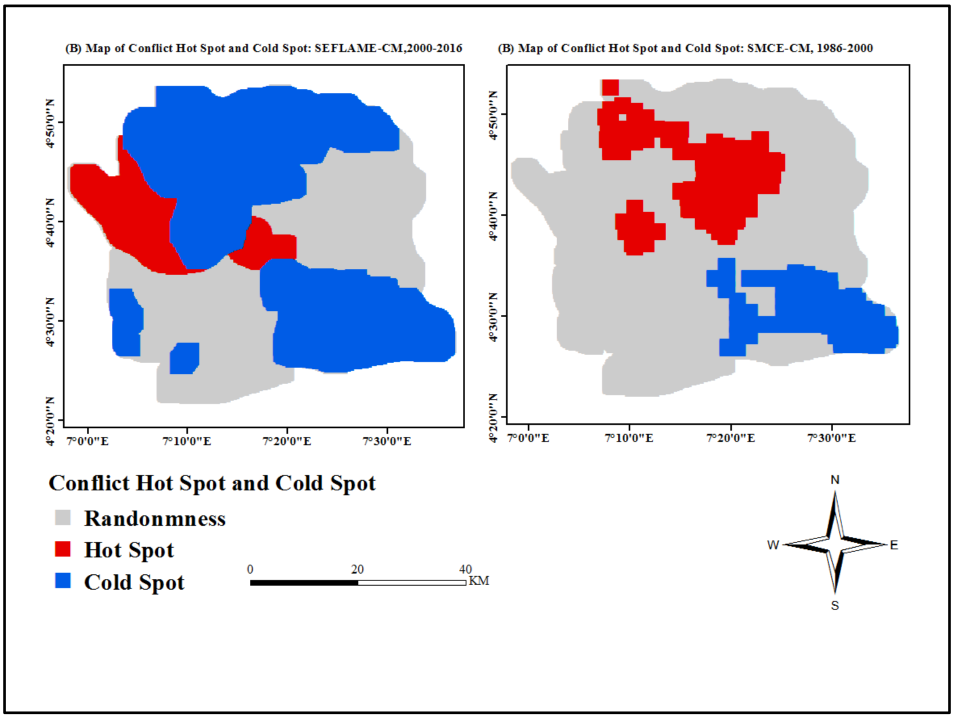
A. 6.21 MFs: Input vs Outputs.



A. 6.21: Inputs vs Outputs (Continued).



A. 6.22 Spatial Conflict Clusters: SEFLAME-CM and SMCE, 1986-2000.



A. 6.23 Spatial Conflict Clusters: SEFLAME-CM and SMCE-CM, 2000-2016.