Complex climate change adaptation network in Bhutan; how actor type impacts actor inclusion and clustering

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Abstract

The successful delivery of climate change adaptation policies and projects requires the engagement, participation and inclusion of a broad range of stakeholders at all levels – from international organisations, NGOs and national governments, down to local governments and communities. The impact of climate change has a disproportionate impact on communities at the local level, and policy and project success hinges on the participation and inclusion of local actors through polycentric institutional arrangements. Using the country of Bhutan as a case study, this paper addresses questions of actor participation and inclusion in the design of climate change adaptation policies and projects. A formal social network analysis is used to evaluate inclusion via embededness, clustering and fragmentation in a complex network of actors. The results identify differences between "top-down" and "bottom-up" institutional designs, with national actors clustering and occupying the centre of the network in top-down designs, cooperating with many different actor types, thereby increasing coordination by linking other disconnected actors. We especially note a lack of inclusion of local governments and communities, which may be an impediment to on-the-ground implementation and the long-term effectiveness of projects. Top-down institutional designs are less fragmented than bottom-up designs, however both types demonstrate fragmentation. We recommended a hybrid approach between top-down, and bottom-up designs, increasing both horizontal and especially vertical collaboration between actors, in order to overcome the challenge of local actor integration and increase adaptive capacity. This approach will help create a polycentric system, thereby empowering Bhutan to cope with climate change impacts through adaptation.

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Asian Development Bank	ADB
Asian Institute of Technology	AIT
Austrian Development Agency	ADA
Bhutan Chamber of Commerce and Industry	BCCI
Bhutan Power Corporation	BPC
Council for RNR Research in Bhutan, Ministry of Agriculture and Forests	CoRRB
Council of Research and Extension, Ministry for Agriculture	R&E-MoA
Danish International Development Assistance	DANIDA
Department of Aid and Debt Management- Ministry of Finance	DADM-MoF
Department of Disaster Management, Ministry of Home and Cultural Affairs	DDM-MoHCA
Department of Energy- Hydro-Meteorological Services Division	DoE-Hydro-Met
Department of Energy- Ministry of Trade and Industry	MoTI
Department of Engineering Services	DoES
Department of Forestry, Social Forestry Division	SFD
Department of Forests and Park Services- Ministry of Agriculture and Forests	DoFPS-MoAF
Department of Geology and Mines- Ministry of Economic Affairs	DMG-MoEA
Department of Hydro-met Services, Ministry of Economic Affairs	DHMS-MoEA
Department of Local Governance- Ministry of Home and Cultural Affairs	DLG-MoHCA
Department of Local Governance-Disaster Management Office	DLG-DMO
Department of Public Health, Ministry of Health	DoPH-MoH
Department of Renewable Energy	DoRE
Department of Roads- Ministry of Works and Human Settlement	DoR-MoWHS
Druk Green Power Corporation Bhutan	DGPC
European Union	EU
Forestry Development Corporation Limited	FDCL
Global Environment Facility	GEF
Glacial Lake Outburst Flood	GLOF
International Center for Integrated Mountain Development, Nepal	ICIMOD
International Institute for Environment and Development	iied
Japan Aerospace Exploration Agency, Japan	JAXA
Japan International Cooperation Agency	JICA
Mendrelgang Farmers Association	MFA
Ministry of Agriculture	MoA
Ministry of Agriculture and Forests	MoAF
Ministry of Economic Affairs	MoEA
Ministry of Education	MoE
Ministry of Finance	MoF
Ministry of Works and Human Settlement	MoWHS
National Biodiversity Centre	NBC
National Environment Commission	NEC
National Land Commission Secretariat	NLCS

National Statistics Bureau	NSB
Norwegian Agency for Development Cooperation	NORAD
Renewable Natural Resources Extension Agent- Agriculture	RNREA-A
Renewable Natural Resources Extension Agent- Forest	RNREA-F
Renewable Natural Resources Extension Agent- Livestock	RNREA-L
Royal Government of Bhutan	RGoB
Royal Society for Protection of Nature	RSPN
Stockholm Environment Institute	SEI
Swedish Government- Swedish International Development Agency	Sida
Swiss Agency for Development and Cooperation	SDC
Tata Power Company India	TPC
Ugyen Wangchuck Institute for Conservation and Environment	UWICE
UN Capital Development Fund	UNCDF
UN Children's Fund	UNICEF
UN Development Programme	UNDP
UN Economic and Social Commission for Asia and the Pacific	UNESCAP
UN Educational, Scientific and Cultural Organisation	UNESCO
UN Environment Programme	UNEP
UN Food & Agriculture Organisation	UNFAO
UN Framework Convention on Climate Change	UNFCCC
UN International Fund for Agricultural Development	IFAD
UN Programme on Reducing Emissions from Deforestation and Degradation	UN-REDD
UNDP/UNEP Poverty and Environment Initiative program	PEI
United Nations Environment Program Regional Office for Asia and the Pacific	UNEP ROAP
Watershed Management Division of Ministry of Agriculture	WMD-MoA
World Health Organisation	WHO
World Meteorological Organisation	WMO
World Wildlife Fund	WWF

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1. Introduction

Climate change refers to changes in the climate system over time. The cause of climate change may be due to human activities, or from natural internal system variability (UNEP, 2014). Anthropogenic greenhouse gas emissions have increased since the pre-industrial era driven by population and economic growth, causing atmospheric carbon dioxide, methane and nitrous oxide concentrations to be higher now than at any time within the last 800,000 years (IPCC, 1. 2014). According to the Intergovernmental Panel on Climate Change (IPCC), it is extremely likely that these and other anthropogenic forcings have contributed substantially to the observed temperature increase since the middle of the 20th century, arctic sea-ice loss since 1979, and have very likely contributed substantially to heating of the upper ocean and sea level rise since the 1970's (IPCC, 1. 2014). The surface temperature of the Earth has experienced warming, with each decade being successively warmer than the preceding decade since 1850, with a global average increase of 0.85 (0.65 to 1.06) °C from 1880 to 2012 (IPCC, 1. 2014).

A climate change impact is defined as the effect of climate change on both natural and human systems (UNEP, 2014). The future impact of climate change depends on the amount of carbon emissions emitted in the past, the emissions pathway chosen for the future, and the natural internal variability of the climate system (IPCC, 1. 2014). According to the IPCC, it is virtually certain that there will be an increase in hot and decrease in cold temperature extremes over land areas over daily and seasonal timescales in the future due to the continued increase in global average surface temperature, with a very likely increase in the occurrence of heat waves and extreme precipitation events (IPCC, 1. 2014). The propensity to be negatively affected by climate change defines climate change vulnerability (UNEP, 2014). Risks of climate change impacts are the result of climate hazards, vulnerability, exposure, and the ability to adapt (IPCC, 1. 2014). Due to this high risk of impacts from climate change, adaptation is important and relevant; therefore we dedicate our thesis to the issue of climate change adaptation.

Climate change adaptation is the process of adjustment to observed or predicted changes in the climate so that the risk of harm can be moderated, and opportunities may be taken advantage of. The human system may adapt to climate change through changes in the economic, ecologic or social system, to enable the individual, community or society to react to changes more easily and enhance adaptive capacity (UNEP, 2014), (Adger et al., 2005). Adaptive capacity involves the combination of available strengths, attributes and resources to undertake actions to adapt to climate change (UNEP, 2014). Adaptation occurs on various scales and with the involvement of various actors. On the scale of the individual, people may choose to adapt due to an extreme event, on the national scale, governments can undertake adaptive projects on behalf of the society (Adger, 2003). Some examples of climate change adaptation include crop diversification, water management, and disaster risk management (Noble et al., 2014). Adaptive capacity and vulnerability reduction are relevant especially in the context of developing countries, as hazards related to climate change can have a greater impact on developing countries due to their reduced adaptive capacity (IPCC, 2001).

The UNFCCC Least Developed Countries (LDC) Work Programme developed national climate change mechanisms such as National Adaptation Programmes of Action (NAPAs), so that LDCs can report any needs for adaptation. At the 12th COP in Nairobi in 2006, the Nairobi Work Programme (NWP) was developed to address climate change impacts, vulnerability and adaptation, under the Subsidiary Body for Scientific and Technological Advice (SBSTA) (UNFCCC, 3. n.d) (SBSTA, 2005). The IPCC's Forth Assessment Report was released in 2007, while parties negotiated outcomes post-2012, under the Bali Road Map at COP13 (UNFCCC, 1. n.d).

The Copenhagen Accord was drafted in 2009, with parties submitting non-binding emission reduction pledges. The Cancun Agreements under the UNFCCC were widely accepted in 2010, at the 16th COP and is currently the largest effort to collectively reduce emissions to date. Under the Cancun Adaptation Framework (CAF), the Adaptation Committee enabled LDCs to formulate National Adaptation Plans (NAPs) to implement financial, technological and capacity building support for adaptation (UNFCCC, 3, n.d) (UNFCCC, 1. n.d) (UNFCCC, 4, n.d) (UNFCCC, 2, n.d). The COP accepted the Durban Platform for Enhanced Action in 2011 and the Doha Amendment to the Kyoto Protocol was adopted in 2012. The Durban Platform was advanced in 2013, along with the Green Climate Fund, the long term finance to fund climate change adaptation projects and the Warsaw Framework for REDD+ (UNFCCC, 1. n.d).

Given the complexity of the problem, it is important for a broad range of stakeholders to participate and be included in policy responses to climate change, with public participation and inclusion being an important goal in responding to the threat of climate change. We define "inclusion" as policy and projects that involve a wide range of stakeholders, in the design and decision-making process (Few et al., 2007). The inclusion of diverse stakeholders is particularly important for climate change adaptation, as the governance scale of climate change adaptation is from the local to global, with most action occurring at the non-global scale (Adger, 2001). Public participation in adaptive responses to climate change impacts are outlined in Article 6 of the United Nations Framework Convention on Climate Change, in the call for Parties to promote and facilitate "public participation in addressing climate change and its effects and developing adequate responses" (UNFCCC, 1992). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, includes "participatory action" as an approach to manage the risks of climate change (IPCC, 2. 2014).

Not all groups of actors have equal capacity and opportunity to participate in policy-making, or be involved in decision-making, at the same level. Whilst local actor participation and engagement at the policy-making level is often difficult to achieve in practice, it may be particularly relevant for the management of natural resources, and land-use policies (Agrawal and Gibson, 1999) (Koontz, 2005). Climate impacts have a disproportionate effect on poor, rural communities at the local level, especially impacting those who are dependent on natural resources. Adaptation to the impacts of climate change are highly local in scope, and the success of climate change adaptation practices in local areas is highly dependent on the nature of local institutions, with the structure of institutional arrangements being critical in the response to climate impacts (Mearns and Norton, 2010). In this thesis, we define institutions as policies and projects relating to climate change. Therefore we highlight the importance of local actor participation and inclusion in the design of climate change adaptation policies and projects.

An analysis of local actor participation and inclusion in the design of climate change adaptation policies and projects, invites a comparison of "top-down" and "bottom-up" designs for climate change adaptation policies and projects, which we will discuss in the context of Bhutan. Social Network Analysis (SNA) is used to analyse actor inclusion, using measures of centrality via the embeddedness of national and local actors in top-down and bottom-up institutional designs (Freeman, 1979) (Grewal et al., 2006). Local actors are generally defined as those that operate at the local or sub-national level, and include public authorities such as regional, city, town and municipal government administrations and local environmental management committees. For the purposes of this paper, we define local actors as those acting at the local level, including public authorities such as the city or region and local government ministries of Bhutan. We define national actors as those acting at the national level, including public authorities such as the national government, or issue-based departments and ministries (Corfee-Morlot et al., 2009).

This thesis contributes to the discussion of the importance of actor participation and inclusion in climate change adaptation policies and projects by comparing actor inclusion of local and national actor types in policies and projects via embeddedness. We identify whether actor type has an effect on actor inclusion, specifically comparing the embeddedness of national and local actors in top-down and bottom-up institutional designs in order to discuss the role of vertical and horizontal integration, as a means to improve actor inclusion.

The aim of research question 1 is to examine how actor inclusion in climate change adaptation institutions is shaped in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 1 asks: *which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs*. This approach will highlight differences in the structural network pattern between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up designs.

Given the historical context of Bhutan - a kingdom that only recently began undertaking the process of decentralisation, mandating the formation of local governments for the first time in 2009 (GNH Commission, n.d) - we expect national actors to be more central in the network than other actors, having a high degree centrality, betweenness centrality, and eigenvector centrality. The independent variable we analyse is actor type; the actor types and we analyse include international organisations, foreign government, national government, local government, NGOs, corporations and communities.

The aim of research question 2, part A is to examine whether clustering occurs according to actor type in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 2 asks: *Do actors of the same type cluster together within networks?* We define drivers for clustering as variables allowing actors to collaborate with each other on projects within institutions, using the independent variable, "actor type", as a potential driver of clustering in networks. We analyse whether the independent variable "actor type", has a significant effect on the dependent variable "clustering" (Hannenman and Riddle, 2005). We test the hypothesis that *actors of the same type collaborate by clustering, as evidenced by significant differences in the density between "within-group" ties and "outside-group" ties.* We expect that actor-type has a significant effect on clustering, with the expectation that similar actors interact and collaborate with each other within the network (Berardo and Scholz, 2010) (Scholz et al., 2008) (Ingold, 2014). Measures of tie density were used to test the hypothesis.

In part B of research question 2, we aim to examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within these networks. Asking the research question, "*Which actors make up the core and periphery of the network?*" we use a simple Core/Periphery model to see which actors make up the core of the network, having the highest density of ties amongst themselves, therefore collaborating in common climate-related institutions, with all other actors making up the periphery of the network, having a lower density of ties amongst themselves (Hannenman and Riddle, 2005) (Borgatti and Everett, 1999).

Climate adaptation institutions may be complex and fragmented involving various policies, programs or plans (Termeer et al., 2011), the fragmentation of institutions may cause spill-overs or institutional externalities (Lubell, 2013). The aim of research question 3 is to examine fragmentation in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 3 asks: *Does the network display fragmentation?* We use fragmentation analysis to gain a fragmentation score for the total network (that includes both top-down and bottom-up institutional designs), and the two individual sub-networks (top-down and bottom-up respectively). We test the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*.

This thesis is structured according to the following: in the theory section we generally discuss policy processes and governance as networks, outlining why actor inclusion matters from the perspective of policy analysis. We compare actor inclusion in top-down, and bottom-up institutional designs, discussing how we assess the dependent variable; actor inclusion via embeddedness, through measures of centrality borrowed from Social Network Analysis. We discuss why clustering matters from the perspective of policy analysis and how we assess the dependent variable; clustering via tie density. Lastly, we discuss why fragmentation matters, fragmentation in top-down, and bottom-up institutional designs, and how we assess fragmentation via the fragmentation score. We introduce Bhutan as the ideal case study, outline how data was collected and analysed and give results on the level of inclusion of different actor types comparing top-down and bottom-up institutional designs, clustering according to actor type in the total network, and a comparison of fragmentation in top-down and bottom-up institutional designs. We discuss any significant results as being confirmation of a difference in structural configuration between top-down and bottom-up institutional designs. Finally, we draw conclusions of these results for the level of cooperation between actors, and make recommendations for how actor inclusion may be encouraged, and fragmentation may be decreased via horizontal and vertical integration.

2. Theory

2.1. Theory, and aim of research question 1

In this section, we firstly discuss policy processes and governance as networks and secondly the relevance of scales and multi-level approaches. Thirdly we discuss actor inclusion in top-down and bottom-up designed policy processes, and highlight the importance of a polycentric approach to governance throughout. Lastly we explain how actor inclusion can be assessed in terms of "embeddedness", to compare the level of actor inclusion of local actors compared to other actor types, in top-down and bottom-up designed climate change adaptation policy processes and projects.

2.1.1. Policy processes and governance as networks

In the following section, we discuss policy processes and governance as networks, how and why actors participate in networks, and evaluate the relevance of networks for climate change adaptation. We also demonstrate the importance of having a polycentric approach to governance.

For the purposes of this paper, we define an actor as an organisation or group of individuals working together towards a common purpose (Borgatti and Foster, 2003). Different actors have different preferences, political capacity, knowledge, access to power and financial resources (Lubell, 2013). Actors participate in a particular collective decision-making process, called an institution, because they have an interest in the particular problem associated with that institution (Lubell, 2013). When transactions between certain actors occur repeatedly through time, they become institutionalised in a network (Waarden, 1992).

A network is a complex of tied human relations; actor participation in a network is what makes each network arrangement unique. Actors collaborate within the network through the linking or sharing of information, working together on a defined project to achieve goals that would be difficult to achieve independently, creating a tie between the actors (Bryson et al., 2006) (Snijders et al., 2010). Compared to a hierarchical structure, a network operates more through cooperation and facilitation, rather than directing actions from an actor at the top to the bottom. Compared to other types of organisational structures, network management aims to enhance collectiveness and trust between actors, giving coherence to activities, where there should be no central decision-making (Wilson-Grau and Nuñez, 2007) (Waarden, 1992).

Networks are now favoured by many communities to replace formal, authoritative hierarchical decision-making structures with more informal networks of diverse actors to help resolve environmental governance problems (Schneider et al., 2003). Shared governance networks are seen as being flexible and adaptable allowing them to work efficiently to achieve goals and respond quickly to environmental threats such as natural disasters and opportunities, while hierarchies are seen as less efficient and slower to respond (Kapucu and Van Wart, 2006) (Provan and Kenis, 2007). This new paradigm can be described as a "polycentric approach" to governance, where responsibility for decision-making and implementation is distributed throughout multiple levels (Ostrom, 2014).

2.1.2. The relevance of scales and multi-level approaches

In this section, we discuss the relevance of scales and multi-level approaches to governance, with the multi-level governance framework, and the field of Social Network Analysis (SNA), being used as a methodology to analyse the relationships between actors at different governance levels. We describe key actors at local, national and international scales and how different actor types participate in networks, defining the importance of interconnected-ness of actors at various scales for climate change adaptation specifically; with vertical and horizontal scale integration as the current practice to better implement climate change policies.

Globally a multi-scale, multi-actor view of responsibility for climate impacts and issues is growing (Bulkeley and Moser, 2007). The conceptual framework of multilevel governance can be used to understand how central governments and public and private actors form networks with institutions, and how cooperation occurs throughout the network. The framework can also be used within the context of global climate change to understand the relationships between different governance levels including local and national government actors, and various stakeholders including non-governmental organisations (NGOs), corporations and communities (Corfee-Morlot et al., 2009) (Betsill and Bulkeley, 2006). The field of Social Network Analysis (SNA) has developed as a method to mathematically analyse relationships between actors in networks (Freeman, 2004) (Knoke and Yang, 2008).

In the context of climate change and multilevel governance, there are key actors at local, national and international scales. Key actors at the local level include public authorities such as local government administrations and local environmental management committees. Key actors at the national level include public authorities such as national government or issue-based commissions, departments or ministries, and key actors at the international level include intergovernmental organisations and multinational companies (Corfee-Morlot et al., 2009).

The widespread acceptance of climate change has given scientists, researchers, government officials, international organisations, corporations, businesses and NGOs influence in the climate change policy process through influential networks, often through actions in developing countries such as funding local community groups, community science education programs and working in coalition with other groups (Gough and Shackley, 2001). Networks can be important for climate change adaptation because adaptation occurs on various scales, from local to national and with the involvement of various actors, from individual to societal or governmental. The relationships and interconnected-ness of actors at various scales with each other and wider institutions form an actor network which affects overall adaptive capacity (Adger, 2003).

The multilevel governance framework involves two levels of action; the vertical dimension, crossing multiple government scales or levels (local to national for example), and the horizontal dimension, across government departments (Corfee-Morlot et al., 2009) (OECD, 2008). Vertical integration can be implemented in order to bridge any climate change gaps between local action plans and national frameworks, while the horizontal dimension of multilevel governance aims to increase coordination across national line ministries by implementing programmes that cut across different climate change policies (Corfee-Morlot et al., 2009) (Charbit and Michalun, 2009). Vertical and horizontal governance integration is the current practice in order to better implement climate change policies (Bulkeley and Moser, 2007) (Corfee-Morlot et al., 2009). The multilevel governance framework is useful in the context of climate change adaptation specifically, as climate change adaptation is a multi-scale and multi-sector issue, requiring a response at multiple geographical and jurisdictional and governance levels, by multiple actors (Termeer et al., 2010), (Termeer et al., 2011).

2.1.3. Actor inclusion in top-down and bottom-up designed policy processes

In the following section, we define a bottom-up, versus a top-down institutional design, with horizontal and vertical collaboration between actors being particularly important in reference to climate change adaptation, and vertical and horizontal integration occurring through bottom-up and top-down processes. We discuss the importance of actor inclusion in the policy process, especially the inclusion of local actors for climate change adaptation policies and projects. We outline how embeddedness can be used to assess actor inclusion, using measures of centrality. We discuss the embeddedness of national actors in top-down institutional designs, the embeddedness of local actors in bottom-up institutional designs and national actors being more central in the total network. We also outline how we used the Ecology of Games Theory to look at the complex actor network.

Bottom-up institutions are locally led initiatives and projects influencing national action, while top-down institutions are nationally led and organised. We define top-down institutional designs as policies or projects with corporations, NGOs, international organisations, foreign governments or national government as lead actors, and we define bottom-up institutional designs as those with lead actors at the local government or community level. Horizontal and vertical collaboration between actors is particularly important in reference to climate change adaptation, to achieve coherence and adaptive capacity in the long term and overcome any fragmentation or jurisdictional overlap (OECD, 2008) (Charbit and Michalun, 2009) (Corfee-Morlot et al., 2009). Vertical and horizontal integration can occur via bottom-up local initiatives influencing national action, and top-down initiatives, where national frameworks empower actors at the local level (Corfee-Morlot et al., 2009). Thus we use the difference between top-down and bottom-up institutional designs to encase the vertical and horizontal characteristics of policy design.

It is important that a broad range of stakeholders participate and are included in projects and policy responses to climate change. The inclusion of local stakeholders is important for climate change adaptation particularly, as the governance scale of climate change adaptation is mostly at the non-global scale (Few et al., 2007) (Adger, 2001). Local actor inclusion and participation is particularly important, as climate change impacts mostly affect local areas, communities and economies (Charbit and Michalun, 2009). The current practice is for increasing local government action on climate change (Corfee-Morlot et al., 2009). We assess local actor inclusion by comparing the embeddedness of local actors to national actor types.

Actor inclusion can be assessed via embeddedness, using measures of centrality. Embeddedness is defined as the “extent to which an entity is entrenched in a network of relationships” (Grewal et al., 2006). It is important to look at both the immediate relationships between actors, the local embeddedness, the actors’ position within the wider network and the global embeddedness. Centrality is a structural attribute of social networks indicating how actors are connected to each other (Freeman, 1979). Social Network Analysis (SNA) can be used to analyse the actor network structure using three measures of point centrality - degree centrality, betweenness centrality and eigenvector centrality - to assess the embeddedness of actors in networks (Freeman, 1979) (Grewal et al., 2006).

Degree centrality is a local measure of structural embeddedness. The degree is the number of direct actor ties, with the degree centrality being a function of the degree, we define the degree centrality as the number of ties an actor directly shares with others in the network. If an actor has a high degree centrality then we can say that they have many direct ties with other actors, therefore the actor is well embedded in the network (Freeman, 1979). Betweenness centrality is a local measure of structural embeddedness, being the number of times an actor connects two disconnected actors (Prell et al., 2009). If an actor has a high betweenness centrality then we can say that they are well embedded in the network, as they connect many unconnected actors (Freeman, 1979). In betweenness centrality, the relationship between two unconnected actors depends on the central actor; therefore, an actor with a high betweenness centrality means the actor is highly central (Wasserman and Faust, 1994) (Freeman, 1979). The eigenvector centrality of an actor is higher when an actor is connected to institutions that are also well connected (Lubell et al, 2011). Eigenvector centrality is a global measure of structural embeddedness, if an actor has a high eigenvector centrality, then we can say that they are well embedded in the network, and highly central in the network (Freeman, 1979) (Grewal et al., 2006). An actor that is well embedded in the network therefore has a high inclusion and ability to participate in decision-making.

Given the historical context of Bhutan, we expect climate change adaptation policies and projects to be largely top-down in design. With a lack of local actor inclusion and participation in top-down designs with national actors having a higher inclusion in policies, projects and decision-making processes. Bottom-up designs, by definition, have a high level of local actor inclusion and participation. We therefore expect to see a difference in the structural network pattern when comparing bottom-up and top-down designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs. We also expect national actors to be more central in the network, compared to other actors, as we assume that local actors would be located further away, in a peripheral location, away from the centre of decision-making.

The Ecology of Games Theory was first developed by Norton Long in 1958. Long stated that in politics, particular social structures cooperate with each other while aiming to achieve particular goals, and operate in relationships with others, however the theory focused only on one policy game at a time (Long, 1958). In reality however, multiple policy games operate simultaneously, and in response to this, an updated Ecology of Games (EG) Framework was developed, meshing concepts from Long's Ecology of Games, (Long, 1958), the Institutional Analysis and Development (IAD) Framework (Ostrom, 2011), political power (Knight, 1992) (Moe, 2005), and others (Lubell, 2013). The original IAD Framework (Ostrom, 1990) only considers one collective action problem at a time, whereas the EG Framework considers multiple collective action problems (Lubell, 2013).

The updated EG Framework recognises that policy outputs and outcomes are a result of many policy games over time, and aims to analyse how actors cooperate with each other within multiple games in a complex adaptive governance system (Smaldino and Lubell, 2011), (Lubell, 2013). Transaction costs may increase due to changes in resources causing a collective-action problem or changes in institutions at multiple levels caused by natural or social changes, some institutions may have high transaction costs while others have low transaction costs (Lubell, 2013). Some parameters used to analyse a particular Ecology Game include resilience, robustness, and adaptive capacity. In this thesis I will particularly look at the complex actor network, because the actor's decisions are the "driving force" in Ecology of Games interactions (Lubell, 2013).

The aim of research question 1 is to examine how actor inclusion in climate change adaptation institutions is shaped in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. In this thesis, we define drivers for actor inclusion as variables allowing actors to collaborate with each other on projects within institutions. With the independent variable, "actor type", being a possible driver of actor inclusion in networks. We ask whether this driver for actor inclusion causes structural effects in the network. Significant effects of the independent variable, "actor type", on the dependent variable, "actor inclusion", indicate effects in the network that cant be due to any random effect of tie formation or destruction (Hannenman and Riddle, 2005). Regression analysis is used to test the strength of the effect of the independent variable on the dependent variable, with the null hypothesis being that the independent variable, "actor type", has no effect on the network configuration.

The specific networks we analyse in this thesis include the total network, and a sub-set of this network we call the sub-networks. The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks being either top-down or bottom-up institutional designs, are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Specifically, research question 1 posits: *Which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs*. We contend that there is a difference in the structural network pattern between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs, and that national actors are more central in the network than other actors; having a high degree centrality, betweenness centrality, and eigenvector centrality.

2.2. Theory, aim, research questions and hypothesis: research question 2

In this section, we firstly discuss the relevance of clustering in networks and the relevance of clustering in environmental governance institutions specifically. Lastly we explain how clustering can be analysed via tie density, to compare the level of clustering of different actor types in climate change adaptation policy processes and projects.

2.2.1. The relevance of clustering

We define "clustering" in the network based on an assessment of the connectedness of groups of actors. Actors who have historically worked together on projects or who regularly interact with each other as part of a group are defined as a "cluster". Those actors at the centre of the cluster, with many connections to other actors, are described as being "core" actors, whilst those at the edges, with fewer connections to others are described as being "peripheral" actors (Freeman, 2011). Clusters with high levels of closure often share overlapping links, with actors collaborating inside and outside their own homogenous clusters. Whilst some of these links can be redundant, serving little continuing purpose and often being costly to maintain, they can also help build trust between actors, helping to facilitate cooperation and reputation building, resulting in a more cohesive and collaborative network structure (Lubell et al., 2011) (Friedkin, 1984). In this way, closed groups or small dense networks have repeated transactions leading to trust, thus supporting cooperation (Berardo and Scholz, 2010) (Scholz et al., 2008).

Clustering is relevant in environmental governance institutions specifically. Studies of estuary management networks, have demonstrated that density increases agreement between actors, as actors tend to cluster together that have similar beliefs (Scholz et al., 2008), sharing overlapping, redundant links in a dense network, which can affect the project and levels of cooperation (Berardo and Scholz, 2010). Coleman also notes that reputation and trust cannot develop in an open network (Coleman, 1988). However we also demonstrate that even though high density and the creation of subgroups have generally positive outcomes, we highlight the importance of ties between groups, which also serve to increase collaboration throughout the network (Granovetter, 1973). Therefore we note the balance of the formation of subgroups, and allowing for links between groups to increase overall collaboration.

According to the social capital perspective, if the network is dense with many actors overlapping and a higher amount of network closure, then there is more trust, reciprocity and a reduction of externalities. This occurs by lowering the cost of sanctioning, monitoring or influencing actor behaviour and facilitating information sharing between those who share similar norms and beliefs, thus making problems be easier to solve (Coleman, 1988) (Putnam, 2000) (Pretty and Ward, 2001). Dense networks reduce transaction costs and allow the efficient sharing of information between actors to plan and negotiate a project, and to monitor and enforce project terms (Scholz et al., 2008). We highlight the location of actors; whether they are within the core or the periphery of the network, as actors in the core of the network have a structural advantage over those in the periphery, as those in the core are more able to coordinate their activities (Hannenman and Riddle, 2005).

2.2.2. Clustering and actor type

We expect that actors of the same type, for example local level governments, will collaborate with each other in climate change adaptation institutions, creating clusters within the network, as it is known that actors sharing similarities tend to share more ties with each other, interact and collaborate with each other within networks (Berardo and Scholz, 2010) (Scholz et al., 2008) (McPherson et al., 2001). We therefore expect actor type to have a significant effect on clustering.

An MDS plot can be used to initially define clusters of actors, where we see actors located at the centre of the cluster, we can define those actors as being in the core of the cluster, and actors located further away as being peripheral actors (Freeman, 2001). On a mathematical level, clustering can be analysed via tie density. Clustering according to actor type can be assessed by comparing tie density within and between different actor types, with the density table being used to show the probability of different actor types being tied to one-another (Hannenman and Riddle, 2005). A simple Core/Periphery model can be used to see which actors make up the core of the network, having the highest density of ties amongst themselves, therefore collaborating in common institutions, with all other actors making up the periphery of the network, having a lower density of ties amongst themselves, and therefore fewer institutions in common (Hannenman and Riddle, 2005) (Borgatti and Everett, 1999).

The aim of research question 2 is to examine whether clustering occurs according to actor type in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. In this thesis, we define drivers for clustering as variables allowing actors to collaborate with each other on projects within institutions. With the independent variable actor type being a possible driver of clustering in networks. We ask whether this driver for clustering causes structural effects in the network; significant effects of actor type (independent variable), on the dependent variable; clustering indicate effects in the network that can not due to any random effects tie destruction or formation (Hannenman and Riddle, 2005).

Specifically, research question 2 asks: *Do actors of the same type cluster together within networks?* We expect that actor type has a significant effect on clustering; therefore, we expect tie density within common actor types will be higher than the tie density outside common actor types, with the difference between "within-group" ties and "outside-group" ties being significantly different (Hannenman and Riddle, 2005). We also test the hypothesis that *actors of the same type collaborate by clustering, as evidenced by significant differences in the density between "within-group" ties and "outside-group" ties*. The network we analyse to answer research question 2 is the total network, being made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Measures of tie density are used to test the effect of the independent variable on the dependent variable, with the null hypothesis being that the driver for clustering; actor type has no effect on the network configuration.

We also aim to examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Asking the research question, "*Which actors make up the core and periphery of the network?"* we use a simple Core/Periphery model to see which actors make up the core of the network, represented by those with the highest density of "within-group" ties, and who therefore collaborate most frequently in common climate-related institutions. All other actors thereby constitute the periphery of the network, having a lower density of "within-group" ties, and therefore fewer climate-related institutions in common (Hannenman and Riddle, 2005) (Borgatti and Everett, 1999). The network we analyse to answer this research question is the total network, being made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (including both top-down and bottom-up institutional designs).

2.3. Theory, aim and hypothesis: research question 3

In the below section, we discuss the importance of analysing fragmentation and how the multilevel governance framework is useful in the context of fragmentation in climate change adaptation institutions specifically. We discuss fragmentation in the policy process generally and discuss the fragmentation of top-down and bottom-up institutional designs through vertical and horizontal dimensions and our expectations for fragmentation comparing top-down down and bottom-up institutional designs. We define our aim, research question and hypothesis specifically, and discuss how the fragmentation score can be used to assess network fragmentation.

2.3.1. The relevance of fragmentation

In this thesis we analyse the fragmentation of institutions in a complex network. Here, fragmentation is used as a relative concept, as most networks are fragmented to some extent (Biermann et al., 2009). We define fragmentation where there are a high proportion of actors unable to reach each other in the network (Hannenman and Riddle, 2005). It is important to analyse fragmentation; as it causes gains to be not fully taken advantage of, costs to be not fully avoided and causes extra costs within the system overall (Lubell and Lippert, 2011) (Lubell, 2013), and may cause spill-overs or institutional externalities (Lubell, 2013).

We examine the fragmentation of institutions in a complex network, by applying a multilevel governance framework. Climate change adaptation institutions may be complex and fragmented involving various policies, programs or plans at different scales (Termeer et al., 2011) (Lemos and Agrawal, 2006), one way in which fragmentation can be reduced in networks is through the integration of institutions; the issue of fragmentation in environmental governance institutions is becoming widely recognised by policy-makers, one example in which this has been addressed is through the possible creation of the World Environment Organisation, to increase integration of environmental institutions (Biermann et al., 2009).

In policy literature, there are differing perspectives on the role of fragmentation in climate change institutions, and whether it has an overall positive or negative impact, with proponents in favour of fragmentation arguing that it increases policy ambition, innovation and participation of different actor types through the reduction of costs of entry for actors such as private business or industry. Critics of fragmentation argue that it can allow actors to use the network in a way that best suits their individual objectives, rather than the group objectives, in a process known as "venue shopping" (Biermann et al., 2009). Since we define fragmentation where there are a high proportion of actors unable to reach each-other in the network (Hannenman and Riddle, 2005), we come to the conclusion that, relatively high institutional fragmentation has a negative impact overall, as it could affect actors' ability to implement projects effectively, through inhibiting joint decision-making between actors, possibly resulting in misunderstandings and conflicting strategies for project implementation, creating barriers to cooperation (Klijn and Teisman, 2002).

2.3.2. Fragmentation in top-down and bottom-up designed policy processes

We define horizontal fragmentation as the fragmentation of institutions in different sectors such as forestry or water, and vertical fragmentation as the fragmentation of institutions at different scales, for example national to local (Pahl-Wostl, 2006). In this thesis we analyse fragmentation in networks of institutions, with institutional design being either top-down, or bottom-up. One way in which fragmentation can be reduced in networks is through the integration of institutions through vertical and horizontal integration. Vertical integration can occur through bottom-up designed projects and policies, and horizontal integration can occur through top-down designed projects and policies (Corfee-Morlot et al., 2009). Horizontal and vertical collaboration between actors is particularly important in reference to climate change adaptation, to overcome fragmentation in the network (OECD, 2008) (Charbit and Michalun, 2009) (Corfee-Morlot et al., 2009).

Government actors have a greater capacity to coordinate in the network as they have access to the most political, financial and information resources (Lubell et al., 2011), as we expect top-down institutional designs to have a higher participation of national level actors, including government, then we expect top-down institutional designs to be less fragmented than bottom-up institutional designs, with more involvement of actors able to coordinate activities, and collaborate across levels. Since we also expect that national actors will increase coordination across the network by linking other disconnected actors, we can say that a high participation of national level actors linking actors at different scales across the network will decrease fragmentation, therefore we expect top-down institutional designs to be less fragmented than bottom-up institutional designs (Berardo and Scholz, 2010).

The aim of research question 3 is to examine fragmentation in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 3 posed is: *Does the network* *display fragmentation?* The specific networks we analyse include the total network, and a sub-set of this network called the sub-networks. The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up). Sub-networks being either top-down or bottom-up institutional designs, are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects.

The fragmentation score can be used to analyse the level of fragmentation in the network by analysing the proportion of actors that are unable to reach each-other in the network (Hannenman and Riddle, 2005). We use fragmentation analysis to gain a fragmentation score for the total network (that includes both top-down and bottom-up institutional designs), and the two individual sub-networks (top-down and bottom-up respectively). We hypothesise that there is a difference in the structural network pattern between top-down and bottom-up institutional designs, with top-down institutional designs being less fragmented compared to bottom-up institutional designs. We compare the results between the fragmentation scores of each institutional design, to test the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*.

2.4. The importance of cooperation in networks

We discuss the impact of the results from the research questions 1, 2, and 3 including; actor inclusion, clustering and fragmentation have on cooperation in the network, and make recommendations on how cooperation may be strengthened to more effectively implement adaptation policies and projects. The most effective way to address climate change issues is through a complex, multilevel system; taking a polycentric approach where governance units are independent but linked in networks (Ostrom, 2010). These networks can be used by actors in a society for the public good, and can be described as social capital. Cooperation is specifically relevant for climate change adaptation; through cooperation, vertical and horizontal integration can create stronger and new institutional arrangements to increase adaptive capacity; allowing societies to cope with the impacts of climate change, and increase the effectiveness and implementation of adaptation policies (IPCC, 1. 2014) (Adger, 2003) (Ostrom, 2014). Overall, we may say that networks themselves promote adaptive capacity and resilience (Charbit and Michalun, 2009) (Adger, 2003).

3. Case Study

3.1.1. Climate change impact in Bhutan

Although a small country with a population of approximately 745,150 people, and spanning an area of only 38,394 square kilometres, Bhutan possesses a number of diverse climatic regions. The Southern plains and foothill areas are warm, humid and subtropical, while the Himalayan valleys and alpine areas in the upper mountain region are cool and temperate (National Statistics Bureau, 2014), (Ahmed and Suphachalasai, 2014). Even though the historical climate data for Bhutan is limited, observations have demonstrated an increasing minimum and maximum temperature trend from 2000 to 2009 (Kingdom of Bhutan, 2011). Bhutan is vulnerable to many climate change impacts including a projected rise in temperature of 1.5°C–1.9°C in 2030, 2.2°C–2.6°C in 2050, and 3.3°C–4.5°C in 2080. The average temperature rise in Bhutan is projected to exceed 2°C by 2050, and 4.8°C by 2100, by comparison, this increase is higher than the global average increase due to the fact that Bhutan is both inland and high in latitude (Ahmed and Suphachalasai, 2014).

The average annual precipitation for Bhutan is 2200 mm, varying in different regions of the country. 60 to 90% of this rainfall comes from the summer monsoon, lasting from June to September (Ahmed and Suphachalasai, 2014). Projected changes in precipitation for Bhutan include a likely range of decrease of 3.3% to an increase of 4.1% by 2030, decrease of 1.1% to increase of 6.4% by 2050, and increase of 0.1% to 1.1% by 2050, with no clear change in the average overall, with a range of 5% to 10% change by 2100, although with a low confidence of rainfall projections (Ahmed and Suphachalasai, 2014).

Climate-related impacts that are expected to affect Bhutan in the future as a result of climate change include monsoon floods and associated landslides, a reduction of rice and wheat yields, increasing pests and diseases, with an impact on human settlement, industry, infrastructure, the economy and flooding from Glacial Lake Outburst Floods (GLOF) (Hijioka et. al., 2014), (Royal Government of Bhutan, 2012), (Tse-ring et al., 2010). GLOFs result from melting glaciers and an increase in temperature, causing glacial lakes to form that can burst causing flooding downstream, the frequency of these events has increased over the last decades (Ahmed and Suphachalasai, 2014). Landslides and floods resulting from the summer monsoon can cause a loss of lives and damage to local livelihoods, for example in 2004 the monsoon flooding in south-eastern Bhutan affected approximately 1,500 households, damaged 160 houses and affected 300 hectares of farmland, causing a significant loss of crops (Kingdom of Bhutan, 2006).

Climate change in Bhutan is a cross-sectoral issue. The agriculture sector is highly dependent on the monsoon and temperature patterns. With climate change projected to cause crop failure and impact livestock, this poses a significant threat for the 69% of the population who depend on agricultural activities (Kingdom of Bhutan, 2006) (Kingdom of Bhutan, 2011). The agriculture sector is also at risk of crop loss due to flooding and landslides resulting from GLOFs. Food production is also expected to be affected by climate change, as rice yields in tropical and subtropical regions are projected to decrease by as much as 23% by 2080 (Ahmed and Suphachalasai, 2014).

Bhutan is highly dependent on hydropower, as the sector accounts for over 21% of GDP and 45% of revenue, with almost 100% of electrical production in Bhutan coming from hydropower (Kingdom of Bhutan, 2011), however climate change could impact the energy sector through melting glaciers, changing precipitation patterns and temperature, affecting hydropower (Ahmed and Suphachalasai, 2014). The finance sector is also expected to be affected through a 1.4% loss of GDP by 2050 under a "business-as-usual" emissions scenario (Ahmed and Suphachalasai, 2014).

In the above section, we see that the impacts of climate change on Bhutan are particularly severe. Due to the significant current and expected impacts of climate change in Bhutan, climate change adaptation projects and policies must be prioritised and implemented, making Bhutan an ideal case study. In the research design of this thesis, we identify and analyse climate change policies and projects that are the result of the particular impacts of climate change affecting specific sectors, for example Glacial Lake Outburst Flood (GLOF) related projects as a response to monsoon floods and associated landslides.

3.1.2. Strategies and laws regulating Bhutan's climate change adaptation policy

The evolution of environmental policies in Bhutan began with the Forestry Act of 1969, with the nationalisation of all of Bhutan's forests by the Government, removing any traditionally held ownership, with the objective to safeguard forests from unsustainable use and exploitation (Davis and Li, 2013). The national Forest Policy of 1974 set the goal to maintain 60% forested land. The Land Act of 1979 allowed the domestic and non-commercial use of forest on private land and community engagement through "social forestry". The Forest and Nature Conservation Act of 1995 then approved management plans for private and community forestry, which continue today (Davis and Li, 2013) (Wangdi et al., 2013).

Bhutan ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, the national Climate Change Committee (NCCC), the Convention on Biological Diversity, the National Environment Strategy (NES) in 1998, the Environmental Assessment Act in 2000, the Sustainable Development Agreement (SDA), the South Asia Cooperative Environment Program (SACEP), the UN Commission on Sustainable Development (UNCSD) conference participation, the Kyoto Protocol in 2002, the United Nations Environment Programme (UNEP), the Economic and Social Commission for Asia and the Pacific (ESCAP), the World Bank, the Asian Development Bank, the International Centre for Integrated Mountain Development (ICIMOD) and the World Summit on Sustainable Development (WSSD) (Kingdom of Bhutan, 2006) (NEC and Royal Government of Bhutan, 2009).

Bhutan submitted their Initial National Communication (INC) to the UNFCCC in 2000 including a GHG emission inventory, vulnerability and adaptation assessment, and policies, research, education, training and public participation related to climate change (NEC and Royal Government of Bhutan, 2009). The National Adaptation Programme of Action Forest and Nature Conservation Rules Revision in 2006 allowed the rapid increase in community forestry, which has helped slow deforestation by illegal logging. The National Environment Protection Act of 2007 set out the sustainable use and management of forestry policy that is currently used, and then in 2008 the government reaffirmed their goal of maintaining 60% forested land (Davis and Li, 2013). The Economy Policy of 2009 increased hydropower development to increase electricity availability, while the National Forest Policy of 2010 integrated an approach to sustainable forest management and recognised commitments under all ratifications (Davis and Li, 2013).

The Bhutan National Adaptation Programme of Action (NAPA) is under the framework of the UNFCCC, aiming to allow least developed countries to respond to and plan for climate change through adaptation, with each plan being specific for each country (Kingdom of Bhutan, 2006) (UNFCCC, 2011). Bhutan's NAPA, published in 2006 was prepared with a grant from the Least Developed Countries Fund (LDCF), and includes nine priority projects chosen from 55 originally proposed projects (NEC and Royal Government of Bhutan, 2009). The first NAPA project involved the lowering of the Thorthormi Lake and established early warning systems from GLOFs in Punakha and Wanduephodrag, and was completed in 2012. The second NAPA project "Addressing the Risks of Climate Induced Disasters Through Enhanced National and Local Capacity for Effective Action" due to be completed in 2017, is known as the world's largest climate change adaptation project (UNDP, 2014).

3.1.3. Institutions and political system

Bhutan made the transition from a kingdom, to a democracy in 2008, with the adoption of the Constitution of Bhutan. With the move to democracy, there is now greater institutional transparency and accountability through decentralisation (GNH Commission, n.d). The move to decentralisation has been promoted by the Royal Government since the 1980's. The major landmark events in the decentralisation of Bhutan include; the formation of the district; dzongkhag DYT and sub-district; gewog GYT development committees in 1981 and 1991, the establishment of regional city councils in Thimphu and Phuentsholing in 1999, the 2002 ratification of the DYT and GYT Acts, the appointment of village headman as chairpersons in 2002, and the planning approach based on Gewogs in the Ninth Five Year Plan from 2002 to 2007 (GNH Commission, n.d).

The decentralisation process is overseen by the Department of Local Governance, which was established in 2005. The principle for democracy and decentralisation was added under article 22 of the constitution in 2008. The Local Government Act was passed in 2009, which mandated the formation of local governments (GNH Commission, n.d). As a democratic constitutional monarchy, the King and Prime Minister lead at the national level, with ministerial bodies including the Ministry of Agriculture and Forests, and the Ministry of Works and Human Settlement, and non-ministerial bodies including the Gross National Happiness Commission (GNHC) and National Environment Commission (NEC), with dzongkhags and gewogs at the sub-national and local levels (Royal Government of Bhutan, 2012). Local governments have increased in their capacity to implement development projects; however, a need still exists to increase local institutional capacity. Challenges affecting the decentralisation process include the limited resources of local areas, and institutional spill-overs and externalities (GNH Commission, n.d).

In Bhutan, the key way in which development plans, programs and projects are implemented is through the Five Year Plan (FYP). Currently Bhutan is in the year of the Eleventh FYP (2013-2018). Bhutan focuses not only on economic growth, but also on citizen well-being, which is measured by the Bhutan Gross National Happiness (GNH) Index (UNEP, 2012). Article 9 of the Constitution of Bhutan states that the conditions enabling the pursuit of Gross National Happiness should be promoted (Ura et al., 2012). The GNH index is made up by 9 domains including psychological well-being, health, time-use, education, cultural diversity and resilience, good governance, community vitality, ecological diversity and resilience and living standards, and is linked with concrete policies and programmes. The GNH Index sets a framework and provides indicators to different sectors to guide development and compare progress across the country (Ura et al., 2012).

In the previous section, we see that the unique institutions and political system make Bhutan an ideal case study. In the research design of this thesis, the independent variable we analyse is actor type; we identify relevant actor types in this institutional landscape, including international organisations, foreign government, national government, local government, NGOs, corporations and communities. We identify and analyse many of the relevant actors and institutions highlighted here, including the Gross National Happiness Commission (GNHC), and the National Environment Commission (NEC) at the national government level, with dzongkhags and gewogs at the local government level, and relevant policies and projects, including the Sector Action Plan for Adaptation (SAPA) to mainstream adaptation into 11th FYP in the Renewable Natural Resources (RNR) Sector. We note that the concept of decentralisation is important. We expect national government actors to have the highest presence in the network with less local governmental and community actor participation, due to the historical context of Bhutan as a kingdom undertaking a relatively slow decentralisation process, with the formation of local governments only being mandated in 2009 (GNH Commission, n.d). This is reflected in our contention that *national actors are more central in the network than other actors*.

3.1.4. Multi-level climate adaptation network in Bhutan

Given the crosscutting nature of climate change, a polycentric approach is required with climate policy being integrated under multiple governing authorities over different scales, with collaborative planning and coordination between many actors and sectors (Ostrom, 2010) (European Union, 2012) (Charbit, and Michalun, 2009). The UN and the Secretariat have put processes in place in Bhutan to promote institutional coordination. The Royal Government of Bhutan is also planning to foster coordination among all levels of the network. A strategy will be undertaken in the Eleventh FYP, aiming to improve institutional coordination, separate agency functions, and clarify the roles of government agencies where they overlap (Royal Government of Bhutan, 2012).

The aim of the Bhutanese government is to foster coordination amongst all levels of the network. As previously discussed, this helps deliver a polycentric approach to governance, which is reflected in the research design of this thesis. We analyse the structure of climate change adaptation institutions in a complex network in Bhutan, and the relationship of relevant variables, including "actor type" on "actor inclusion" and "clustering", and the impact of "fragmentation", in order to recommend ways in which cooperation and coordination can be improved in the network. Improved horizontal and vertical integration, as well as local actor inclusion, can help create a more polycentric system, thereby helping Bhutan cope with future climate change impacts through adaptation.

3.2. Thesis structure

In the first section of this thesis we ask which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs. We discuss macro-structure relations by generally showing actor inclusion in networks, referring to an MDS plot to discuss the actor network. We then use statistical tests to answer the question of whether actor type has an effect on actor inclusion. To achieve this, we analyse microstructure relations, comparing degree centrality, betweenness centrality and eigenvector centrality with actor type. We discuss the structural embeddedness of national and local actors in institutional types, as an operationalisation of actor inclusion.

In the second section of the thesis we examine whether clustering occurs according to actor type in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks, by asking: *Do actors of the same type cluster together within networks*? We use macro-structure relations with the MDS plot to discuss the effect of clustering in the network, and analyse clustering within the actor network by comparing the microstructure relations of tie density within and between actor types.

Also in the second section, we examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks, asking; *Which actors make* *up the core and periphery of the network?* Looking again at macrostructure relations with the MDS plot we discuss which actors appear to make up the core and periphery of the network, and then compare the microstructure relations of tie density within and between actors.

In the third section of this thesis, we examine fragmentation in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks, posing the question: *Does the network display fragmentation?* We look at macro-structure relations with the MDS plot to discuss which networks appear to have the highest amount of fragmentation, and then analyse microstructure relations within and between actors, to determine the level of fragmentation. In the discussion section, we discuss the impact of results from these questions on co-operation and actor inclusion in the networks, and make recommendations of how actor inclusion can be encouraged, discussing general challenges facing local actor inclusion in projects and making recommendations for improving co-operation.

4. Data and Methodology

A literature review revealed 130 key actors, which were defined as nodes (Snijders et al., 2010) for the purposes of this paper. These 130 actors were categorised into 7 actor types including international organisations, foreign governments, national government, local government, NGOs, corporations and community groups. Examples of foreign government actors include the governments of Finland and India. International organisations include the UN Development Programme (UNDP) and the Asian Development Bank (ADB). National government actors include the Gross National Happiness Commission (GNHC) and the National Environment Commission (NEC). NGOs include the World Wildlife Fund (WWF) and Association ANDES. Corporations include the Bhutan Power Corporation (BPC) and Emergent Ventures India, and community actors include schools and village leaders. In this thesis, local governments include the Dzongkhag and Gewog, as we did not differentiate between sub-national and local actors (see Appendix A for a full list of actors).

The institutional type or design is made up of climate change-related policies and projects, with the institution being the project, institutional type being the project type and institutional design being either top-down or bottom-up. Through a literature review, data for 73 institutions (projects) from all regions of Bhutan was collected, noting the institutional type and design, with 4 institutions being categorised as bottom-up, and 69 institutions being categorised as top-down. In this thesis, the actor with the most influence in the design of the project is referred to as the "ego", with other actors in the project referred to as the "alter". We define top-down institutional designs as those with ego actors at the corporation, NGO, international organisation, foreign government or national government level; and we define bottom-up designs as those with ego actors at the local government or community level.

These 73 institutions were categorised into 14 institutional types, as some projects are either directly, or only indirectly related to climate change adaptation with adaptation not being the single focus, with all projects being climate-related. The first institutional type is “Climate Change Adaptation” projects, then “Mainstreaming Adaptation” projects, with “Climate Change” encompassing climate change adaptation, mainstreaming, communication, renewable energy, capacity building, adaptive capacity, sustainability, resource management, awareness, disaster management, sustainable forestry and climate change health. All of which, though indirectly related, nevertheless fall under the general theme of climate change related projects. Projects were then categorised as being either top-down or bottom-up. The years chosen for data collection of institutions are from 1996 to 2018 or on going. An example of a top-down climate change adaptation institution includes Local Climate Adaptive Living Facility (LoCAL), and top-down mainstreaming adaptation institution is the Sector Action Plan for Adaptation (SAPA).

An example of a bottom-up climate change adaptation institution includes the International Network of Mountain Indigenous Peoples (INMIP). We include the NAPA projects as a top-down disaster management institution, including projects; disaster management for emergency food security and first aid, lowering the water level of the Thorthormi lake, landslide and flood prevention, downstream flood protection, prepare a hazard zonation map for GLOF in Chamkhar Chhu basin, and community forest fire prevention (see Appendix B for a full list of institutions).

The method used to analyse ties between actors and institutions is the Ecology of Games Framework with Social Network Analysis (SNA). The software used to analyse the actor network is UCINET (Borgatti et al., 2002). In UCINET, ties between actors and institutions were coded as a dummy variable, with 1 denoting a tie being present, and 0 denoting no tie present, with binary ties making up the 2 mode (actor x institution) asymmetric actor network matrix (Hannenman and Riddle, 2005). This 2 mode data was then transformed into a 1 mode (actor x actor) symmetric actor network matrix to run analysis. With the ties between actors being undirected, not noting the strength of relationship with data not being weighted, no dichotomization was required during analysis (Hannenman and Riddle, 2005).

The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks being either top-down or bottom-up institutional designs, are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network. In Table 1 we give descriptive statistics including count of actor type, count of institutional type as either sub-network top-down or bottom-up institutional designs, count of actor types within each institutional type, and the density, number of ties, degree, average degree, betweenness, and betweenness standard deviation for the total network, and sub-networks (Table 1).

The degree is defined as the number of ties that a node has, being the number of actors with which it is connected (Freeman, 1979). The degree of a node is also related to its position within the network, if an actor has a high degree, then they are seen as being central in the network, with actors with a low degree being seen as a peripheral actor (Freeman, 1979). In a binary network, density is measured by dividing the number of observed ties, with the maximum possible ties, giving a percentage value (Hannenman and Riddle, 2005). If the density score is equal to 1, then all actors within the network are tied directly to each other; if the density score is equal to 0, then the network is fully disconnected and therefore fragmented (Prell et al., 2009).

4.1. Data and Methodology: research question 1

We aim to examine how actor inclusion in climate change adaptation institutions is shaped in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. To answer the research question, "*which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs"*, a multidimensional scaling (MDS) plot was created using NetDraw in UCINET, to visualise the overall network showing ties between actors working jointly within institutions, with similar actors being located closer together on the graph (Hannenman and Riddle, 2005). The MDS plot is used to visualise the overall structure of the network, but not the function, showing the network at only one point in time, not the evolution of the institutions or which ones survive within the network (Lubell, 2013). Each node is an actor with "actor type" denoted by a different colour, connected by ties (Hannenman and Riddle, 2005).

The independent variable, "actor type", is a possible driver of inclusion in networks. Significant effects of independent variable, "actor type", on the dependent variable, "actor inclusion", indicate effects in the network that are not due to random formation or destruction of ties (Hannenman and Riddle, 2005). We use Social Network Analysis (SNA) to analyse the actor network structure using three measures of point centrality - degree, betweenness and eigenvector centrality - to assess the embeddedness of national and local actors in top-down and bottom-up institutional designs (Freeman, 1979) (Grewal et al., 2006), using embeddedness as an operationalisation of actor inclusion.

The degree is the number of direct actor ties, with the degree centrality being a function of the degree (Freeman, 1979). Betweenness centrality is the number of times an actor connects two disconnected actors (Prell et al., 2009). An actor with a high betweenness centrality means the actor is highly central, as the relationship between two unconnected actors depends on the central actor (Wasserman and Faust, 1994) (Freeman, 1979). The eigenvector centrality of an actor is higher when an actor is connected to institutions that are also well connected. Centrality is measured by the degree dispersion; being the variance around the mean (Lubell et al, 2011). If centrality is measured as 1, the maximum numbers of actors are tied to a central actor, if the centrality is measured as 0; all actors are evenly connected across the network (Prell et al., 2009).

We ask whether dependent variable, “actor inclusion”, depends on the independent variable, “actor type”. Specifically we contend that there is a difference in the structural pattern between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs (Ingold, 2014). To assess this structural difference, we look at whether national actors have a higher degree centrality, betweenness centrality, or eigenvector centrality, in the total actor network (including top-down and bottom-up) or top-down designs only. Likewise, whether local governments have a higher degree centrality, betweenness centrality, or eigenvector centrality in bottom-up designs only. A t-test is used to compare the mean degree centrality, betweenness centrality and eigenvector centrality of national government actors and all other groups, and local governments and all other groups. The two-way ANOVA tests the level of significance of differences in normed degree centrality, betweenness centrality, and eigenvector centrality means between the 7 actor types, with the p-value. A regression model is used to fit the data and estimate the significance and strength of the relationship between independent variable, “actor type” and dependent variable, “centrality” as an operationalisation of embededness, and therefore actors’ inclusion (Table 2) (Table 3) (Table 4).

If an actor has a high degree centrality, betweenness centrality and eigenvector centrality relative to other actors in the network then we conclude that the actor is well embedded. We use relative values based on the review of this methodology by Christopoulos and Ingold (Christopoulos and Ingold, 2015). We do not calculate closeness centrality as another measure of centrality between actors, as it was found that degree centrality and closeness centrality were highly correlated (with $r = 0.85$, $p = 0.00$). We also test the hypothesis that national actors are more central in the network than other actors. If an actor has a high degree centrality, betweenness centrality and eigenvector centrality, relative to other actors then we conclude that the actor is central in the network (Wasserman and Faust, 1994) (Freeman, 1979) (Grewal et al., 2006).

4.2. Data and Methodology: research question 2

In research question 2 we aim to examine whether clustering occurs according to actor type in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. To answer research question 2, “*Do actors of the same type cluster together within networks?”,* we ask whether the dependent variable, “clustering”, depends on the independent variable, “actor type”, testing the hypothesis that *actors of the same type collaborate by clustering, as evidenced by significant differences in the density between “within-group” ties and “outside-group” ties*. We firstly refer to the multidimensional scaling (MDS) plot created using NetDraw in UCINET, to visualise the overall actor network, where each node is an actor with actor type denoted by a different colour, connected by ties. with more similar actors being located closer together on the graph (Hannenman and Riddle, 2005).

The software used to analyse the actor network is UCINET (Borgatti et al., 2002). In UCINET, ties between actors and institutions were coded as a dummy variable, with 1 denoting a tie being present, and 0 denoting no tie present, with binary ties making up the 2 mode (actor x institution) asymmetric actor network matrix (Hannenman and Riddle, 2005). This 2 mode data was then transformed into a 1 mode (actor x actor) symmetric actor network matrix to run analysis, with the ties between actors being undirected (Hannenman and Riddle, 2005). We analyse the total network, being made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (both top-down and bottom-up institutional designs), in a transformed 2 mode to 1 mode symmetric actor network.

We analyse clustering within the total network by comparing tie density within and between different actor types. To test that the patterns of within and between group ties are different across actor types we use a Structural Block model option of an ANOVA Density model in UCINET. A density table is used to show the probabilities of actor types being tied to one-another and a model is used to fit the data (Hannenman and Riddle, 2005). The model fit shows the differences among actor types, explaining the variance in the pair-wise presence or absence of ties. 5000 random permutation trials for pair-wise presence or absence of actors are used to calculate standard errors. We compare the density between within-group ties and outside-group ties relative to other actor types to analyse the effect of clustering according to actor type (Hannenman and Riddle, 2005), we use relative values based on the review of Christopoulos and Ingold (Christopoulos and Ingold, 2015).

As the second part of research question 2, we aim to examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Asking the research question, "*Which actors make up the core and periphery of the network?",* we use a simple Core/Periphery model to see which actors make up the core of the network, having the highest tie density amongst themselves, therefore collaborating in common climate-related institutions, with all other actors making up the periphery of the network, having a lower tie density amongst themselves, and therefore fewer climate-related institutions in common (Hannenman and Riddle, 2005) (Borgatti and Everett, 1999).

4.3. Data and Methodology: research question 3

Research question 3 asks: *Does the network display fragmentation?* In UCINET, ties between actors and institutions were coded as a dummy variable, with 1 denoting a tie being present, and 0 denoting no tie present, with binary ties making up the 2 mode (actor x institution) asymmetric actor network matrix (Hannenman and Riddle, 2005). This 2 mode data was then transformed into a 1 mode (actor x actor) symmetric actor network matrix to run analysis, with the ties between actors being undirected (Hannenman and Riddle, 2005). We use UCINET to perform the fragmentation analysis and attribute a fragmentation score for both the total network (that includes both top-down and bottom-up institutional designs), and the two individual sub-networks (top-down and bottom-up respectively).

We compare the results between the fragmentation scores of each institutional design relative to each other, to test the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*. We also look at the density score; if the density score is equal to 1, then all actors within the network are tied directly to each other; if the density score is equal to 0, then the network is fully disconnected and therefore fragmented (Prell et al., 2009). We chose to compare relative values based on the paper by Christopoulos and Ingold (Christopoulos and Ingold, 2015).

5. Results

5.1. Descriptive statistics and results: research question 1

Table 1 shows that there are 16 foreign government actors, 23 international organisations, 35 national government actors, 11 local governments, 19 NGOs, 13 corporations and 13 community groups; that make up a total of 130 actors in the actor network. Foreign governments constitute 16% of the total actor network, international organisations 23%, national government actors 35%, local governments 11%, NGOs 19%, corporations 13% and communities 13% (Table 1), (Figure 1).

Looking at Table 1 we see that there are a total of 73 climate-related institutional types that actors participated in. There is a total of nine projects under the institutional type “climate change adaptation”, two under “mainstreaming adaptation”, six “climate change”, five “mainstreaming”, three “communication”, seven “renewable energy”, seven “capacity building”, three “adaptive capacity”, eight “sustainability”, eight “resource management”, one “awareness”, twelve “disaster management”, one “sustainable forestry” and one under “climate change health”. As a percentage of the total, the institutional type “climate change adaptation” accounted for 12.3% of the total number of projects, sustainability accounted for 11%, and disaster management accounted for 16.4% (Table 1), (Figure 1).

Looking at actor participation in climate-related projects (Table 1) we see that foreign governments participated in different projects 20 times, international organisations 73 times, national government actors 132 times, local governments 30 times, NGOs 39 times, corporations, 18 times and community actors 26 times. This makes a total of 130 actors participating 338 times in climate-related projects, with foreign governments comprising 5.9% of total participation, international organisations 21.6%, national government 39%, local government 8.9%, NGOs 11.5%, corporations 5.3% and communities 7.7% (Table 1), (Figure 1).

Table 1. Descriptive network statistics for the total actor network. The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks (being either top-down or bottom-up institutional designs), are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Actor Type	Count	Institutional Type	Count	Top-down	Bottom-up
Foreign Governments	16	Climate Change Adaptation	9	8	1
International Organisations	23	Mainstreaming Adaptation	2	2	0
National Government Actors	35	Climate Change	6	6	0
Local governments	11	Mainstreaming	5	5	0
NGOs	19	Communication	3	3	0
Corporations	13	Renewable Energy	7	7	0
Community	13	Capacity Building	7	7	0
Total	130	Adaptive Capacity	3	3	0
		Sustainability	8	8	0
		Resource Management	8	6	2
		Awareness	1	0	1
		Disaster Management	12	12	0
		Sustainable Forestry	1	1	0
		Climate Change Health	1	1	0
		Total	73	69	4

	Foreign Govt.	Internat. Org	National Govt.	Local Govt.	NGO	Corporation	Community
Climate Change Adaptation	6	12	23	3	11	8	2
Mainstreaming Adaptation	2	3	3	0	2	0	0
Climate Change	0	5	6	0	2	0	0
Mainstreaming	1	6	11	2	3	0	0
Communication	0	6	6	2	2	1	0
Renewable Energy	2	8	5	0	1	8	2
Capacity Building	1	3	8	1	1	0	3
Adaptive Capacity	0	6	7	1	2	0	0
Sustainability	0	8	0	1	3	0	4
Resource Management	3	2	12	7	5	0	5
Awareness	0	0	0	2	1	0	2
Disaster Management	5	12	48	9	4	0	7
Sustainable Forestry	0	0	2	0	0	1	0
Climate Change Health	0	2	1	2	2	0	1
Top-down	17	71	130	23	33	18	19
Bottom-up	3	2	2	7	6	0	7
Ego	13	65	38	0	11	0	2
Alter	7	8	94	30	28	18	24
Total	20	73	132	30	39	18	26

Network type	Density	No. of Ties	Degree	Avg. Degree	Betweenness	Bet. S.D
Total Network (Top & Bottom)	0.036	338	0.5725	2.522	0.982	2.841
Top-down designs	0.035	311	0.5817	2.321	0.982	2.841
Bottom-up designs	0.052	27	0.1153	0.206	0.906	4.020

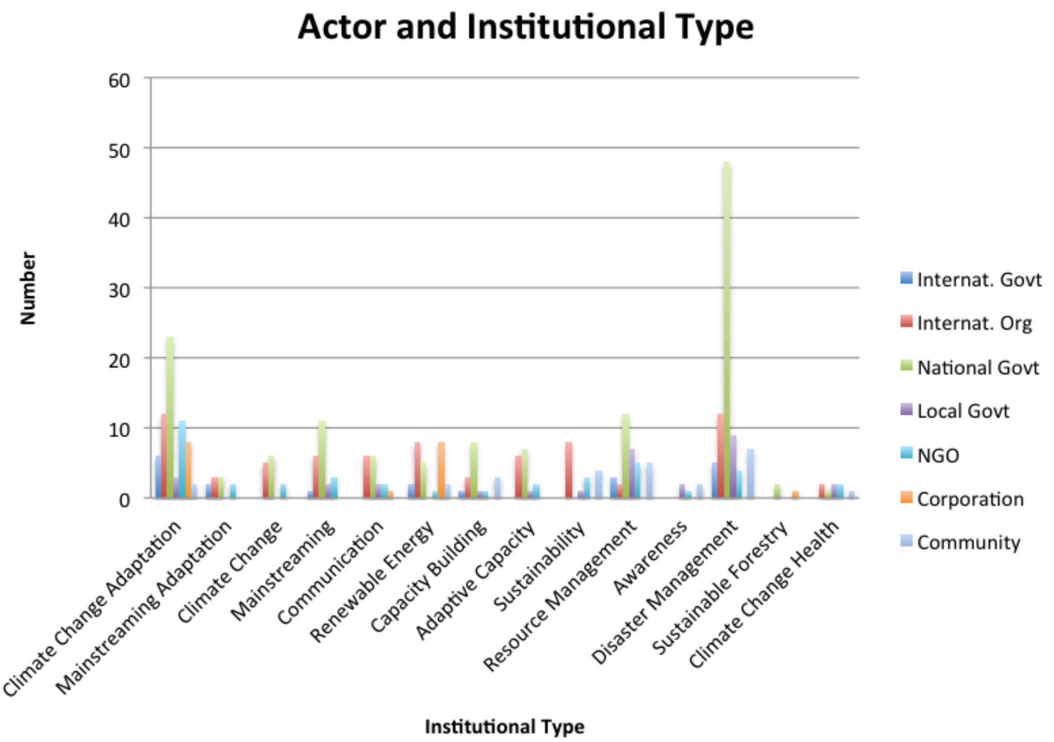

Figure 1. Comparison of actor type and institutional type

Looking at actor type and institutional type in Table 1 and Figure 1, and comparing to other project types, we see that foreign governments, international organisations and national government actors have a high participation in climate change adaptation and disaster management projects, local governments have a high participation in resource management and disaster management projects, NGOs participate mostly in climate change adaptation and resource management projects, corporations participate in renewable energy and climate change adaptation projects, and communities participate mostly in disaster management and resource management projects (Table 1), (Figure 1).

We see that national government actors participate most frequently in climate change adaptation institutional types, participating 23 times, with foreign governments participating 6 times, international organisations 12 times, local governments only 3 times, NGOs 11 times, corporations 8 times and communities only twice. We also see that national government actors participate most frequently in disaster management institutional types (48 times), with foreign governments participating 5 times, international organisations 12 times, local governments 9 times, NGOs participating 4 times, communities participating seven times, with no participation by corporations (Table 1), (Figure 1).

We see less actor participation in mainstreaming adaptation and adaptive capacity projects (with actors participating only 10 times in each), compared with 13 times on climate change projects, 23 times on mainstreaming, 17 times on communication projects, 26 times on renewable energy projects, 17 times on capacity building, 16 times on sustainability projects and 34 times on resource management. The least amount of actor participation occurred on awareness building projects (5 times), sustainable forestry (3 times) and climate change health (8 times). Overall, we see a lower level of participation in climate-related projects by foreign governments, local governments, corporations and communities, with increased participation in climate-related projects by international organisations, national government actors and NGOs (Table 1), (Figure 1).

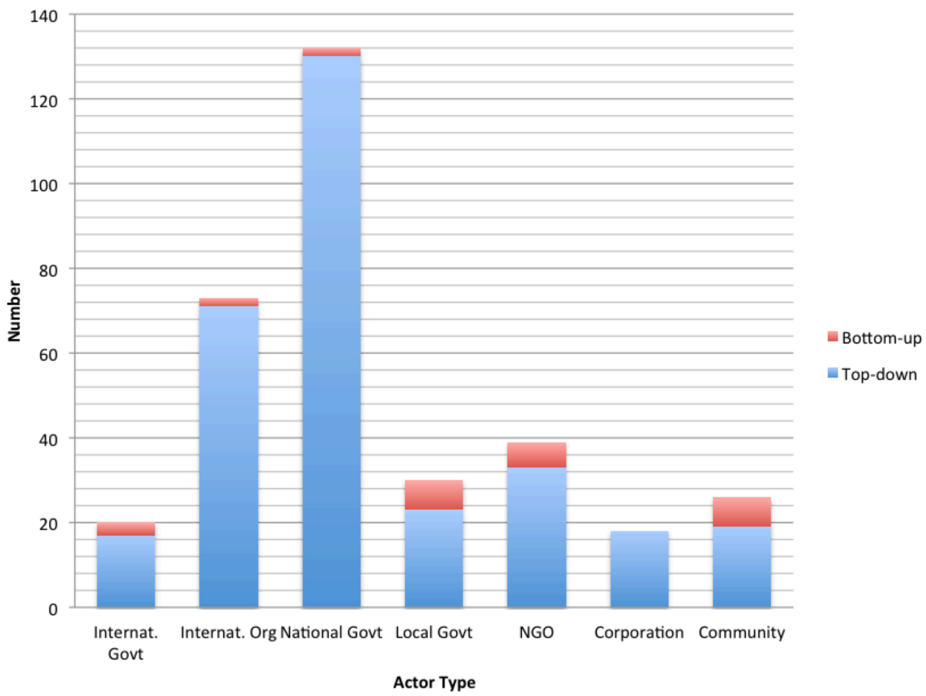

Figure 2. Actor type and institutional design

Looking at Table 1 and Figure 2, comparing actor type as "actor attribute" (1 mode) and institutional design (top down or bottom up) as "project attribute" (2 mode), from a total of 311 instances of actor participation, we see that national government actors have the highest participation in top-down institutional designs, comprising 41.8% of the network, foreign governments comprising 5.4%, international organisations 22.8%, local governments 7.4%, NGOs 10.6%, corporations 5.8%, and communities comprising 6.1%. From a total of 27 instances of actor participation, we see that local governments and communities have the highest participation in bottom-up institutional designs, comprising 25.9% of the network each, NGOs comprising 22.2%, foreign governments 11.1%, international organisations 7.4%, national government actors 7.4%, and corporations 0% (Table 1), (Figure 2).

Overall, we see a lower amount of participation in top-down institutional designs by actor types; foreign governments, local government actor, corporations and communities, with increased participation by actor types international organisations, national government actors and NGOs. And a lower amount of participation in bottom-up institutional designs by foreign governments, international organisations, national government actors and corporations, with increased participation by local governments, NGOs and communities (Table 1), (Figure 2).

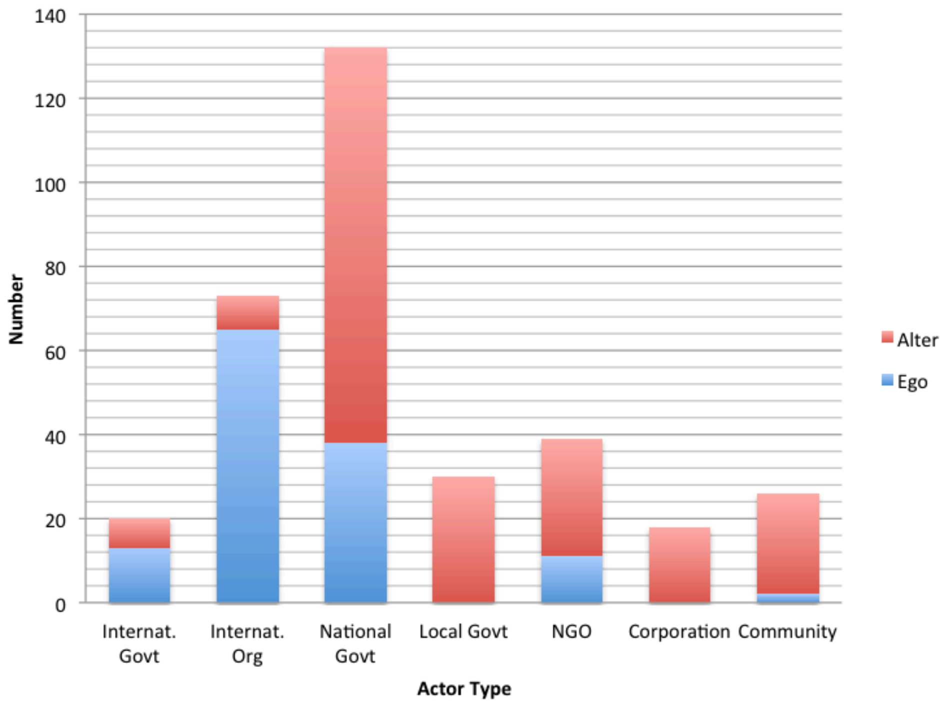

Figure 3. Actor type as ego or alter role

In this thesis, the actor or actors with the most influence on the design of the policy or project are referred to as "ego" actors; with other actors referred to as "alter" actors. Looking at Table 1 and Figure 3, comparing "actor type" and role as an "ego" or "alter", overall, we see a higher amount of ego roles in institutions by foreign governments and international organisations, with alter roles taken more often by national government actors, local governments, NGOs and communities (Table 1), (Figure 3).

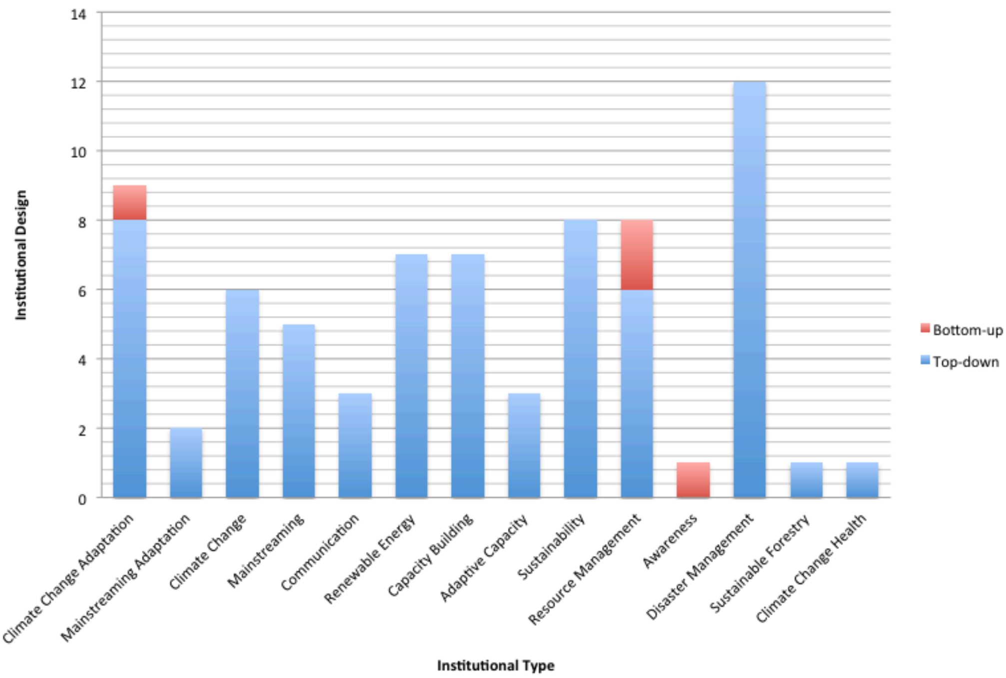

Figure 4. Institutional type and institutional design

We define top-down institutional designs as those with ego actors at the corporation, NGO, international organisation, foreign government or national government level, and we define bottom-up designs as those with ego actors at the local government or community level. Looking at Table 1 and Figure 4, comparing institutional type and institutional design, we see that 88.9% (or 8 of 9) climate change adaptation projects are top-down. All mainstreaming adaptation projects (2 in total), climate change projects (6), mainstreaming (5) communication (3), renewable energy (7), capacity building (7), adaptive capacity (3), and sustainability projects (8) are top-down. 75% (or 6 out of 8) resource management projects are top-down and the one awareness project was bottom-up. All 12 disaster management projects, and both sustainable forestry and climate change health projects were top-down. Overall, we can that say the overwhelming majority of climate-related projects (94.5% in total) are top-down, with only 5.5% being bottom-up (Table 1), (Figure 4).

Looking at Table 1, we see that from a total of 338 ties representing cooperation on a joint project between actors as nodes, that top-down institutional design networks have 311 ties, and bottom-up institutional design networks have only 27 ties. Looking at the density of these sub-networks, we see that top-down designs have a density of 0.035, and bottom-up designs have a density of 0.052 with top-down designs having a degree of 0.5817, and bottom-up designs a degree of 0.1153. We see that the average degree is higher for top down institutional designs at 2.321, compared to 0.206 for bottom-up (Table 1).

To answer research question 1, "*which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local* *actors in top-down and bottom-up institutional designs"*, we ask whether the independent variable, "actor type", is a possible driver for actor inclusion, thereby causing structural effects in the network. The significant impact of this independent variable on the dependent variable, "actor inclusion", indicates effects in the network that cannot be attributed to any random formation or destruction of ties (Hannenman and Riddle, 2005). We use Social Network Analysis (SNA) to analyse the actor network structure using three measures of point centrality (degree, betweenness and eigenvector) to assess national and local actor embededness in top-down and bottom-up institutional designs, using embeddedness as an operationalisation of actor inclusion (Freeman, 1979) (Grewal et al., 2006).

We contend that there is a difference between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs (Ingold, 2014). To determine this, we look at whether national actors have a higher degree centrality, betweenness centrality, or eigenvector centrality, in the total actor network (including top-down and bottom-up), top-down designs only, and whether local governments have a higher degree centrality, betweenness centrality, or eigenvector centrality in bottom-up designs only (Table 2) (Table 3) (Table 4).

A t-test is used to compare the mean centrality (degree, betweenness and eigenvector) of national government actors with all other groups, and also to test the mean centrality of local governments with all other groups. The two-way ANOVA tests the level of significance of differences in normed degree centrality, betweenness centrality, and eigenvector centrality means between the 7 actor types. A regression model (independent variable, "actor type" and dependent variable, "centrality") is used to fit the data and estimate the significance and strength of the relationship between independent variable, "actor type", and dependent variable, "actors' inclusion" (Table 2) (Table 3) (Table 4). If an actor has a high degree centrality, betweenness centrality and eigenvector centrality, relative to other actors then we conclude that the actor is is well embedded in the network, and also a central actor. (Table 2) (Table 3) (Table 4).

Table 2. Normed degree centrality means

The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks (being either top-down or bottom-up institutional designs), are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Degree Centrality with Actor Type

	Foreign Govt.	Int. Org	Nat. Govt	Local Govt.	NGO	Corp.	Community
Group Centrality							
Total Network	0.043	0.116	0.180	0.133	0.098	0.093	0.071

T-test normed degree means. National government with all other types (total network & top-down)
Local government with all other types (bottom-up)

T- test results	Total Network	Top-down	Bottom-up
Mean (national or local govt.)	0.0890	0.0780	0.3210
All other types mean	0.1800	0.1780	0.2790
Difference in means	-0.0910	-0.1000	0.0420
One-tailed test 1 > 2	1.0000	1.0000	0.1350
One-tailed test 2 > 1	0.0000	0.0000	0.8840
Two Tailed Test	0.0004	0.0001	0.3304

ANOVA Freeman Degree with Actor Type

	Treatment DF	F-statistic	Significance	R-squared
Total Network	7	2.8777	0.0122	0.138
Top-down	7	3.3050	0.0042	0.155
Bottom-up	5	1.0442	0.4469	0.235

Regression Freeman Degree with Actor Type

	R-square	Adj. R-square	F. Value	One-Tailed Prob.
Total Network	0.009	-0.005	1.258	0.26
Top-down	0.009	-0.005	1.258	0.27

Results from the group degree of actor types in the total actor network, show that national government actors have the highest degree (at 0.180), with international organisations having the next highest degree (at 0.116), local governments (0.133), NGOs (0.098), corporations (0.093), communities (0.071), and foreign governments having the lowest group degree (at 0.043) (Table 2).

We compare normed degree centrality actor type means, to assess embeddedness across institutional design, as an operationalisation of actor inclusion. A t-test is used to compare the mean degree centrality of national government actors with all other groups, and local governments with all other groups. We assess whether national actors have a higher degree centrality in the total actor network (both top-down and bottom-up institutional designs) as well as in top-down only designs. We also assess whether local governments have a higher degree centrality in bottom-up only designs. We find that national government actors do not have a higher degree centrality in the total network, as the average normed degree centrality of national government actors (0.089) is 0.091 units lower compared to other actors (0.18) (Table 2). We find that national government actors do not have a higher degree centrality in top-down designs, as the average normed degree centrality of national government actors (0.078) is 0.1 units lower compared to other actors (0.178). We see that local governments have a slightly higher degree centrality in bottom-up designs, as the average normed degree centrality of local governments (0.321) is 0.042 units higher compared to other actors (0.279).

A two-way ANOVA is used to test the level of significance of differences in normed degree centrality means between the 7 actor types. For the total actor network we see that the differences in actor means is significant, with the F-statistic 2.877, 7 degrees of freedom, at p-value of significance 0.01. The difference between group means accounts for 14% of the total variance in normed degree centrality means. For top-down designs, we see that the differences between actor means are significant, with the F-statistic 3.305, 7 degrees of freedom, at p-value of significance 0.004. The difference between group means accounts for 16% of the total variance in normed degree centrality means. For bottom-up designs we see that the differences between actor means are not significant, with the F-statistic 1.044, 5 degrees of freedom, at p-value of significance 0.45. The difference between group means accounts for 24% of the total variance in normed degree centrality means (Table 2).

The regression analysis testing independent variable, "actor type", and dependent variable, "degree centrality", shows that the differences among actor types explains only 0.9% of the variance in the degree centrality of actors. Permutation trials suggest that the results may be random (p= 0.26). We can say that the model does not predict degree centrality very well using variable actor type (R-square= 0.009), and that there is no significant effect of "actor type" on degree centrality in the network (p= 0.26) (Hanneman and Riddle, 2005) (Table 2).

Table 3. Betweenness centrality means

The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks being either top-down or bottom-up institutional designs, are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Betweenness Centrality with Actor Type

	Foreign Govt.	Int. Org	Nat. Govt	Local Govt.	NGO	Corp.	Community
Group Centrality Total Network	0.563	1.262	1.550	0.978	1.109	0.196	0.377

T-test normed betweenness means. National government with all other types (total network & top-down). Local government with all other types (bottom-up)

T- test results	Total Network	Top-down	Bottom-up
Mean (national or local govt.)	1.5500	1.2860	0.0000
All other types mean	0.7810	0.4920	1.4880
Difference in means	0.7690	0.7930	-1.4880
One-tailed test 1 > 2	0.9050	0.9610	0.3090
One-tailed test 2 > 1	0.0950	0.0390	1.0000
Two Tailed Test	0.1736	0.0419	0.6140

ANOVA Freeman Betweenness with Actor Type

	Treatment DF	F-statistic	Significance	R-squared
Total Network	7	0.5637	0.7892	0.030
Top-down	7	0.9519	0.4307	0.050
Bottom-up	5	0.9074	0.3711	0.211

Regression Freeman Betweenness with Actor Type

	R-square	Adj. R-square	F. Value	One-Tailed Prob.
Total Network	0.009	-0.006	1.167	0.283

Results from the group betweenness of actor types in the total actor network, show that national government actors have the highest betweenness at 1.55, with international organisations having the next highest betweenness at 1.262, NGOs at 1.109, local governments at 0.978, foreign governments at 0.563, communities at 0.377, and finally corporations with the lowest betweenness score at 0.196 (Table 3). Specifically top 5 actors with the highest betweenness scores include the Global Environment Facility (GEF) with betweenness score 18.356, Royal Society for Protection of Nature (RSPN) with score 16.507, Department of Forests and Park Services, Ministry of Agriculture and Forests (DoFPS-MoAF) at 14.445, National Environment Commission (NEC) at 10.506 and Gross National Happiness Commission (GNHC) at 6.453 (results not shown).

We contend that there is a difference in the structural pattern between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs (Ingold, 2014). To determine this, we compare normed betweenness centrality actor type means to assess embeddedness across institutional design, as an operationalisation of actor inclusion. Overall we see that the mean betweenness score for the top-down institutional designs is low, at 0.982, with standard deviation 2.841, with the mean betweenness score for bottom-up institutional designs also being low, at 0.906, standard deviation 4.020 (Table 1). We compare normed betweenness centrality means across institutional design using a t-test to compare the mean betweenness centrality of national government actors with all other groups, and local governments with all other groups. We ask specifically whether national actors have a higher betweenness centrality in the total actor network or top-down designs only, and whether local governments have a higher betweenness centrality in bottom-up designs. We find that national government actors have a higher betweenness centrality in the total actor network, as their average normed betweenness centrality (1.55) is 0.769 units higher compared to other actors (0.781) (Table 3). We find that national government actors have a higher betweenness centrality in top-down designs, as the average normed betweenness centrality of national government actors (1.286) is 0.793 units lower compared to other actors (0.492). We see that local governments have no betweenness centrality in bottom-up designs, as their average normed betweenness centrality is 0, compared to other actors (1.488) (Table 3).

A two-way ANOVA is used to test the level of significance of differences in normed betweenness centrality means between the 7 actor types. For the total actor network we see that the differences in actor means are not significant, with the F-statistic 0.564, 7 degrees of freedom, at p-value of significance 0.79. For top-down designs, we see that the differences in actor means are also not significant, with the F-statistic 0.952, 7 degrees of freedom, at p-value of significance 0.431. For bottom-up designs, again we see that the differences in actor means are not significant, with the F-statistic 0.907, 5 degrees of freedom, at p-value of significance 0.371 (Table 3).

The regression analysis testing independent variable, "actor type", and dependent variable, "betweenness centrality", shows that the differences among actor types explains only 0.9% of the variance in the betweenness centrality of actors. Permutation trials suggest that the results may be random (p= 0.283). We can say that the model does not predict betweenness centrality very well using variable actor type (R-square= 0.009), and that there is no significant effect of actor type on betweenness centrality in the network (p= 0.283) (Hanneman and Riddle, 2005) (Table 3).

Table 4. Eigenvector centrality means

The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network. Sub-networks (being either top-down or bottom-up institutional designs), are also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Eigenvector Centrality with Actor Type

	Foreign Govt.	Int. Org	Nat. Govt.	Local Govt.	NGO	Corp.	Community
Group Centrality Total Network	1.201	8.651	9.408	6.082	4.252	2.869	3.073

T-test normed eigenvector means. National government with all other types (total network & top-down). Local government with all other types (bottom-up)

T- test results	Total Network	Top-down	Bottom-up
Mean (national or local govt.)	9.4080	9.4080	36.0270
All other types mean	4.4760	4.4760	16.0990
Difference in means	4.9320	4.9320	19.9280
One-tailed test 1 > 2	0.9810	0.9820	0.9820
One-tailed test 2 > 1	0.0190	0.0180	0.0180
Two Tailed Test	0.0196	0.0182	0.0255

ANOVA Freeman Eigenvector with Actor Type

	Treatment DF	F-statistic	Significance	R-squared
Total Network	7	1.7398	0.1170	0.088
Top-down	7	1.7762	0.0902	0.090
Bottom-up	5	1.4428	0.2539	0.298

Regression Freeman Eigenvector with Actor Type

	R-square	Adj. R-square	F. Value	One-Tailed Prob.
Total Network	0.015	0	1.956	0.165

Results from the group eigenvector of actor types in the total actor network, show that national government actors have the highest eigenvector at 9.408, with international organisations having the next highest eigenvector at 8.651, local governments at 6.082, NGOs at 4.252, communities at 3.073, corporations at 2.869, and lastly foreign governments, with the lowest group eigenvector at 1.201 (Table 4).

We contend that there is a difference in the structural pattern between top-down and bottom-up institutional designs, with national actors being well embedded in top-down institutional designs, and local actors being well embedded in bottom-up institutional designs (Ingold, 2014). To support this contention, we compared normed eigenvector centrality actor type means to assess embeddedness across institutional design, as an operationalisation of actor inclusion. A t-test is used to compare the mean eigenvector centrality of national government actors and all other groups, and local governments and all other groups. We ask specifically whether national actors have a higher eigenvector centrality in the total actor network or top-down designs only, and whether local governments have a higher eigenvector centrality in bottom-up designs. We find that national government actors have a higher eigenvector centrality in the total actor network, and top-down designs only, as the average normed eigenvector centrality of national government actors (9.408) is 4.932 units higher compared to other actors (4.476) (Table 4). We see that local governments have a higher eigenvector centrality in bottom-up designs, as the average normed eigenvector centrality of local governments (36.027) is 19.928 units higher compared to other actors (16.099) (Table 4).

A two-way ANOVA is used to test the level of significance of differences in normed eigenvector centrality means between the 7 actor types. For the total actor network we see that the differences in actor means are not significant, with the F-statistic 1.739, 7 degrees of freedom, at p-value of significance 0.117. For top-down designs, we also see that the differences in actor means are not significant, with the F-statistic 1.7762, 7 degrees of freedom, at p-value of significance 0.0902. For bottom-up designs, again we see that the differences in actor means are not significant, with the F-statistic 1.443, 5 degrees of freedom, at p-value of significance 0.254 (Table 4). The regression analysis testing independent variable, “actor type”, and dependent variable, “eigenvector centrality”, shows that the differences among actor types explains 1.5% of the variance in eigenvector centrality. Permutation trials suggest that the results are random (p= 0.165). We can say that the model does not predict actor eigenvector centrality very well (R-square= 0.015), and that there is no significant effect of actor type on eigenvector centrality in the network (p= 0.165) (Hanneman and Riddle, 2005) (Table 4).

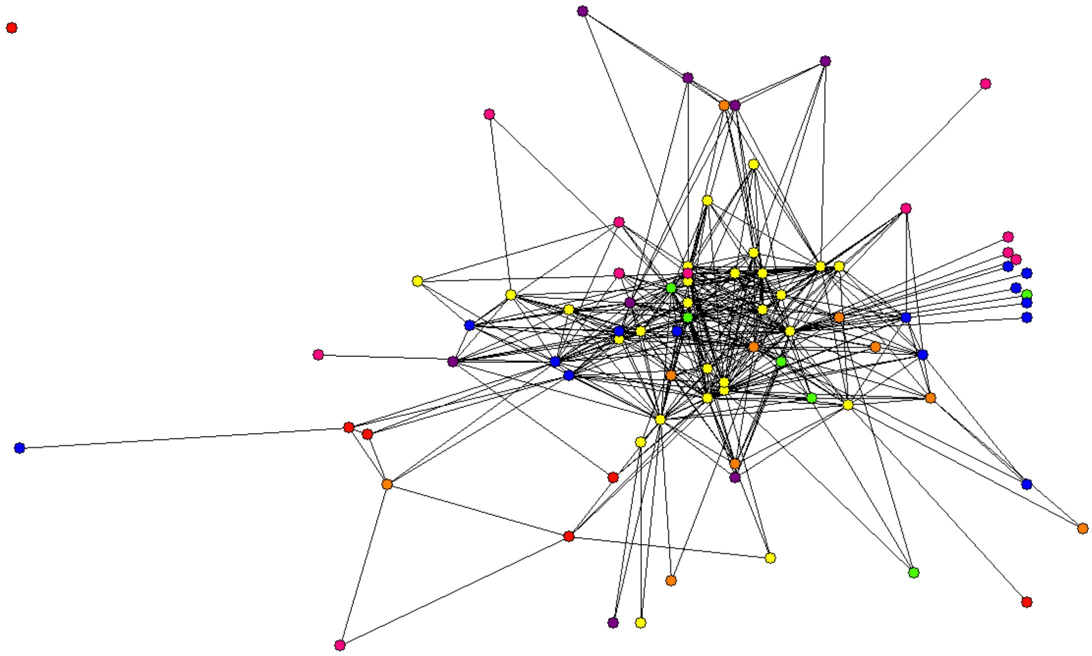

Figure 5. An MDS plot of the total actor network. The total network is made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up), in a transformed 2 mode to 1 mode actor network.

(Please note, in Figure 5, Figure 6 and Figure 7 red circles represent international organisations, orange circles are foreign governments, yellow circles are national government actors, green circles represent local governments, blue circles are NGOs, corporations are depicted as purple circles and community actors are shown as pink circles).

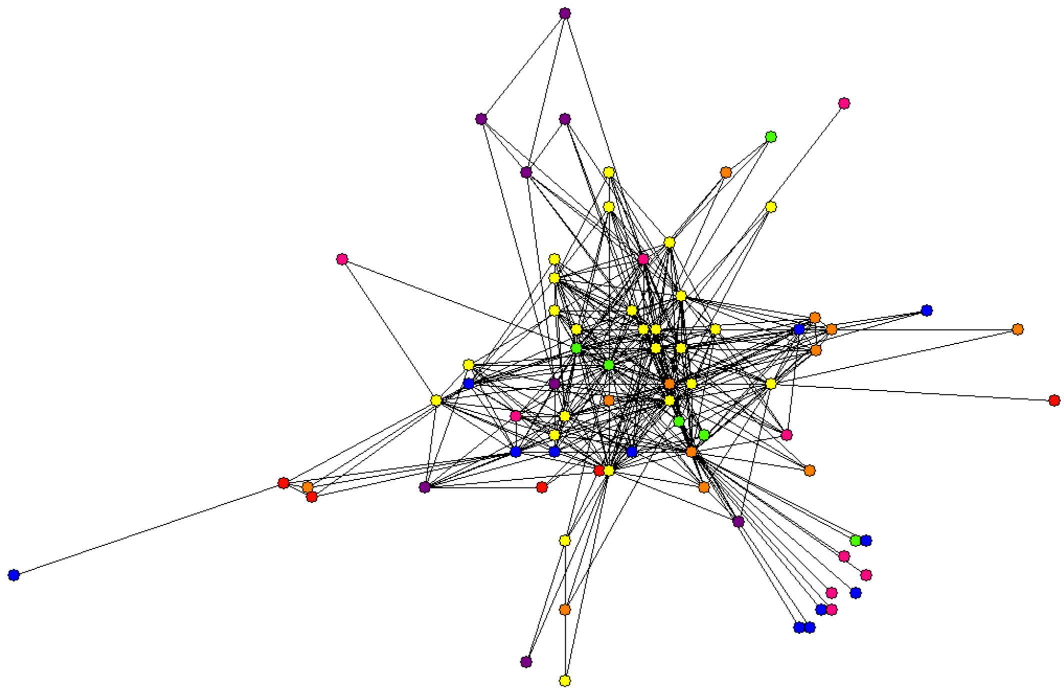

Figure 6. An MDS plot of the sub-network top-down institutional designs made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Figure 7. An MDS plot of the sub-network bottom-up institutional designs, made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

We contend that national actors are more central in the network than other actors. We use an MDS plot to visualise the total network, including both top-down and bottom-up institutional designs. First impressions show national government actors (denoted with yellow circles) have a more central position in the network, while foreign governments, corporations and communities have a more peripheral role in the network, being located further away from the other actors. The graph shows a main component group of all actors, with one isolate actor (UNFAO), being unconnected to any others (Hanneman and Riddle, 2005) (Figure 5).

Comparing the MDS plot for top-down institutional designs, and bottom-up institutional designs, first impressions show that national actors are more embedded in top-down designs, occupying a more central position in the network, as other actors including local government and communities occupy a more peripheral position (Figure 6). First impressions show that local governments and communities are more embedded in bottom-up institutional designs, occupying a more central position in the network, as other actors including NGOs and foreign governments occupy a peripheral position (Hannenman and Riddle, 2005) (Figure 7).

5.2. Results: research question 2

To answer research question 2, "*Do actors of the same type cluster together within networks?*" we ask whether dependent variable, "clustering", significantly impacts the independent variable, "actor type". Testing the hypothesis that, *actors of the same type collaborate by clustering, as evidenced by significant differences in the density between "within-group" ties and "outside-group" ties*. We use an MDS plot to visualise the total network; including both top-down and bottom-up institutional designs. First impressions show that the network generally displays high clustering, with national government actors (denoted by yellow circles) occupying a core position in the network, while foreign governments, corporations and communities have a more peripheral role in the network, being located further away from the other actors. The graph shows a main component group of all actors, with one isolate actor (UNFAO), being unconnected to any others (Hanneman and Riddle, 2005) (Figure 5).

We analyse clustering within the total network by comparing tie density within and between different actor types. To test that the patterns of within and between group ties are different across groups we perform a Structural Block model option of an ANOVA Density model in UCINET to analyse the total network as made up of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up institutional designs), in a transformed 2 mode to 1 mode symmetric actor network. We look at the density table to show the probabilities of actor types being tied to one-another.

We see that international organisations, national government actors and local governments show a strong tendency for "within-group" ties with 0.182, 0.334 and 0.327 units respectively. Foreign governments, NGOs and corporations also have a strong tendency toward within-group ties with 0.050, 0.111 and 0.231 units respectively. We see that national government actors have a high probability of sharing ties with many actor types, including foreign governments at 0.057 units, international organisations at 0.160 units, local governments at 0.210 units, NGOs at 0.138 units, corporations at

0.127 units and communities at 0.103 units. Finally, we see that communities have the highest probability of sharing ties with local governments (0.147). The model fit shows that the differences amongst actor types, explains 3.4% of the variance in the pair-wise presence or absence of ties. Permutation trials suggest that the results however are not random (p= 0.0094). We can say that although the model does not predict actor ties very well (R-square= 0.034) and that there is a significant effect of clustering according to actor type in the network (p= 0.0094) (Hannenman and Riddle, 2005) (Table 5).

Table 5. Structural Block model option of an ANOVA Density model (a) with model fit (b), and a Simple Core/Periphery model with density matrix table (c) for the total network comprised of all actors as nodes, with ties being actors working jointly on all climate-related projects (top-down and bottom-up institutional designs), in a transformed 2 mode to 1 mode actor network.

a) Structural Block model option of an ANOVA Density Model
Density Table

	Foreign Govt.	Internat. Org	National Govt	Local Govt	NGO	Corporation	Community
Foreign Govt	0.050	0.046	0.057	0.040	0.039	0.014	0.038
Internat. Org	0.046	0.182	0.160	0.095	0.110	0.097	0.057
National Govt	0.057	0.160	0.334	0.210	0.138	0.127	0.103
Local Govt	0.040	0.095	0.210	0.327	0.091	0.049	0.147
NGO	0.039	0.110	0.138	0.091	0.111	0.089	0.069
Corporation	0.014	0.097	0.127	0.049	0.089	0.231	0.030
Community	0.038	0.057	0.103	0.147	0.069	0.030	0.051

b) Structural Block Model Fit

R- square	Adj. R-Sqr	Probability
0.034	0.031	0.0094

c) Simple Core-Periphery Model
Density Matrix Table

	Core	Periphery
Core	2.165	0.252
Periphery	0.252	0.054

As the second part of research question 2, we aim to examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan. To answer the research question, "*Which actors make up the core and periphery of the network?*" we use an MDS plot to visualise the total network, including both top-down and bottom-up institutional designs. First impressions show that the network generally has a low density and high clustering, with national government actors (denoted by yellow circles) having a more central or core position in the network, whilst foreign governments, corporations and communities have a more peripheral role in the network, being located further away from the other actors. The graph shows a main component group of all actors, with one isolate actor (UNFAO), being unconnected to any others (Hanneman and Riddle, 2005) (Figure 5).

A simple Core/Periphery model was run for 1 mode network binary data, to see which actors make up the core of the network, sharing the highest amount of ties with each other. The Density Matrix of the Core/Periphery model for actors shows within-core ties of 2.165 units, between core and periphery ties of 0.252 units, and within-periphery ties of 0.054 units (Hannenman and Riddle, 2005) (Table 6) We found that the core of the network is made up of actors GEF, UNDP, GNHC, NEC, DoFPS-MoAF, DMG-MoHCA, RGoB, MoA, MoWHS, Dzongkhag, Gewog, RSPN and Communities, with all other actors making up the periphery of the network, sharing fewer ties (results not shown).

5.3. Results: research question 3

Research question 3 asks: *Does the network display fragmentation?* Using UCINET to perform fragmentation analysis we attribute a fragmentation score for the total network (that includes both top-down and bottom-up institutional designs), and the two individual sub-networks (top-down and bottom-up respectively) to test the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*. We also look at the density score to assess fragmentation in the networks (Prell et al., 2009).

The fragmentation score is the proportion of nodes in the network that are unable to reach each other (Hannenman and Riddle, 2005). We see that the proportion of actors unable to reach each other in the total actor network is 0.074, therefore the proportion of actors who can reach each-other is 0.926. The fragmentation score for top-down institutional designs is the same as for the total actor network. The proportion of actors unable to reach each other in bottom-up institutional designs is 0.984, hence the proportion of actors who can reach each other is 0.016 (Table 6).

Table 6. Fragmentation score for the total network, and sub-networks being either top-down or bottom-up institutional designs, also made up of actors as nodes, with ties being actors working together jointly on climate-related projects, in a transformed 2 mode to 1 mode actor network.

Fragmentation Centrality

	Frag. Score
Total Network	0.074
Top-down	0.074
Bottom-up	0.984

6. Discussion

6.1. Discussion: research question 1

The aim of research question 1 is to examine how actor inclusion in climate change adaptation institutions is shaped in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Specifically, research question 1 posits: *Which type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs*. To answer this question, firstly we discuss actor participation in climate change institutions generally, using the descriptive actor network results. We saw that in the total actor network (including both top-down and bottom-up institutional designs), national government actors make up the largest group, with international organisations being the second largest group, then NGO's, communities, corporations, and finally local government actors making up the smallest percentage of the total actor network (Table 1) (Figure 1). National government actors were expected to have the highest participation in the network with less local government and community actor participation, due to the historical context of Bhutan being a kingdom undergoing a relatively slow decentralisation process (with the formation of local governments only mandated in 2009) (GNH Commission, n.d). We also expected the presence of international organisations and NGOs in the network, due to Bhutan's listing as a least-developed country (LDC) (UNCTAD, 2014). In light of Bhutan's historical context, and future strategy for development path focus on country independence, and environmental and cultural conservation, we also expected a lack of presence of corporations in the network (Royal Government of Bhutan, 1999).

Looking at the total network (including both top-down and bottom-up institutional designs), we found a high level of participation in climate-related institutions by international organisation, national government and NGO actor types, and a lower amount of participation in climate-related projects by foreign governments, local government, corporations and communities (Table 1), (Figure 1). Overall, we found a high amount of participation in top-down institutional types by international organisations, national government actors and NGOs, and a high amount of participation in bottom-up institutional types by local government, NGOs and communities (Table 1), (Figure 2). These results were anticipated, as we expect a difference in actor participation between top-down and bottom-up institutional designs, with national government actors having a higher participation in top-down institutional design, and local actors having a higher participation in bottom-up institutional designs (Corfee-Morlot et al., 2009).

We found that most climate-related institutions are top-down designs (Table 1), (Figure 4), this result was expected as Bhutan is a developing country (UNCTAD, 2014), with most climate change adaptation projects being designed and funded by international actors (Figure 3). Also due to the high participation in the network by actor types international organisations and national government actors, where we defined top-down institutional designs as having a national government or international level actor as having an ego role in the project. While looking at actor type and role as an ego or alter, overall, we saw a higher amount of ego roles in institutions by foreign governments and international organisations, with alter roles taken more often by national government, local government, NGOs and communities (Table 1), (Figure 3).

To answer research question 1, "w*hich type of actors are most included within complex networks and projects in climate change adaptation policy in Bhutan via the embeddedness of national and local actors in top-down and bottom-up institutional designs"*, we assess actor inclusion via embeddedness, using measures of centrality. Embeddedness is defined as the extent to which the actor is entrenched in the network (Grewal et al., 2006). We look at both the immediate relationships between actors (or local embeddedness) and the actors' position within the wider network (global embeddedness). The three measures of point centrality borrowed from Social Network Analysis that we use to assess the embeddedness of actors in networks include; degree centrality, betweenness centrality and eigenvector centrality (Freeman, 1979) (Grewal et al., 2006).

We refer to the results from UCINET used to test how the independent variable, "actor type", is related to the dependent variable, "actor inclusion", via embeddedness. We use degree centrality as a local measure of structural embeddedness, with the degree centrality being the number of ties an actor directly shares with others in the network (Freeman, 1979). We expect there to be a difference in the structural network pattern comparing bottom-up and top-down designs and contend that national actors are well embedded in top-down institutional designs, whilst local actors are well embedded in bottom-up institutional designs. If an actor has a high degree centrality then we can say that they have many direct ties with other actors in the network, therefore the actor is well embedded in the network (Freeman, 1979).

We asked whether national actors have a higher degree centrality in the total network (including both top-down and bottom-up institutional designs), or top-down institutional designs only. We expected national actors to have the highest degree centrality in the total network and top-down designs, due to the historical context of Bhutan being a kingdom undergoing a relatively recent decentralisation process (GNH Commission, n.d). Results from the group degree of actor types in the total actor network, show that national government actors have the highest degree, with international organisations having the next highest degree (Table 2). However, using the t-test, we find that national government actors do not have a higher degree centrality in the total actor network or top-down designs. We also asked whether local governments have a higher degree centrality in bottom-up designs. We found that local governments have a slightly higher degree centrality in bottom-up designs, but found that the differences in actor means are not significant. Overall, regression analysis showed that there is no significant effect of independent variable actor type on dependent variable degree centrality in the total network (Table 2).

We use betweenness centrality as a local measure of structural embeddedness, being the number of times an actor connects two disconnected actors (Prell et al., 2009). If an actor has a high betweenness centrality then we can say that they are well embedded in the network connecting many unconnected actors (Freeman, 1979). Results from the group betweenness of actor types in the total actor network, show that national government actors have the highest betweenness, with international organisations having the next highest betweenness, local governments, communities and lastly corporations, with the lowest group betweenness (Table 3). These results were anticipated, as we expected national government actors to have the highest presence in the network with less local government and community actors, due to the country's historical context (GNH Commission, n.d).

Generally, the mean betweenness score for the top-down and bottom-up institutional designs are very low, indicating that actors did not often fall between two other actors (Table 1). A t-test was used to compare the mean betweenness centrality of national government actors and all other groups, and local governments and all other groups. We asked whether national actors have a higher betweenness centrality in the total actor network, top-down only designs, and whether local governments have a higher betweenness centrality in bottom-up designs. We found that national government actors have the highest betweenness centrality in the total actor network and in top-down designs and that local governments have no betweenness centrality in bottom-up designs. However, a two-way ANOVA found that for the total actor network, top-down designs, and bottom-up designs, the differences in betweenness centrality means are not significant (Table 3).

Therefore, we conclude that national actors have a high betweenness centrality compared to other actors, referring to the total actor network, and top-down designs. However the results are not significant, as a regression analysis shows that there is no significant effect of independent variable "actor type" on dependent variable "betweenness centrality" in the network (Table 3). Even though it is not a significant result, we do see that national actors connect disconnected actors throughout the network (Freeman, 1979), (Bodin et al., 2006). An actor with a high betweenness centrality means the actor is highly central (Wasserman and Faust, 1994) (Freeman, 1979).

We refer to the results from UCINET used to test how the independent variable, "actor type", is related to the dependent variable, "actor inclusion", via embeddedness. We used eigenvector centrality as a global measure of structural embeddedness. The eigenvector centrality of an actor is higher when an actor is connected to other actors that are also well connected (Lubell et al., 2011). Results from the group eigenvector of actor types in the total actor network, show that national government actors have the highest eigenvector, with local governments, NGOs and communities with lower group eigenvectors (Table 4). We asked whether national actors have a higher eigenvector centrality in the total actor network, and top-down designs only, and whether local governments have a higher eigenvector centrality in bottom-up only designs. We found that national government actors have a higher eigenvector centrality in the total actor network, and top-down designs only. We also found that local governments have a higher eigenvector centrality in bottom-up designs. However, for the total actor network, top-down designs, and bottom-up designs, we saw that the difference in actor means were not significant. With the regression analysis showing that there is no significant effect of independent variable "actor type" on dependent variable "eigenvector centrality" (Table 4).

Overall, in answer to research question one, we find that national government actors do not have a high degree centrality in top-down institutional designs, but do have a high betweenness centrality and a high eigenvector centrality in top-down institutional designs. We find that local actors have a slightly higher degree centrality, no betweenness centrality, but a high eigenvector centrality, in bottom-up institutional designs. Though in most analysis, 2-way ANOVA results show that the difference in group means are not significantly different, therefore we conclude that there is some difference between top-down and bottom-up institutional designs, with national actors being relatively better embedded in top-down institutional designs, and local actors being relatively better embedded in bottom-up institutional designs (Grewal et al., 2006).

We find that national government actors have the highest degree centrality (Table 2), a high betweenness centrality (Table 3), and high eigenvector centrality (Table 4) (though results are not significant), therefore we conclude that they are central actors in the network, and contend that the network is weakly influenced by central national actors who increase coordination by linking other disconnected actors (Berardo and Scholz, 2010).

6.2. Discussion: research question 2

The aim of research question 2 is to examine whether clustering occurs according to actor type in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 2 asks: "*Do actors of the same type cluster together within networks?*" The model fit (Table 5) showed that there is a statistically significant effect of independent variable, "actor type" on dependent variable, "clustering" in the total network (both top-down and bottom-up designs), therefore we can accept that the density between "within-group" ties and "outside-group" ties are significantly different, and we accept the hypothesis that *actors of the same type collaborate by clustering, as evidenced by significant differences in the density between "within-group" ties and "outside-group" ties*. We expected actor type to have a significant effect on clustering, as actors sharing similarities tend to share more ties with each other, interact and collaborate with each other within the network (Berardo and Scholz, 2010) (Scholz et al., 2008) (Ingold, 2014) (McPherson et al., 2001).

In the second part of research question 2, we aim to examine which actors make up the core and periphery in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. To answer the research question, "*Which actors make up the core and periphery of the network*?" the Core/Periphery model shows us that actors GEF, UNDP, GNHC, NEC, DoFPS-MoAF, DMG-MoHCA, RGoB, MoA, MoWHS, Dzongkhag, Gewog, RSPN and communities share a high density of ties amongst themselves, therefore collaborating in common climate-related institutions, making up the core of the network. All other actors have a lower density of ties amongst themselves, with fewer climate-related institutions in common, making-up the periphery of the network. These actors in the core of the network are important, as they are more able to coordinate their activities (Hannenman and Riddle, 2005).

6.3. Discussion: research question 3

The aim of research question 3 is to examine fragmentation in climate change adaptation institutions in a complex network in Bhutan, by applying a multilevel governance framework to explore links between actors and institutions within networks. Research question 3 asks: *Does the network display fragmentation?* We used UCINET to perform fragmentation analysis and attribute a fragmentation score to the total network (both top-down and bottom-up institutional designs), and the two individual sub-networks (top-down and bottom-up respectively) to test the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*.

We found that with a low fragmentation score, the proportion of actors able to reach each-other in the total actor network and top-down institutional designs is relatively high (Table 6). But with a high fragmentation score, we found that the proportion of actors able to reach each-other in bottom-up institutional designs is relatively low. Therefore, we conclude that there is a high amount of fragmentation in bottom-up designs, and a low amount of fragmentation in top-down designs (Table 6), and we accept the hypothesis that *top-down institutional designs are less fragmented than bottom-up institutional designs*. We also note that top-down institutional designs have a much higher amount of ties, a higher degree, and higher average degree compared to bottom-up institutional designs, and top-down designs were found to be less dense compared to the higher density of bottom-up institutional designs. However, since the overall density scores are extremely low for each institutional design, we conclude that there are few ties through which information can flow, with the network being very disconnected and therefore fragmented (Prell et al., 2009) (Table 1).

High institutional fragmentation could affect actors' ability to implement projects effectively, through inhibiting joint decision-making, possibly resulting in misunderstandings and conflicting strategies for project implementation, creating barriers to cooperation in climate change adaptation policy-making and project implementation (Klijn and Teisman, 2002). Since we conclude that the network; including both top-down and bottom-up institutional designs have high fragmentation, we conclude that there may be barriers to decision-making, and co-operation between actors, affecting actors' ability to implement climate change adaptation projects effectively.

6.4. Discussion: research questions 1, 2 and 3

In looking at results from research questions 1, 2 and 3; we conclude that there is some difference in the structural pattern between top-down and bottom-up institutional designs, with national actors being relatively better embedded in top-down institutional designs, and local actors being relatively better embedded in bottom-up institutional designs, and that national actors are more central in the network than other actors (Table 2), (Table 3), (Table 4). We hold that national actors cluster and occupy the centre of the network, sharing many ties and cooperating with many different actor types, but accept that overall, actors of the same type collaborate by clustering (Figure 5), (Table 5). We also contend that top-down institutional designs are less fragmented than bottom-up institutional designs. However, since the overall density scores are extremely low for each institutional design (Table 1), we conclude that both institutional designs demonstrate fragmentation (Table 6).

6.5. Recommendations

In this section, we draw conclusions from these results for the level of cooperation between actors; including the impact of actor inclusion, clustering and fragmentation on cooperation. We discuss general challenges related to local actor inclusion and make recommendations for how actor inclusion may be encouraged via horizontal and vertical integration. We make recommendations for a hybrid approach between top-down, and bottom-up designs, to ensure key sector inclusion such as the private sector, and finally, discuss general issues affecting actors' ability to implement climate change adaptation projects effectively.

We draw conclusions from our results for the level of cooperation between actors. Cooperation across levels is important because it can increase the effectiveness and implementation of adaptation policies (IPCC, 1. 2014). We found that national government actors have the highest number of ties in the total network (Table 2), have a high betweenness connecting disconnected actors in the network (Table 3), and high eigenvector (Table 4) (though results are not significant). As national government actors and international organisations have the highest degree in the network, and as actors with high degree have more influence in the network and are more able to collaborate in the network (Bodin and Crona, 2009), (Degenne and Forsé, 1999), we recommend that national government actors and international organisations play a greater role in the network as governments have greater resources, responsibilities and ability to complete projects jointly with other actors (Scholz et al., 2008). Specifically we note that actors with the highest betweenness scores in the network, mostly consisting of national government actors including the GEF, RSPN, DoFPS-MoAF, NEC and GNHC are important to provide social capital (Burt, 2004).

Since we find that the overall actor network structure in Bhutan has a very low density, but displays clustering, we can conclude that information sharing between actors to plan, monitor and enforce climate change adaptation projects may be low (Table 1) (Scholz et al., 2008). Nevertheless, there is an increased amount of cooperation between actors due to the effect of clustering and closure, through repeated transactions leading to trust and supporting cooperation (Berardo and Scholz, 2010) (Scholz et al., 2008) (Table 5) (Table 6).

We make recommendations for how cooperation and coordination can be encouraged or improved within the actor network of Bhutan. Recommendations include the increased involvement of government agencies most able to coordinate policy decisions (Lubell, 2013). We encourage increased involvement from government actors with the highest levels of access to the majority of political, financial and information resources, as they have a greater capacity to coordinate and influence outcomes (Lubell et al., 2011).

In 1999 the Royal Government of Bhutan set out a vision for the country's future of sustainable development and governance in Bhutan in the paper entitled *Bhutan 2020- A vision for Peace, Prosperity and Happiness*. The paper reaffirmed Gross National Happiness (GNH) as the main concept to follow under development, community forestry (CF) is an important part of these development goals, in terms of both reaching sustainable development, and also allowing the decentralisation of governance (Royal Government of Bhutan, 1999) (Gilmour, 2009). Our results show the current state of governance, as we see a higher amount of inclusion in climate-related projects by national government actors, and a lower amount of inclusion in climate-related projects by local governments and communities (Table 1), (Figure 1).

In the future, local levels of government are to gain new responsibility under the process of decentralisation from national control (Royal Government of Bhutan, 1999). This process of decentralisation in Bhutan is important, as decentralised, shared governance networks are seen as being flexible and adaptable, allowing them to work efficiently to achieve goals and respond quickly to environmental threats and opportunities, while hierarchies are seen as less efficient and slower to respond (Kapucu and Van Wart, 2006) (Provan and Kenis, 2007). This new paradigm of decentralisation can be described as a polycentric approach to governance, where responsibility for decision-making and implementation is distributed throughout multiple levels (Ostrom, 2014).

Since fragmentation creates extra costs within a complex system, it is important to avoid these costs, by increasing coordination and cooperation among actors (Lubell, 2013). Fragmentation can be reduced in networks through the integration of institutions via vertical and horizontal integration (Corfee-Morlot et al., 2009). We therefore recommend supporting the integration of institutions through vertical and horizontal integration, in order to decrease fragmentation. Cooperation may be improved by increasing the interaction between stakeholders, which can increase learning and build relationships. Programs can increase information availability, the dissemination of ideas and knowledge sharing (Ostrom, 2010).

We find that Bhutan generally has a cross-sectoral and multilevel approach to climate change adaptation, working both vertically and horizontally through levels of government (Corfee-Morlot et al., 2009). Cross-sectoral domains aiming to tackle climate impacts in Bhutan include deforestation reduction, such as the Reduced Emissions from Deforestation and Degradation (REDD) project under the UNFCCC (NEC and Royal Govt. of Bhutan, 2009), mainstreaming sustainable development (Royal Government of Bhutan, 2012), and the focus on a sectoral approach, such as the Sector Action Plan for Adaptation (SAPA) (Appendix B).

We also see a mixture of policies and projects at different institutional levels, including international climate change adaptation projects, for example the Hindu Kush Himalayan Hydrological Cycle Observing System (HKH HYCOS) project involving collaboration between Nepal, Bangladesh, Pakistan, India and China (ICIMOD, 2009) and the International Network of Mountain Indigenous Peoples (INMIP) involving collaboration between communities in 10 countries including Peru, India and China (INMIP, 2014). National projects include the Bhutan National Adaptation Programme of Action (NAPA) (Kingdom of Bhutan, 2006) and the National Disaster Risk Management Framework (Appendix B). And local projects, including local conservation support groups and community-based natural resource management projects (Appendix B). While we note that Bhutan generally has a cross-sectoral and multilevel approach to climate change adaptation, we recommend furthering this approach through the integration of institutions via vertical and horizontal integration (Corfee-Morlot et al., 2009).

The vertical dimension of multilevel governance recognises that national government actors must build capacity and support local governments in order to effectively implement climate strategies (OECD, 2008). We note that many projects and actions for climate change adaptation in Bhutan do not consider the involvement of actors at all spatial levels within the network, we especially note a lack of inclusion and decision-making by local governments and local communities and groups (Table 1) (Figure 1), which may be an impediment to adaptation project implementation on the ground and long-term effectiveness (Corfee-Morlot et al., 2009).

The current practice is for increasing local government action on climate change. In the context of climate change adaptation, decision-making at the local level specifically is very important, as climate change impacts mostly affect local areas, communities and economies. Local conditions determine vulnerability and adaptive capacity and local level implementation of adaptation activities is often the most effective strategy. Local adaptation activities and projects can provide an opportunity for learning to scale up successful projects (Charbit, and Michalun, 2009) (Corfee-Morlot et al., 2009). There are however, many challenges involved in integrating local actors into projects and institutions in Bhutan, including many different ethnic groups with different dialects, the historical background of Bhutan being a kingdom, and a general lack of community climate change awareness (Royal Government of Bhutan, 2012) (Davis and Li, 2013).

Neither bottom-up, nor top-down initiatives alone offer a complete view on climate adaptation policy effects and integration, therefore it is important to view both approaches as potentially complementary (Urwin and Jordan, 2008). It is now widely accepted that exclusively top-down, or bottom-up climate change adaptation strategies are not effective enough on their own. A review of climate change adaptation policies in the Asian Highlands, for instance, concluded that local adaptive capacity, based on community knowledge of local areas, must be better combined with state initiatives and government support, if local climate adaptation projects are to be successful (Xu and Grumbine, 2013). Our results show that most climate-related projects are top-down (Table 1) (Figure 4). For the future, we recommend a hybrid approach between top-down, and bottom-up designs, with the national government providing a guiding framework, but allowing local communities to make implementation decisions based on local area and community knowledge (Corfee-Morlot et al., 2009).

We recommend increasing both horizontal and especially vertical collaboration between actors in Bhutan for climate change adaptation projects, aiming to overcome the challenges in integrating local actors into projects and policies in Bhutan to achieve coherence and adaptive capacity in the long term (OECD, 2008) (Corfee-Morlot et al., 2009). We also recommend horizontal and especially vertical integration, especially through local actor inclusion to help create a polycentric system, by creating stronger institutional arrangements to increase adaptive capacity, allowing societies in Bhutan to cope with climate change impacts through adaptation (Adger, 2003) (Ostrom, 2014).

Recommendations to ensure that climate change adaptation is effective in the long term in Bhutan include making sure key sectors are involved, helping to link impacts on the local level with responses on the national level and strengthening capacity and institutions (UNDP-UNEP, 2011). One key sector that could have a larger role in climate adaptation in Bhutan are private sector businesses, as we found a lower amount of participation in climate-related projects by corporations, including local Bhutanese business groups and hydropower companies (Figure 1) (Table 1) (Appendix A). Private sector businesses in Bhutan will be directly affected by climate change through resource availability affecting supply and demand, financial losses associated with the increasing frequency of natural disasters, and also new business opportunities for technology, infrastructure and insurance (UNDP, 2011). Some specific adaptation projects that private sector businesses could be involved in include resilient infrastructure and innovative technology development, cutting across multiple sectors including agriculture, health, energy and urban planning. In the agricultural sector private businesses can invest in drought-resistant crops or irrigation technology with an aim to adapt to climate change impacts (UNDP, 2011).

Looking at the actor network in Bhutan, we have seen that the private sector is relatively under-involved in climate adaptation projects; this could be due to limitations including access to financial resources, market opportunities, and specific knowledge and skills to be involved in these projects. Through public-private partnerships and collaboration in Bhutan, resources can be better mobilised and access to financial resources can be increased. Public-private partnerships for climate change adaptation include the engagement and increased role of the private sector in national adaptation plans and programmes (NAPAs) (UNDP, 2011). To enable public-private partnerships to develop, the private sector requires improved information about investment opportunities and sectoral climate change impacts in the future, support of investment decision-making, better understanding of corporate social responsibility and improved dialogue between the public, private and civil society sectors (UNDP, 2011).

Many issues can affect an actor's ability to implement projects effectively, some current examples in Bhutan include lack of available finance affecting the Department of Forest and Park Services and community forest groups to achieve objectives (Davis and Li, 2013) (Wangdi et al., 2013), this could cause a significant issue for Bhutan, as we found that the Department of Forest and Park Services (DoFPS), is part of the core of the network, sharing a high amount of ties. We found that some actors may work on climate change projects in isolation, for example UNFAO (Figure 5), this institutional fragmentation could affect their ability to implement projects effectively, and we therefore recommend a regular forum to discuss climate change issues, inviting government agencies, donors and other stakeholders.

Other issues that are currently affecting actor's in Bhutan's ability to implement climate change adaptation projects effectively include lack of information, technical knowledge and public awareness. Bhutan suffers from a lack of general scientific knowledge on climate change issues among both government officials and communities, recommendations to improve local knowledge include national funding for local learning initiatives, climate change workshops for members of the community and annual formal national workshops for local government workers and schools (Davis and Li, 2013) (Wangdi et al., 2013). We note that some community awareness projects for climate change issues are currently being implemented, including the local conservation support group (Annex B), however we also note that some of the least amount of actor participation occurred on awareness building projects (Table 1).

The current limitation of access to climate data, weather forecasting and climate modelling capacity in Bhutan affects adaptation, as the meteorological records in Bhutan have a limited historical coverage, with a few stations recording patterns only over the last 15 years, however there is scope to develop capacity, including collecting data on snowfall, solar radiation and wind. The Hydro-Met office of the Department of Energy within the Ministry of Economic Affairs manages the meteorological service in Bhutan (Annex A) (Kingdom of Bhutan, 2011). In Bhutan most of the meteorological and hydrological stations are located within the inner and southern areas of Bhutan; data for the ranges of the higher mountains are not included due to the difficult topography. Due to a lack of stations to collect data, scientists are unable to model or forecast small-scale temperature and precipitation changes and climate change scenarios (Kingdom of Bhutan, 2011). We note that some capacity building projects for climate data collection are currently being implemented, including the enhancing capacity for hydro-meteorological services and climate modelling and Strengthening hydro-meteorological service for

Bhutan (SHSB) projects (Annex B).

7. Conclusion

In this thesis, we addressed the question of actor participation and inclusion in the design of climate change adaptation policies and projects, by comparing top-down designs of climate change adaptation policies and projects with bottom-up designs, using Bhutan as a case study.

Generally speaking, it is important that a broad range of stakeholders take part and are included in policy responses to climate change, with local actor participation and engagement being particularly relevant for the management of natural resources and land-use policies (Agrawal and Gibson, 1999) (Koontz, 2005). Adaptation to the impacts of climate change is highly local in scope, as impacts have a disproportionate impact on communities at the local level, especially those who are dependent on natural resources. In Bhutan the agriculture sector is highly dependent on the monsoon and temperature patterns, with climate change projected to impact livestock and cause crop failure, this poses a significant threat for the 69% of the population who depend on agricultural activities for their livelihood (Kingdom of Bhutan, 2006) (Kingdom of Bhutan, 2011). Climate change adaptation project success is highly dependent on the nature of local institutions and the structure of institutional arrangements (Mearns and Norton, 2010), therefore we highlight the importance of local actor participation and inclusion in climate change adaptation policies and projects.

The most effective way to address climate change issues is by taking a polycentric approach, where governance units are independent but linked in networks (Ostrom, 2010). We analyse the structure of climate change adaptation institutions in a complex actor network in Bhutan, examining the impact of "actor type" on "actor inclusion" and on network clustering and fragmentation. The aim of this analysis is to recommend ways in which cooperation and coordination can be improved through horizontal and vertical integration, especially through local actor inclusion, with the aim of helping to create a polycentric system.

We noted some differences between top-down and bottom-up institutional designs, with national actors being relatively better embedded in top-down designs, and local actors being relatively better embedded in bottom-up designs. We conclude that national actors cluster together and occupy the centre of the network, sharing many ties, but also cooperate with many different actor types, thereby increasing coordination by linking other disconnected actors. Overall however we find that actors of the same type generally collaborate by clustering with each other. We also found that top-down institutional designs are less fragmented than bottom-up designs. However, since the overall density scores are extremely low for each institutional design, we concluded that both types demonstrate fragmentation.

We found that many climate change adaptation policies and projects in Bhutan do not consider the involvement of actors at all spatial levels within the network. We especially note a lack of inclusion of local governments and communities, which may be an impediment to on-the-ground implementation and the long-term effectiveness of projects (Corfee-Morlot et al., 2009). We therefore recommend increasing local actor inclusion and participation in climate change adaptation policy and decision-making, though we recognise that there are many practical challenges and obstacles that must be overcome in order to achieve this. We also found that some actors may work on climate change projects in isolation, for example UNFAO (Figure 5). This institutional fragmentation could affect their ability to implement projects effectively, and we therefore recommend a regular forum to discuss climate change issues, inviting government agencies, donors and other stakeholders.

Our results showed that most climate-related policies and projects in Bhutan are top-down. For the future, we recommended a hybrid approach between top-down, and bottom-up designs, with the national government providing a guiding framework, but allowing local communities to make implementation decisions based on community knowledge of local areas (Corfee-Morlot et al., 2009). The key to success in this regard could lie in better education and awareness building at the local level to ensure community engagement and ownership of outcomes.

We recommend increasing both horizontal and especially vertical collaboration between actors in Bhutan, in order to overcome the challenge of local actor integration and to achieve coherence and adaptive capacity in the long term (OECD, 2008) (Corfee-Morlot et al., 2009). This approach should also help create a polycentric system, by creating stronger institutional arrangements to increase adaptive capacity, thereby allowing societies in Bhutan a strategy to cope with climate change impacts through adaptation, especially given the uncertainty of climate change impacts on the country (Adger, 2003) (Ostrom, 2014). The strategy promoted by the the Royal Government of Bhutan, and also recommended by us, is to foster coordination among all levels of the network, continue the process of decentralisation and improve institutional coordination. This will promote adaptive capacity and resilience to climate impacts in the future (Charbit and Michalun, 2009) (Adger, 2003) (Ura et al., 2012) (Royal Government of Bhutan, 2012) (Ostrom, 2010) (Ostrom, 2014).

We note some limitations of this thesis. Only a snapshot of the actor network could be taken, therefore it is hard to get a very detailed view of deeper network processes and changes through time. We experienced general difficulties with data collection for Bhutan due to a lack of detailed and documented information, especially when collecting data on local actor involvement such as local community groups and local non-state actor participants. As this thesis is country and situation specific to Bhutan, all recommendations will not apply to all other countries, however lessons learned from this thesis may be generalised.

The study of the actor network and institutional designs in Bhutan is very interesting and deserves further work, for example to answer the question of how institutional design affects project outputs and levels of success by analysing the impact of actor reciprocity on the network. However, as many projects are currently on-going, this would be an interesting topic for future study. Further questions that would be interesting to discuss include whether adaptation projects in Bhutan are linked to measurement, review and verification under the Climate Change Convention, and whether Bhutan is receiving adequate financial and technological assistance from the UNFCCC to enable them to achieve adaptation goals and targets. It would also be interesting to look at the adaptation gap in Bhutan, in terms of the lack of financial resources available to actually achieve adaptation goals, including financial pledges, versus the financial costs of adaptation in the future according to a business as usual emissions pathway. Finally, a comparison of Bhutan's Gross National Happiness Index as a driver for climate change adaptation, with other more traditional measures such as GDP, could also provide valuable insights.

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A. Appendix

A.1. Full list of actors by actor type

A.1. Full list of actors by actor type foreign governments

Actor	Acronym
European Union	EU
Estonia Government	Estonia Government
Swedish Energy Agency	Swedish Energy Agency
Norwegian Agency for Development Cooperation	NORAD
Embassy of Finland	Embassy of Finland
UKAid	UKAid
Government of Finland	Government of Finland
Department of Hydro-Met Services China	Hydro-Met Services China
Department of Hydro-Met Services India	Hydro-Met Services India
Finnish Meteorological Institute	Finnish Meteorological Institute
Swiss Agency for Development and Cooperation	SDC
UN Food & Agriculture Organisation	UNFAO
Swedish Government- Swedish International Development Agency	Sida
Government of India	Government of India
Japan International Cooperation Agency	JICA
Government of Austria	Government of Austria

A.2. Full list of actors by actor type International Organisation

Actor	Acromyn
UN International Fund for Agricultural Development	IFAD
Global Environment Facility	GEF
UN Development Programme	UNDP
UN Capital Development Fund	UNCDF
UN Environment Programme	UNEP
UNEP RISO Centre	UNEP RISO Centre
Asian Institute of Technology	Asian Institute of Technology
Asian Development Bank	ADB
International Institute for Environment and Development	iied
First Peoples Worldwide	First Peoples Worldwide
International Center for Integrated Mountain Development, Nepal	ICIMOD
World Meteorological Organisation	WMO
UN Framework Convention on Climate Change	UNFCCC
HELVETAS Swiss Intercooperation	HELVETAS Swiss Intercooperation
UN Programme on Reducing Emissions from Deforestation/Degradation	UN-REDD
World Health Organisation	WHO
UN Environment Program Regional Office for Asia and the Pacific	UNEP ROAP
UNDP/UNEP Poverty and Environment Initiative program	PEI
UN Economic and Social Commission for Asia and the Pacific	UNESCAP
UN Children's Fund	UNICEF
UN Educational, Scientific and Cultural Organisation	UNESCO
Japan Aerospace Exploration Agency, Japan	JAXA
The Mountain Institute, USA	The Mountain Institute, USA

A.3. Full list of actors by actor type National Government

Actor	Acromyn
Gross National Happiness Comission	GNHC
National Environment Commission	NEC
Council for RNR Research in Bhutan, Ministry of Agriculture and Forests	CoRRB
Department of Aid and Debt Management- Ministry of Finance	DADM-MoF
Department of Forests and Park Services- Ministry of Agriculture and Forests	DoFPS-MoAF
Ministry of Finance	MoF
Department of Energy- Ministry of Trade and Industry	MoTI
Ministry of Economic Affairs	MoEA
Watershed Management Division of Ministry of Agriculture	WMD-MoA
Ministry of Education	MoE
Department of Energy- Hydro-Meteorological Services Division	DoE-Hydro-Met
Department of Geology and Mines- Ministry of Economic Affairs	DMG-MoEA

Department of Local Governance- Ministry of Home and Cultural Affairs	DLG-MoHCA
Department of Disaster Management, Ministry of Home and Cultural Affairs	DDM-MoHCA
Department of Hydro-met Services, Ministry of Economic Affairs	DHMS-MoEA
Road Surface and Transport Authority	Road Surface and Transport Authority
Department of Renewable Energy	DoRE
Department of Forestry, Social Forestry Division	SFD
Ugyen Wangchuck Institute for Conservation and Environment	UWICE
Royal Government of Bhutan	RGoB
Department of Public Health, Ministry of Health	DoPH-MoH
Ministry of Agriculture	MoA
Renewable Natural Resources Extension Agent- Agriculture	RNREA-A
Renewable Natural Resources Extension Agent- Forest	RNREA-F
Renewable Natural Resources Extension Agent- Livestock	RNREA-L
Ministry of Agriculture and Forests	MoAF
Ministry of Home and Cultural Affairs	MoHCA
Ministry of Works and Human Settlement	MoWHS
Department of Engineering Services	DoES
National Land Commission Secretariat	NLCS
Department of Roads- Ministry of Works and Human Settlement	DoR-MoWHS
Department of Local Governance-Disaster Management Office	DLG-DMO
National Statistics Bureau	NSB
Council of Research and Extension, Ministry for Agriculture	R&E-MoA
National Biodiversity Centre	NBC

A.4. Full list of actors by actor type Local Government

Actor	Acromyn
Dzongkhag	Dzongkhag
Gewog	Gewog
Samdrup jongkher	Samdrup jongkher
Trashigang District Administration	Trashigang District Administration
Womrong Dungkhag	Womrong Dungkhag
Lumang gewog administration	Lumang gewog administration
Kangpara Gewog Administration	Kangpara Gewog Administration
Kangpara Environment Management Committee	Kangpara Environment Management Committee
Zhemgang and Wangduephodrang	Zhemgang and Wangduephodrang
Thimphu, Thromde	Thimphu, Thromde
Phuentsholing Thromde	Phuentsholing Thromde

A.5. Full list of actors by actor type NGO

Actor	Acromyn
World Wildlife Fund	WWF
MacArthur Foundation	MacArthur Foundation
Danish International Development Assistance	DANIDA
Royal Society for Protection of Nature	RSPN
National Women's Association of Bhutan	National Women's Association of Bhutan
Mendrelgang Farmers Association	MFA
Tsirang Women Group	Tsirang Women Group
Zilukha Nunnery	Zilukha Nunnery
Merak Sakten	Merak Sakten
Kidhekhar Buddhsit Institute	Kidhekhar Buddhsit Institute
The Bhutan Water Partnership	The Bhutan Water Partnership
The Christensen Fund	The Christensen Fund
Association ANDES	Association ANDES
Association of Bhutanese Industry	Association of Bhutanese Industry
Tarayana Foundation	Tarayana Foundation
Stockholm Environment Institute	SEI
Austrian Development Agency	ADA
Bhutan Chamber of Commerce and Industry	BCCI
Construction Association of Bhutan	Construction Association of Bhutan

A.6. Full list of actors by actor type Corporation

Dagachhu Hydro Power Corporation Limited	Dagachhu Hydro Power Corporation Limited
Tata Power Company India	TPC
Druk Green Power Corporation Bhutan	DGPC
Bhutan Power Corporation	BPC
Tangsibji Hydro Energy Limited	Tangsibji Hydro Energy Limited
Emergent Ventures India	Emergent Ventures India
SKW Tashi Metals	SKW Tashi Metals
Ugen Ferro Alloy Pty Ltd	Ugen Ferro Alloy Pty Ltd
Bhutan Ferro Alloys Ltd	Bhutan Ferro Alloys Ltd
Norbu Samyul Consulting	Norbu Samyul Consulting
Forestry Development Corporation Limited	FDCL
Tala Hydroelectric Power Authority	Tala Hydroelectric Power Authority
Kurichu Hydro Power Corporation Ltd	Kurichu Hydro Power Corporation Ltd

A.7. Full list of actors by actor type Community

Actor	Acromyn
21 Community Lhakhangs	21 Community Lhakhangs
Community Schools	Community Schools
Bajo Higher Secondary School	Bajo Higher Secondary School
Wama, Pangthang, and Udaric in Mongar	Wama, Pangthang, and Udaric in Mongar
Communities	Communities
Communities in Wamrong and Kangpara	Communities in Wamrong and Kangpara
Monpas and Uraps community	Monpas and Uraps community
Jangbi and Ura community	Jangbi and Ura community
Tshogpa (village leader)	Tshogpa (village leader)
Highland, riverine communities	Highland, riverine communities
Districts of Gasa and Punakha	Districts of Gasa and Punakha
Local communities- Lunana area	Local communities- Lunana area
Synoptic stations in the Dzongkhags	Synoptic stations in the Dzongkhags

B. Appendix

B.1. List of Institutions by Institution Type and Institutional Design

B.1. Top-down climate change adaptation projects and policies

Climate change adaptation in Bhutan's renewable natural resources sector

Capacity Strengthening of Least Developed Countries for Adaptation to Climate Change (CLACC)

Local Climate Adaptive Living Facility (LoCAL)

Technology Needs Assessment and Technology Actions Plans for Climate Change Adaptation

Addressing the Risks of Climate-induced Disasters through Enhanced National and Local-

Capacity for Effective Action

Lowering of the Raphstreng Tsho Lake

NAPA- Climate Change Adaptation

Sectoral Adaptation Assessment

B.2. Top-down mainstreaming adaptation projects and policies

Sector Action Plan for Adaptation (SAPA) to mainstream adaptation into 11th FYP in the RNR Sector

Climate Summit for a Living Himalayas

B.3. Top-down climate change projects and policies

Establishment of Climate Change Unit

Establishment of Multi-Sectoral Technical Committee on Climate Change (MSTCCC)

Regional Climate Change, Energy Ecosystems Project

Climate Sensitivity Analysis in the Agriculture and Forestry Sectors

Capacity Building on Climate Change
NAPA

B.4. Top-down mainstreaming projects and policies
Enhancing Global Environmental Management in Bhutan's Local Governance System-
(of the Rio Conventions)
Environmental Mainstreaming
Regional Climate Change Adaptive Knowledge Platform (AKP)
Sustainable Environment Support Programme (SESP) support to 10th FYP, and prepare 11th FYP
Strategy for Development Cooperation

B.5. Top-down communication projects and policies
Initial National Communication to UNFCCC (INC)
Second National Communication to UNFCCC (SNC)
National Capacity Self Assessment for Global Environmental Management

B.6. Top-down renewable energy projects and policies
Community Micro-hydro for Sustainable Livelihoods
National Renewable Energy Policy and Programme for Sustainable Development
Dagachu Hydropower Project
Promoting Alternative Energy through Use of Solar Water Heater (SWH)
The Green Power Development Project
Green Power Development Project II
Hydro-Electric Projects- Tala Hydropower Plant

B.7. Top-down capacity building projects and policies
Enhancing Capacity for Hydro-meteorological services and climate modelling
Green House and Weather Station project
Strengthening Hydro-Meteorological Service for Bhutan (SHSB)
Capacity building of the National Environment Commission in Climate Change
Funding to 32 gewogs- decentralisation support programme (DSP)
NAPA-Provide weather and seasonal forecasts
NAPA-Install an early flood warning system on the Pho Chhu river basin

B.8. Top-down adaptive capacity projects and policies
Study on vulnerable sectors and communities in Thimphu
Support to Enhancing Adaptive Capacity to Climate Change
Strengthen Capacity for Disaster and Risk Management

B.9. Top-down sustainability projects and policies

Biomass Fuel Efficiency Project
Improved Community Cooking Stove
Community-Based Initiative to Energy Conservation in Merak & Sakten
Sustainable Use of Fuel Wood
Environmental Management and Conservation
An Approach to Sustainable Living
Introduction to Fuel Efficient Stoves
Sustainable Use of Fuel Wood (2)

B.10. Top-down resource management projects and policies
Integrated Water Resource Management (IWRM)
Participatory Forest Management Project (PFMP)
Reduced Emissions from Deforestation and Degradation (REDD)
Capacity Development
REDD + Consultation Workshop
NAPA- Safeguard farmers from water shortages by rainwater harvesting

B.11. Top-down disaster management projects and policies
Hindu Kush Himalayan Hydrological Cycle Observing System (HKH HYCOS) Project
Glacial Lake Outburst Floods (GLOF) Reducing Risks and ensuring Preparedness conference
Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in-
the Kingdom of Bhutan
Disaster Response and Recovery Preparedness
NAPA-Disaster Management for emergency food security and first aid
NAPA-Lower the water level of the Thorthormi lake
NAPA- Landslide and Flood Prevention, Intervene in landslide affected areas
NAPA- Downstream Flood Protection, Intervene in landslide affected areas
NAPA-Prepare a hazard zonation map for GLOF in Chamkhar Chhu basin
NAPA- Community Forest Fire Prevention
National Disaster Risk Management Framework
Addressing the Risk of Climate-induced Disasters through Enhanced National and-
Local Capacity for Effective Actions

B.12. Top-down sustainable forestry projects and policies
National Strategy for the Development of Non-wood Forest Products in Bhutan

B.13. Top-down climate change health projects and policies
Climate Change Adaptation to Protect Human Health

B.14. Bottom-up climate change adaptation projects and policies

International Network of Mountain Indigenous Peoples (INMIP)

B.15. Bottom-up awareness projects and policies

Local Conservation Support Groups

B.16. Bottom-up resource management projects and policies

Community-based Natural Resource Management

Community Based Watershed Management

Declaration

under Art. 28 Para. 2 RSL 05

Last, first name: RUSSELL, JESSICA LEIGH

Matriculation number: 13-100-367

Programme: MSc Climate Sciences

Bachelor ☐ Master ■ Dissertation ☐

Thesis title: Complex climate change adaptation network in Bhutan; how actor type impacts actor inclusion and clustering

Thesis supervisor: Prof. Dr. Karin Ingold, Institute of Political Science, University of Bern, Switzerland

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due acknowledgement has been made in the text. In accordance with academic rules and ethical conduct, I have fully cited and referenced all material and results that are not original to this work. I am well aware of the fact that, on the basis of Article 36 Paragraph 1 Letter o of the University Law of 5 September 1996, the Senate is entitled to deny the title awarded on the basis of this work if proven otherwise. I grant inspection of my thesis.

Bonn, Germany, 20/09/15

Place, date

J. Russell

Signature