



**Combining nexus and resilience thinking in a novel
framework to enable more equitable and just
outcomes**

**L.C.Stringer, C.H.Quinn, R.J.Berman, H.T.V.Le,
F.E.Msuya, S.E. Orchard and J.C.B. Pezzuti**

October 2014

Sustainability Research Institute

Paper No. 73

Centre for Climate Change Economics and Policy Working

Paper No.193

SRI PAPERS

First published in 2014 by the Sustainability Research Institute (SRI)

Sustainability Research Institute (SRI), School of Earth and Environment,
The University of Leeds, Leeds, LS2 9JT, United Kingdom

Tel: +44 (0)113 3436461

Fax: +44 (0)113 3436716

Email: SRI-papers@see.leeds.ac.uk

Web-site: <http://www.see.leeds.ac.uk/sri>

About the Sustainability Research Institute

The Sustainability Research Institute conducts internationally recognised, academically excellent and problem-oriented interdisciplinary research and teaching on environmental, social and economic aspects of sustainability. We draw on various social and natural science disciplines, including ecological economics, environmental economics, political science, policy studies, development studies, business and management, geography, sociology, science and technology studies, ecology, environmental science and soil science in our work.

The Centre for Climate Change Economics and Policy (CCCEP) was established by the University of Leeds and the London School of Economics and Political Science in 2008 to advance public and private action on climate change through innovative, rigorous research.

The Centre is funded by the UK Economic and Social Research Council and has five inter-linked research programmes:

1. Developing climate science and economics
2. Climate change governance for a new global deal
3. Adaptation to climate change and human development
4. Governments, markets and climate change mitigation
5. The Munich Re Programme - Evaluating the economics of climate risks and opportunities in the insurance sector

More information about the Centre for Climate Change Economics and Policy can be found at: <http://www.cccep.ac.uk>.

Disclaimer

The opinions presented are those of the author(s) and should not be regarded as the views of SRI, CCCEP or The University of Leeds.

Combining nexus and resilience thinking in a novel framework to enable more equitable and just outcomes

© L.C.Stringer, C.H.Quinn, R.J.Berman, H.T.V.Le, F.E.Msuya, S.E. Orchard and J.C.B. Pezzuti

2014

Email: L.Stringer@leeds.ac.uk

Contents

Contents	3
Abstract	4
About the Authors	5
1 Introduction	7
2 Unpacking resilience and nexus approaches	9
2.1 Systems approaches	9
2.2 Scale and governance	10
2.3 Justice and equity: a core gap	13
2.4 Synthesis	15
3 The WEF-PIK resilience framework	15
3.1 Towards application	17
4 Conclusion	19
5 Acknowledgments	20
References	21

Abstract

Resilience and nexus thinking are often applied separately to investigate social-ecological systems (SES), wherein both approaches are critiqued for a lack of explicit focus on issues of justice and equity. This paper synthesises the main strengths and shortcomings of these approaches, before drawing on resilience and nexus strengths to present a novel, integrated framework to guide future SES research. We link the multi-scale water-energy-food security (WEF) nexus, with a multi-level policies-institutions-knowledge (PIK) nexus to explore resilience outcomes at different points in time. The WEF-PIK framework is presented as a double helix united through resilience outcomes, assessed through empirical analyses of local economic equity, social justice, and environmental equity. The framework focuses on multiple scales and the links and trade-offs between them, both within and between strands of the double helix. Applying the framework across different SES will enhance the identification and understanding of factors that shape equitable and just outcomes.

Submission date 15-10-2014; Publication date 20-10-2014

About the Authors

Lindsay C. Stringer is Professor in Environment and Development at the University of Leeds. Lindsay's research advances understanding of human-environment relationships focusing on: 1) the links between livelihoods and environment; and 2) science, policy and environmental governance and the practical and policy mechanisms that can advance sustainable development. Her work is interdisciplinary and uses theories and methods from both the natural and social sciences.

Dr Claire Quinn is an ecological social scientist with over 10 years of experience working on interdisciplinary projects in Africa and the UK. Her research interests lie in the links between ecological and socio-economic processes in the management and conservation of natural resources. Specifically Claire's research focuses on the distribution of property rights in multi-resource systems and the implications for management; and livelihood vulnerability and adaptation to environmental change in agricultural communities.

Dr Rachel Berman is a Research Fellow at the University of Leeds. Rachel's research interests lie in exploring climate change adaptation and wider socio-ecological processes. Specifically, Rachel's research has focused on the institutional dynamics of climate adaptation in sub-Saharan Africa, including the examining of rural livelihoods and social networks. Rachel's other research interests include the conceptualisation of barriers and limits to adaptation, and socio-ecological and environmental policy associated with land-use change and climate change.

Dr Hue Le works at Vietnam National University in Hanoi in the Centre for Natural Resources and Environmental Studies. Her research focuses on property rights and land tenure, livelihoods, gender and the governance of mangroves, largely in Vietnam. She has worked closely with ethnic groups in the north of Vietnam to improve their livelihoods whilst preserving their cultural identity and the environment.

Dr Flower Msuya is a Senior Researcher at the Institute of Marine Sciences (IMS), University of Dar es Salaam, Zanzibar, Tanzania. Her research focuses on marine

governance and management, focusing largely on seaweed farming and integrated mariculture. She is the Facilitator of the Zanzibar Seaweed Cluster Initiative, in which she does research and training in innovative farming, integrating environmental and sustainability issues. She has extensive experience in community-based research focusing on relationships between coastal resources and coastal communities as well as effects of climate change on people's livelihoods.

Steven Orchard is a PhD researcher at the Sustainability Research Institute at the University of Leeds, UK. He has BA (Hons) in Business and Economics and MSc in Development Anthropology. Following from an initial interest in international development issues while studying undergraduate economics, he became interested in environmental governance while studying postgraduate anthropological studies. His research focuses on the links between mangrove system use and livelihoods, institutions and social networks in Vietnam.

Dr Juarez Pezzuti works at the Federal University of Pará in Brazil. He trained as a turtle ecologist and has extensive experience in working in Brazil's Amazon region. His recent research has been more interdisciplinary and focuses on community based natural resource management. He is particularly interested in finding ways in which people can benefit from biodiversity and wildlife in environmentally, socially and culturally sustainable ways.

1 Introduction

The environment's capacity to support human needs is reducing as a result of human actions and governance decisions (MEA 2005). Land cover is being altered, marine and terrestrial biodiversity is being lost, ecosystem integrity is being degraded, and the climate is changing due to increased concentrations of atmospheric greenhouse gases. Over time, the environment's ability to deliver the ecosystem services required for the planet to support the survival of future generations is being further undermined (Folke et al. 2011). Maintaining a safe operating space for humanity requires us to alter our current relations with the environment (Rockström et al. 2009). Ensuring that the necessary changes proceed in the intended direction necessitates us to understand human-environment relations in a holistic way, recognising the presence of linkages and feedbacks across different temporal and spatial scales, and between different sectors and groups.

Conceptualising people and the environment as integrated social-ecological systems can help to capture some of these complex and interdependent feedbacks and relationships (Berkes and Folke 1998). Such integration is already reflected in some of today's most widely applied research approaches and tools. These include institutional approaches (Anderies et al. 2004), agent based modelling (Walker and Janssen 2002), panarchy (Holling 2001), vulnerability approaches (Brooks et al. 2005), resilience approaches (Folke 2006), and most recently, nexus approaches (Bazilian et al. 2011). In this paper, we draw on key elements of the thinking that underpins resilience and nexus approaches.

Resilience scholars have a long history of focusing on integrated social-ecological systems. Resilience is defined in a range of different ways depending on the disciplinary lens through which it is studied (Martin-Breen and Anderies 2011). Historically, it has been associated with the ability of social-ecological systems, and the relationships within them, to absorb change and persist (Holling 1973). More recently, resilience has been defined as 'the ability of a social-ecological system to cope with shocks and stresses by responding or reorganising in ways that maintain its essential functions, identities and structures, while also maintaining capacity for adaptation, learning and transformation' (adapted from Arctic Council 2013; IPCC 2014). More resilient social-

ecological systems can cope, adapt and transform in response to pressures over time, and different economic, ecological and social processes feed into the maintenance of the system's operation. Studies of resilience currently remain largely focused at the system level, without considering the equity and justness of resilience as a process or an outcome.

The term 'nexus' refers to linkages and connections. Nexus thinking has become popular more recently. It highlights relationships and interdependencies and the need for integrated management across sectors (Bazilian et al. 2011). It is most commonly used to examine interactions between water, energy and food (WEF). In their simplest form, WEF relationships can be set out as follows: water is needed to generate energy, energy is needed to supply water; energy is needed to produce food, food can be used to produce energy, water is needed to grow food while food transports (virtual) water, often using energy. Changes to any one of water, energy or food can have knock-on implications for the remaining two across a range of scales (Hussey and Pittock 2012). Considerable policy focus is placed on WEF security as a desirable outcome wherein security encompasses WEF supplies, stability and access (Lawford et al. 2013). Governance is important in delivering WEF security. Governance structures and processes that recognise the WEF nexus require attention to be paid to the links and connections between policies, institutions and knowledges (PIK), wherein, similar to WEF, changes to any one component can affect the other two. PIK can therefore also be viewed as a nexus. Across both WEF and PIK, trade-offs are inevitable, but disaggregation of who 'wins' and 'loses' through such trade-offs remains largely veiled.

Despite their shared potential to guide research on the same problems, resilience and nexus thinking have been applied separately, often in different academic, policy and stakeholder arenas, without exploring how their strengths could extend and enhance both approaches. This paper addresses this gap. Our overall aim is to bring together resilience and nexus thinking in a novel framework that addresses some of the current shortcomings and harnesses some of the strengths of each approach, with a particular focus on equity and justice outcomes. It is envisaged that our framework can be used to advance research on complex social-ecological systems beyond the boundaries of that

which could be achieved through the use of either approach alone (cf. Foxon et al. 2009; Westley et al. 2011).

We first outline the key characteristics and strengths of resilience and nexus approaches highlighting areas in which greater mutual interaction could provide enriched insights. We also discuss the lack of attention to important issues of equity and social justice in both approaches. We next present our novel conceptual WEF-PIK resilience framework, demonstrating how it addresses some of the gaps and extends contemporary thinking. We also outline how the WEF-PIK resilience framework could be operationalised. Finally, we consider how our framework could be tested and further disaggregated in order to enable identification of the factors that allow more equitable and just future outcomes.

2 Unpacking resilience and nexus approaches

This section explores some of the key characteristics of resilience and nexus thinking. We identify and explore overlaps in terms of systems approaches, divergence in terms of scale and governance issues, and gaps in both approaches related to justice and equity.

2.1 Systems approaches

Both resilience and nexus thinking appreciate the interactions, interconnectedness and interdependence between the human and biophysical components of social-ecological systems (Berkes et al. 2003). These approaches therefore draw on systems thinking to understand the linkages both within and between social-ecological systems (Hoff 2011). While resilience approaches focus on the capacity of social-ecological systems to absorb, adapt and transform in the face of change (Béné et al. 2014), and so maintain options and alternatives for resource use (Johnson et al. 2013), nexus approaches tend to focus on increasing productivity and resource use efficiency in the face of WEF scarcity, through policy coherence and enabling PIK conditions (Hoff 2011). A nexus approach therefore seeks the development of coherent PIK that reduce transaction

costs, and deliver synergy and multiple wins, across WEF sectors (Ringler et al. 2013). Linking nexus and resilience approaches could help to extend nexus thinking beyond a focus on sustainable intensification (Rockström et al. 2009) to consider other options and alternatives that still harness efficiencies and synergy.

2.2 Scale and governance

Both resilience and nexus thinking recognise the need to consider multiple geographical, spatial and temporal scales and inevitable trade-offs therein (Dixon et al. 2014; Suckall et al. 2014). However, the scales of research (both temporal and spatial) differ between the two different ways of thinking. Resilience research often focuses at the ecosystem scale, linking social systems to ecosystem functions, or at the household scale, exploring how particular livelihood-environment interactions enhance or erode household resilience. However, human actions and decision-making are complex and both multi-scale and multi-level (Zurlini et al. 2006), with processes of globalisation playing an increasing role in shaping social-ecological system resilience (Young et al. 2006), even at sub-ecosystem scale. Calls have been made for greater scale-sensitivity in resilience research (Villasante et al. 2013), as well as a focus on multi-level and poly-centric governance (Ostrom 2010).

In nexus thinking, multi-scale interactions are neatly illustrated through the connections within WEF and PIK. In a biophysical sense, water is controlled by the hydrological cycle, with precipitation and evaporation determined by the combination of the global climate system and regional and local convection and orography. Topographic and geological characteristics of any given area shape water storage and flows below the Earth's surface. Humans intervene in this cycle and extract water, according to prevailing political boundaries (including national borders). Society's formal institutions at local, national, regional and global levels also make policies and laws that set out access, extraction and use rights, often based on scientific research and knowledge. Informal institutions and societal norms also shape local water use by drawing on different knowledges and through the use of particular practices (Pahl-Wostl et al. 2007). Extraction, treatment and distribution of water, as well as waste water, each have an energy demand, and again, are shaped by PIK. Energy sources are often found in

one place but transported to another location where they are consumed. Non-renewable energy resources are subtractable resources, that is, their use by one group precludes their use by other groups at later points in time (Carpenter 1998), resulting in a temporal trade-off. Energy infrastructure can disrupt water flows through the building of hydropower dams, which have a high water demand. This can have important knock-on effects for downstream water users causing a spatial trade-off. Dams can also displace local residents who formerly used the water for food production and food security (Ringler et al. 2013). At the same time, water and other energy-intensive agricultural inputs such as fertiliser are used for food production. Fertilisers are often manufactured far from their site of application and can enrich water bodies through eutrophication and deplete terrestrial systems through nutrient extraction. Runoff from agricultural production, alongside waste water from the energy sector, can alter the quality of water supplies under the governance jurisdictions of groups who were not involved in the water use, while at the same time, reducing soil fertility for future production. In turn, while food is largely grown by smallholder farmers in much of the world (Dixon et al. 2014), supply chains and markets link the local scale to national, regional and international scales. Food consumption often takes place thousands of miles away from the site of its production, and the food sector is highly energy-dependent for its transport. These spatial trade-offs mean that some groups in some locations benefit from WEF security, framed by prevailing PIK, whilst others lose out (Leach 2008).

Within the broader governance context, there are similar networks of relations in the PIK nexus which combine to shape WEF security. For example, policies are developed by different institutions operating at across different scales and within each of the WEF sectors. These policies draw on particular knowledges, privileging some forms of knowledge (often scientific knowledge) over locally-held knowledges, particularly at the national level. In some instance, a lack of knowledge about the broader context in which local level actions and practices are situated can combine, causing larger scale problems elsewhere. An example of this would be the aggregate effects of local water extraction from rivers leading to larger scale food or energy security problems further downstream. At the same time, there are varying degrees of interplay between policies, between institutions and between knowledges at different scales and different levels,

which can change over time in their strength and direction. Cash et al. (2006) use the example of decentralisation reforms, which can trigger strong interactions between national institutions and those at the local government level as power distributions are renegotiated, but which then even out as a steady-state degree of interaction develops. The particular combination of cross-scale and cross-level interactions at a single point in time can sometimes undermine the resilience of a system (Cash et al., 2006).

Policies made by one set of institutions can have important implications (and set up trade-offs) for other institutions both at the same and other levels, and are not always coherent with one another. This can cause problems for WEF security, even if those policies do not directly address WEF. For example, within the international biodiversity arena, there are multiple conventions and treaties that deal with different aspects of biodiversity (Velazquez Gomar et al. 2014). These include the Ramsar Convention, the Convention concerning the protection of the World Cultural and Natural Heritage (WHC), the Convention on International Trade in Endangered Species of wild fauna and flora (CITES), the Convention on the Conservation of Migratory Species of wild animals (CMS), the Convention on Biological Diversity (CBD) and the International Treaty on Plant and Genetic Resources for Food and Agriculture (ITPGFRA). Each agreement entered into force at a different point in time, has the commitment of different country parties and therefore is applicable over a different space. Yet, each is part of a broader biodiversity complex that shares certain desired outcomes that indirectly support WEF. In situations of poor policy coherence, this causes some components of the regime to be winners while others lose out. In extreme situations, overall system resilience can be undermined.

Much resilience research has shown the importance of learning from past exposure and responses to shocks and stresses in order to identify areas for current and future policy support (e.g. Dixon et al. 2014; Fazey et al. 2007). Trajectory analyses can help to pinpoint how particular PIK erode or enable resilience (Sallu et al. 2010), offering an insight into temporal social-ecological system dynamics that look backward as well as forward. Resilience thinking also recognises the importance of flexibility and learning as systems evolve over time (e.g. Tschakert and Dietrich 2010). This is reflected in approaches such as adaptive management, which use experimentation to promote

learning, using the new knowledge gained to guide the future management of integrated social-ecological systems (Armitage et al. 2008). A key point to note here is recognition that the outcomes, or what counts as a resilient system, change over time, reflecting evolution of the social-ecological system and its various components.

Historical factors and learning from experience have been less well captured in nexus thinking. Nexus research tends to take more of a forward-looking stance, employing methods such as scenarios and back-casting to extrapolate system changes into the future and assess the interlinkages therein (Hoff 2011). The WEF sectoral focus of nexus thinking also fails to adequately capture the trade-offs and synergies between the different constituents of PIK, both within and between different governance levels, meaning that the PIK nexus is under-explored beyond a focus on particular snapshots in time (Stringer et al. 2009) and without linking to other sectors such as health, education and so on. Additionally, little nexus research has been conducted at the household or community scale, assessing household WEF security and how this shapes and is shaped by PIK operating at larger scales (Allouche et al. 2014). These gaps represent important considerations in the development of a novel framework to guide research on social-ecological systems, while the areas of divergence between resilience and nexus thinking offer considerable potential for cross-fertilisation.

2.3 Justice and equity: a core gap

Although trade-offs across sectors have been recognised in nexus research, neither resilience or nexus thinking pays particular attention to investigating issues of justice or equity in terms of social, economic or environmental outcomes. This represents a core gap in both approaches. A system level focus in resilience research can overlook choices made by individuals or groups (Coulthard 2012) and neglects to appreciate the notion of 'winners and losers' (Béné et al. 2014). Scale is important here too. While a range of attempts have been made to measure household resilience drawing of aspects of a nexus approach, looking, for example, at the connections and relationships between different types of household assets (Folbre 1986), less focus has been placed on the role of links between WEF at larger scales in determining resilience, and for whom. Even within the same level, scale matters. For example, overall household

resilience may increase as a result of a particular process or action, but potentially to the detriment of one or more individuals within the household. Similarly, strengthening resilience in the short-term can reduce it in the long-term and vice versa (Cabell and Oelofse 2012), reminding us of the importance of temporal trade-offs.

A seemingly resilient system that can maintain 'normal' WEF security both quickly and cost-effectively is largely shaped by PIK via the WEF-PIK nexus, but is not necessarily an equitable or just system (Pelling 2011). Justice and equity are often analysed according to participation, distribution, recognition (Schlosberg 2007) and link to economic and environmental equity, as well as people's capabilities, power and agency to make choices that can enable their resilience (Sen 2009). As such, resilience outcomes can be unequally distributed amongst and between a system's economic, ecological and social components. Similarly, policies and institutions are informed by particular knowledges (often scientific), which, usually through the mediation of institutions, can result in a lack of recognition and the marginalisation of other ways of knowing (Raymond et al. 2010). This can restrict the participation of some groups (Schlosberg 2007), weighting governance decisions such that adverse impacts disproportionately affect some people. This again creates 'winners' and 'losers', and can determine whether or not certain groups are considered in subsequent distributional patterns (Young 2010), with implications for their ultimate resilience outcomes.

The considerations outlined above emphasise the need for researchers to acknowledge not only a WEF nexus and a PIK nexus, but also the implications of a WEF-PIK nexus for resilience. Exploring the trade-offs within and between each nexus, and how they affect the equity and justice of economic, environmental and social resilience outcomes, can provide key insights into issues of power and agency, informing actions so that actors can be enabled to make choices that enable resilience outcomes. It also pushes us to question whether an unjust and inequitable social-ecological system really is resilient. A system may exhibit persistence, resistance and robustness – i.e. be classified as resilient within the prevailing resilience research literature, but without equitable recognition, participation and distributions, the capabilities of system components to be resilient, both individually and as a social-ecological system, is called into question. Developing a framework that can guide research so that it takes into

account these shortcomings in existing ways of thinking, alongside the characterisation of resilience ‘winners and losers’ at different points in time, is therefore paramount.

2.4 Synthesis

Our analysis has highlighted a number of key characteristics of resilience and nexus thinking which are important to include in the development of an integrated framework that draws on and extends the two approaches. It has also illuminated some of the deficiencies in resilience and nexus approaches, highlighting opportunities for a new framework to help reorient focus upon issues of economic and environmental equity and social justice. A lens is needed through which distributions and flows of actors’ knowledges within and across scales within a system can be assessed in terms of their recognition, participation, and capabilities, alongside the ways in which institutions and policies shape potential choices, decisions and outcomes. Trade-offs permeate each of these aspects within and across scales, and are often linked to governance (Villasante et al. 2013). Linking WEF security to PIK and recognising that together they form another nexus that delivers social, ecological and economic resilience outcomes with varying degrees of equity and justice is therefore crucial.

3 The WEF-PIK resilience framework

Figure 1 shows the WEF-PIK resilience framework, which draws on the analysis above to outline a novel approach that brings together nexus and resilience approaches to enable a focus on justice and equity. It links the WEF nexus with the PIK nexus, presented as a double helix, embedded within multiple spatial and temporal scales. It allows us to look backward, forward and assess the present (t_1 , t_2 and t_3 in Figure 1), facilitating analysis of actions surrounding past disturbances and the resilience outcomes of responses (Lemos et al. 2007; Engle 2011). This is captured by the spaces between each of t_1 , t_2 and t_3 . Although the framework shows local level outcomes embedded within multiple spatial scales in its current presentation, it can be applied flexibly such that any of the scales can be brought to the fore, allowing exploration of the same outcome as evident at different scales.

The interaction between WEF and PIK determines and is determined by justice and equity across social, economic and environmental dimensions, represented by 'resilience bases' that unite WEF and PIK. Economic equity encompasses issues surrounding the distribution of economic costs and benefits; social justice allows focus on issues of equity and fairness relating to different groups; while environmental equity captures issues such as access to resources and resource distributions. Each of these 'bases' can be further unpacked, disaggregated or aggregated as required, in order to determine the equity and justness of resilience across dimensions such as gender, culture and ethnicity.

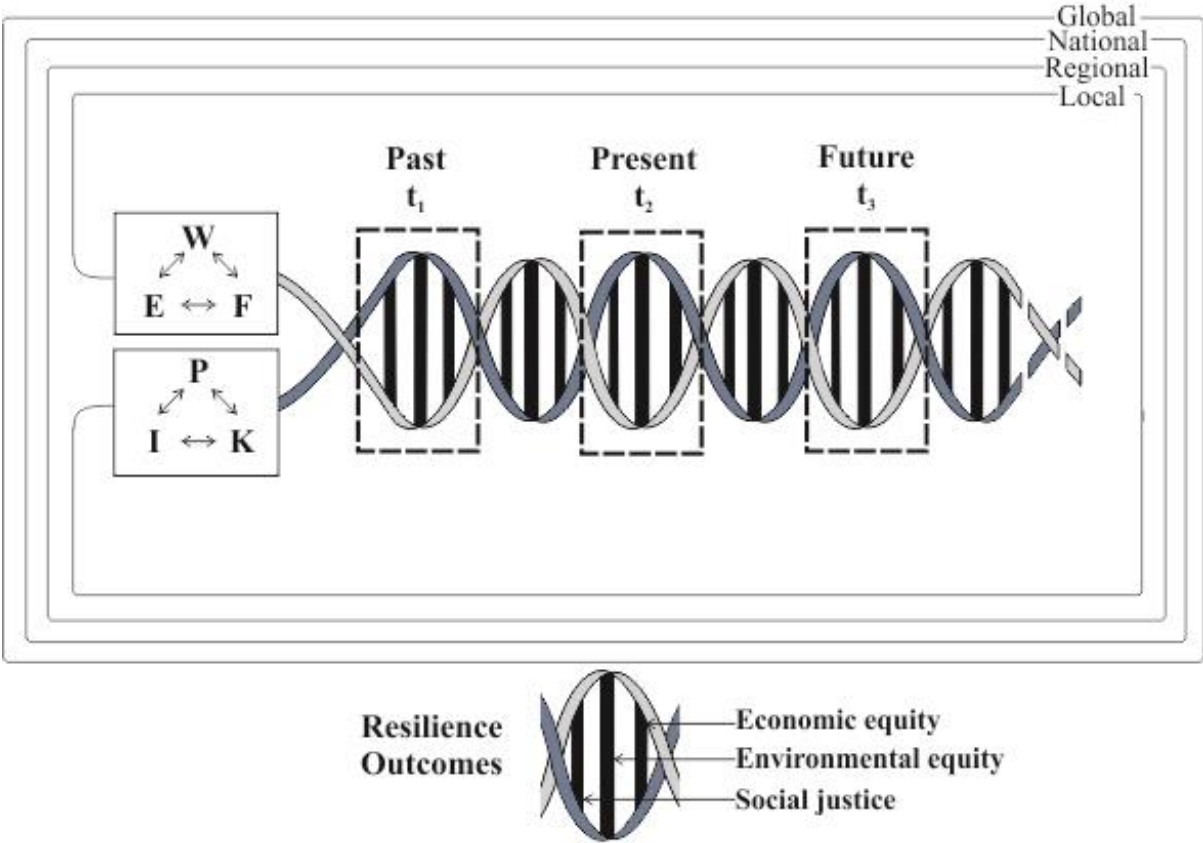


Figure 1. The WEF-PIK Resilience Framework

Trade-offs are present not only in the interactions in the WEF nexus but between sectors and actors at different temporal and spatial scales, within the PIK nexus, and between the resilience of different components of the overall social-ecological system. Combining the strengths of nexus and resilience approaches enables not only the

identification of these trade-offs, but also an assessment of how trade-offs affect the capacity of the system to cope with and adapt to change over time and how they might be managed. As such, the framework can be used to identify the direction of travel along a continuum of resilience outcomes, with particular focus on equity and justice therein. Combining the two approaches allows us to tap into the strength of nexus thinking in terms of seeking synergies and reducing trade-offs, while drawing on aspects of resilience thinking permits an insight into the factors that enable the social-ecological system to cope with and adapt to change over time, and identify who benefits and loses out in the process.

The interaction of PIK with WEF emphasises the importance of governance at all levels and across multiple scales in achieving both WEF security and resilience. It enables examination of the relationships between governance and WEF security, as well the distributions of social, environmental and economic outcomes they deliver. Unpacking this interaction allows us to assess the conditions under which WEF security can be achieved in more just and equitable ways. It permits consideration of how different knowledges are able (or not) to be brought together to frame policies and institutions that affect WEF security, and how, in turn, the status of WEF sectors influence the recognition and capabilities of individuals within and across sectors and scales to participate in and shape decision-making through PIK. There is further opportunity to use the framework to guide research that can identify and reduce conflicts between stakeholders operating at different scales, and across social, economic and environmental dimensions. Through PIK, there is scope to identify institutional gaps and to develop governance arrangements that cross-cut WEF sectoral boundaries, which in the process, can help to facilitate resilience outcomes within the system, over time.

3.1 Towards application

Implementing the WEF-PIK resilience framework to provide novel insight into the factors that lead to more equitable and just resilience outcomes requires an interdisciplinary and mixed-methods approach. The framework has been designed with a view to its application to a range of systems including forests, rangelands, coasts and urban settings. Its application involves empirical research that focuses on different points in

time (past, present, future), drawing on quantitative and qualitative methods used within both nexus and resilience research, alongside a range of different environmental, social, economic, political and institutional indicators (Adger 2000; Twyman et al. 2011), so as to capture a range of different knowledges while asking the same questions. Existing methods could be used such as questionnaire surveys combined with well-being rankings, focus groups and other participatory methods, as well as policy and institutional analysis, allowing investigation of the embeddedness of PIK across spatial scales. Depending on the context of application, it could also require the development of new methods. The selection of methods is critical because the ways in which they are combined in implementing the WEF-PIK resilience framework offers the route to advancing new knowledge and research outcomes that may not have been generated using existing or separate ways of thinking.

Outputs from disaggregated empirical data analysis allow the assessment of (in)equalities and (in)justices along social lines of gender, culture, ethnicity, as well as within and between different social groups. Economic equity outcomes can be identified using methods such as household surveys, wealth ranking and market price trend analyses. Timelines (constructed by both individuals and groups at different spatial scales) can be useful in identifying economic incentives within certain policies or promoted by certain institutions to support particular behaviours and decisions. This would provide insight into the outcomes of specific resource allocation mechanisms for different social groups and their resilience, alongside the identification of subsidies that harm the environment, such that they might be removed. Environmental outcomes can focus on particular land uses, ecosystems, communities or even drill down to the level of individual species. Methodologically, environmental assessments could involve participatory mapping of ecosystem services over time, use of secondary data on vegetation, plant species, meteorological aspects (e.g. rainfall, temperature), soils and so on. These can be analysed in the context of ecosystem goods and services that provide WEF security and the PIK that shape and inform access to and use of environmental resources. Taking this kind of approach facilitates recognition of the vast body of environmental knowledge that is held both locally and at other scales (Sallu et al. 2010). This information gained through application of the framework can be used to

support evidence-based policy making as a result of improved multi-scale data provision, both temporal and spatial, such that social-ecological systems can be guided towards more equitable and just resilience.

4 Conclusion

This paper has drawn together nexus and resilience approaches, combining the two in a novel framework. The WEF-PIK resilience framework can guide research into resilience trajectories, allowing assessment of temporal system dynamics. It considers the spatial nature of interactions by focusing on multiple scales and sectors and the links between them, both within and between each strand of the double helix. It fills a key gap in current nexus and resilience thinking by permitting focus on issues of social justice, environmental equity and economic equity. The WEF-PIK resilience framework offers a flexible, integrated conceptualisation of resilience outcomes in complex social-environmental systems and can be applied to identify and understand factors that both inhibit and enable just and equitable resilience outcomes across a range of social-ecological systems.

The WEF-PIK resilience framework next requires testing through its application to a range of different social-ecological systems, as well as an evaluation of its ability to assess the resilience outcomes that take into account social justice, and both economic and environmental equity. In particular it will be useful to assess the framework's ability to: a) guide enhanced policy decisions through the provision of improved data across scales; b) inform steps towards improved coherence between WEF policies, institutions and knowledges, such that trade-offs are reduced; c) reduce institutional gaps such that organisational arrangements cross-cut WEF sectoral boundaries; d) reduce the marginalisation of particular knowledges; e) improve identification of PIK that can promote more environmentally and economically equitable and socially just outcomes across WEF dimensions; f) reduce conflicts between different stakeholders operating at different scales and between economic, social and environmental bases; and g) improve the management of trade-offs. Applying, testing and reflecting upon the WEF-PIK resilience framework provides an exciting new challenge for researchers from a

range of disciplines who seek to identify how more equitable and just resilience outcomes for integrated social-ecological systems can be enabled.

5 Acknowledgments

The authors would like to thank Katharine Vincent, Andy Dougill, Lisa Ficklin, JouniPaavola, Susannah Sallu and Jami Dixon for their comments on earlier drafts of the manuscript. The workshop at which these ideas were developed was funded through the University of Leeds Facilitating International Research Collaboration (FIRC) scheme.

References

- Adger, W. N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography*,**24**, pp.347-364.
- Allouche, J., C. Middleton and D. Gyawal. 2014. *Nexus Nirvance or Nexus Nullity? A dynamic approach to security and sustainability in the water-energy-food nexus*. STEPS Working Paper 63, Brighton: STEPS Centre.
- Anderies, J. M., M. A. Janssen and E. Ostrom. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* **9**(1), p18.
- Arctic Council. 2013. *Glossary of terms In: Arctic Resilience Interim Report 2013*. Stockholm, Sweden.: Stockholm Environment Institute and Stockholm Resilience Centre.
- Armitage, D., M. Marschke and R. Plummer. 2008. Adaptive co-management and the paradox of learning. *Global Environmental Change*,**18**(1), pp.86-98.
- Bazilian, M., H. Rogner, M. Howells, S. Hermann, D. Arent, D. Gielen, P. Steduto, A. Mueller, P. Komor, R. S. J. Tol and K. K. Yumkella. 2011. Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy*,**39**(12), pp.7896-7906.
- Béné, C., A. Newsham, M. Davies, M. Ulrichs and R. Godfrey-Wood. 2014. Resilience, Poverty and Development. *Journal of International Development*,**26**(5), pp.598–623.
- Berkes, F., J. Colding and C. Folke. 2003. *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge: Cambridge University Press.
- Berkes, F. and C. Folke. 1998. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. New York: Cambridge University Press.
- Brooks, N., W. N. Adger and P. M. Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change Part A*,**15**(2), pp.151-163.
- Cabell, J. F. and M. Oelofse. 2012. An Indicator Framework for Assessing Agroecosystem Resilience. *Ecology and Society*,**17**(1), p18.
- Carpenter, S. R. 1998. Sustainability and common-pool resources: alternatives to tragedy. *Society for Philosophy and Technology* **3**(4), pp.36-57.
- Cash, D. W., W. N. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard and O. Young. 2006. Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society*,**11**(2).
- Coulthard, S. 2012. Can We Be Both Resilient and Well, and What Choices Do People Have? Incorporating Agency into the Resilience Debate from a Fisheries Perspective. *Ecology and Society*,**17**(1).
- Dixon, J. L., L. C. Stringer and A. Challinor. 2014. Farming System Evolution and Adaptive Capacity: Insights for Adaptation Support. *Resources*,**3**(1), pp.182-214.
- Engle, N. L. 2011. Adaptive capacity and its assessment. *Global Environmental Change-Human and Policy Dimensions*,**21**(2), pp.647-656.

- Fazey, I., J. A. Fazey, J. Fischer, K. Sherren, J. Warren, R. F. Noss and S. R. Dovers. 2007. Adaptive capacity and learning to learn as leverage for social-ecological resilience. *Frontiers in Ecology and the Environment*, **5**, pp.375-380.
- Folbre, N. 1986. Hearts and Spades: paradigms of household economics. *World Development*, **14**, pp.245-255.
- Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, **16**(3), pp.253-267.
- Folke, C., A. Jansson, J. Rockstrom, P. Olsson, S. R. Carpenter, F. S. Chapin, A. S. Crepin, G. Daily, K. Danell, J. Ebbesson, T. Elmqvist, V. Galaz, F. Moberg, M. Nilsson, H. Osterblom, E. Ostrom, A. Persson, G. Peterson, S. Polasky, W. Steffen, B. Walker and F. Westley. 2011. Reconnecting to the Biosphere. *Ambio*, **40**(7), pp.719-738.
- Foxon, T., M. Reed and L. C. Stringer. 2009. Governing long-term social-ecological change: what can the adaptive management and transition management approaches learn from each other? . *Environmental Policy and Governance*, **19**, pp.3-20.
- Hoff, H. 2011. *Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus*. Stockholm, Sweden: Stockholm Environment Institute.
- Holling, C. S. 1973. Resilience and Stability of Ecological Systems. *Annual Review in Ecology and Systematics* **4**, pp.1-23.
- Holling, C. S. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* **4**(5), pp.390-405.
- Hussey, K. and J. Pittock. 2012. The Energy-Water Nexus: Managing the Links between Energy and Water for a Sustainable Future. *Ecology and Society* **17**(1), p31.
- Ippcc. 2014. Summary for policymakers. In: C. B. FIELD, V.R. BARROS, D.J. DOKKEN, K.J. MACH, M.D. MASTRANDREA, T.E. BILIR, M. CHATTERJEE, K.L. EBI, Y.O. ESTRADA, R.C. GENOVA, B. GIRMA, E.S. KISSEL, A.N. LEVY, S. MACCRACKEN, P.R. MASTRANDREA and L. L. WHITE, eds. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom Cambridge University Press, pp.1-32.
- Johnson, F. A., B. K. Williams and J. D. Nichols. 2013. Resilience Thinking and a Decision-Analytic Approach to Conservation: Strange Bedfellows or Essential Partners? . *Ecology and Society*, **18**(2), p27.
- Lawford, R., J. Bogardi, S. Marx, S. Jain, C. P. Wostl, K. Knüppe, C. Ringler, F. Lansigan and F. Meza. 2013. Basin perspectives on the Water–Energy–Food Security Nexus. *Current Opinion in Environmental Sustainability*, **5**(6), pp.607-616.
- Leach, M. 2008. Pathways to Sustainability in the forest? Misunderstood dynamics and the negotiation of knowledge, power, and policy. *Environment and Planning A*, **40**(8), pp.1783-1795.
- Lemos, M. C., E. Boyd, E. L. Tompkins, H. Osbahr and D. Liverman. 2007. Developing adaptation and adapting development. *Ecology & Society* **12**(4).
- Martin-Breen, P. and J. M. Anderies. 2011. *Resilience: A literature review*. New York, USA: The Rockefeller Foundation.

- Mea. 2005. *Millennium Ecosystem Assessment: Ecosystems and Human Well-being: General Synthesis*. Washington, DC: Island Press and World Resources Institute.
- Ostrom, E. 2010. Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*,**20**(4), pp.550-557.
- Pahl-Wostl, C., M. Craps, A. Dewulf, E. Mostert, D. Tabara and T. Taillieu. 2007. Social Learning and Water Resources Management. *Ecology and Society*,**12**(2).
- Pelling, M. 2011. *Adaptation to Climate Change: From Resilience to Transformation*. Abingdon, UK: Routledge.
- Raymond, C. M., I. Fazey, M. S. Reed, L. C. Stringer, G. M. Robinson and A. C. Evely. 2010 Integrating local and scientific knowledge for environmental management *Journal of Environmental Management* **91**(8), pp.1766-1777.
- Ringler, C., A. Bhaduri and R. Lawford. 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? *Current Opinion in Environmental Sustainability*,**5**(6), pp.617-624.
- Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin Iii, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. Van Der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen and J. A. Foley. 2009. A safe operating space for humanity *Nature*,**461**(472-475).
- Sallu, S., C. Twyman and L. C. Stringer. 2010. Resilient or Vulnerable Livelihoods? Assessing Livelihood Dynamics and Trajectories in Rural Botswana. *Ecology and Society*,**15**(4).
- Schlosberg, D. 2007. *Defining environmental justice: theories, movements, and nature*. New York: Oxford University Press.
- Sen, A. 2009. *The idea of justice*. Harvard, US: Belknap Press of Harvard University Press.
- Stringer, L. C., J. C. Dyer, M. S. Reed, A. J. Dougill, C. Twyman and D. Mkwambisi. 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy*,**12**(7), pp.748-765.
- Suckall, N., E. Tompkins and L. Stringer. 2014. Identifying trade-offs between adaptation, mitigation and development in community responses to climate and socio-economic stresses: Evidence from Zanzibar, Tanzania. *Applied Geography*,**46**, pp.111-121.
- Tschakert, P. and K. A. Dietrich. 2010. Anticipatory Learning for Climate Change Adaptation and Resilience. *Ecology and Society*,**15**(2), p11.
- Twyman, C., E. D. G. Fraser, L. C. Stringer, C. H. Quinn, A. J. Dougill, F. Ravera, T. A. Crane and S. M. Sallu. 2011. Climate Science, Development Practice, and Policy Interactions in Dryland Agroecological Systems. *Ecology and Society*,**16**(3), p14.
- Velazquez Gomar, J. O., L. C. Stringer and J. Paavola. 2014. Regime complexes and national policy coherence: experiences in the biodiversity cluster. *Global Governance*,**20**, pp.119-145.
- Villasante, S., G. Macho, M. Antelo, D. Rodriguez-Gonzalez and M. J. Kaiser. 2013. Resilience and Challenges of Marine Social-Ecological Systems Under Complex and Interconnected Drivers. *Ambio*,**42**(8), pp.905-909.

- Walker, B. H. and M. A. Janssen. 2002. Rangelands, pastoralists and governments: interlinked systems of people and nature. *Philosophical Transactions of the Royal Society of London Series B - Biological Sciences* **357**(1421), pp.719-725.
- Westley, F., P. Olsson, C. Folke, T. Homer-Dixon, H. Vredenburg, D. Lorbach, J. Thompson, M. Nilsson, E. Lambin, J. Sendzimir, B. Banerjee, V. Galaz and S. Leeuw. 2011. Tipping Toward Sustainability: Emerging Pathways of Transformation. *Ambio*,**40**(7), pp.762-780.
- Young, O. R. 2010. Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes. *Global Environmental Change*,**20**(3), pp.378-385.
- Young, O. R., E. F. Lambin, F. Alcock, H. Haberl, S. I. Karlsson, W. J. Mcconnell, T. Myint, C. Pahl-Wostl, C. Polsky, P. Ramakrishnan, H. Schroeder, M. Scouvar and V. P.H. 2006. A portfolio approach to analyzing complex human-environment interactions: institutions and land change. *Ecology and Society* **11**(2), p31.
- Zurlini, G., K. Riitters, N. Zaccarelli, I. Petrosillo, K. Jones and L. Rossi. 2006. Disturbance patterns in a socio-ecological system at multiple scales *ECOLOGICAL COMPLEXITY*,**3**(2), pp.119-128.