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# The Resilience, Adaptation and Transformation Assessment Framework: from theory to application

## Discussion paper for the Scientific and Technical Advisory Panel of the Global Environment Facility

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# Foreword

As we strive towards sustainable development, efforts are focussing on defining safe operating spaces where human societies can develop and prosper. The concept of resilience is increasingly recognised as relevant in devising policy and informing on-ground interventions to progress sustainability goals.

This is exemplified in the Planetary Boundaries Framework. In defining the processes for the Earth System to persist under changing conditions, the framework relies on the theory of resilience: "The capacity of a system to absorb disturbance and re-organise so as to retain essentially the same function, structure and feedbacks – to have the same identity." Resilience concepts underpin the emerging Sustainable Development Goals (SDGs), and are embedded in the SDG framework linking social, economic and environmental aspects to address the root causes of poverty and environmental degradation.

Recent initiatives under the United Nations Convention to Combat Desertification (UNCCD) seek to identify the biophysical and social thresholds, and develop responses that avert unwanted change. It is clear that the degradation of ecosystems is threatening the productivity of the land and the livelihoods of people that depend on it. The magnitude of these challenges continues to grow with the increasing effects of climate change. The only path forward is improving land users' resilience to drought, desertification, and other disruptions to food production that affect their well-being.

One year ago, I articulated the urgency to intensify our efforts in addressing the global priorities that are shared between the UNCCD, the Convention on Biological Diversity (CBD), and the United Nations Framework Convention on Climate Change (UNFCCC). I discerned the need for a common indicator for assessing and monitoring the contributions of land-based activities to mitigate and adapt to climate change, and I reached out for assistance in meeting this challenge to the Global Environment Facility's Scientific and Technical Advisory Panel. The resilience assessment framework proposed here embodies the STAP's and the Commonwealth Scientific and Industrial Research Organization's (CSIRO) efforts in addressing this challenge.

This report introduces an iterative participatory approach to the assessment of resilience, identifying socio-ecological variables and their interactions across scales. A feature of the assessment is the identification of thresholds for key controlling variables used to assess vulnerability, and warn of impending decline in the capacity of the system to maintain its functions under changing conditions. Based on the outcomes of the assessment, the procedure identifies the need to adapt within the defined system, or transform to a different system. Within these pathways are opportunities to define enabling decisions for climate change adaptation. We expect, therefore, that this resilience framework could successfully harmonize the UNCCD's, CBD's, and UNFCCC's efforts on monitoring and reporting of (agro) ecosystem resilience, climate change adaptation and mitigation, as well as support the Global Environment Facility's aim to streamline monitoring of cross-disciplinary projects and programs.

As the science and policy-making communities have stated, the challenges to "guiding human development on a changing planet" are multiple, complex and require urgent, coordinated action. For our work at the UNCCD, and to facilitate a common approach across the Conventions, a deeper understanding of resilience and how it is assessed and managed is essential as we strive for sustainable development.

**Monique Barbut, Executive Secretary**
United Nations Convention to Combat Desertification (UNCCD)

**Rosina Bierbaum, Chair**
Scientific and Technical Advisory Panel of the Global Environment Facility

# Executive Summary

## BACKGROUND AND OBJECTIVES

The concepts of 'resilience', 'adaptation' and 'transformation' have captured the attention of the global policy community, and are being translated into aspirational goals that guide policy development. Understanding resilience, adaptation and transformation of agro-ecosystems is critical to meeting the Sustainable Development Goals related to food security, land degradation neutrality and climate change adaptation. There are challenges, however, in taking the concepts beyond the phase of research and case-specific studies: further effort is required to operationalise the concepts in the broader global policy and management domains. Devising interventions to progress resilience goals requires methods to evaluate resilience, and identify needs with respect to adaptation and transformation. Monitoring progress toward these goals requires identification of relevant indicators. The development of the Resilience Adaptation Transformation Assessment (RATA) Framework was commissioned by the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF) to address this need.

The RATA Framework is intended to meet common objectives across the three Rio Conventions (the United Nations Convention to Combat Desertification, UNCCD; the Convention on Biological Diversity, CBD, and the United Nations Framework Convention on Climate Change, UNFCCC), the emerging Sustainable development Goals (SDGs), the GEF land degradation strategy, and the GEF's program on *Sustainability and Resilience for food security in Sub-Saharan Africa*. The development of this assessment framework to resilience, adaptation and transformation represents an opportunity to align approaches and monitoring towards common objectives, contribute to integrated strategies, and pursue synergies in reporting between the Conventions.

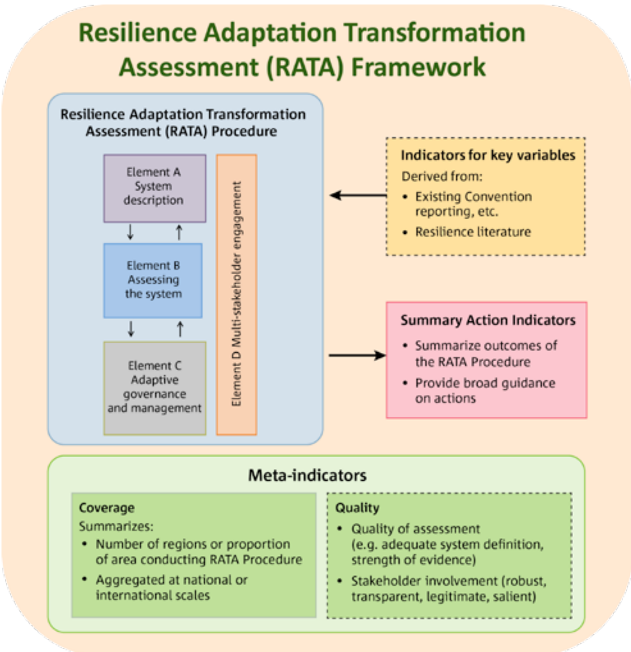
## DEVELOPING THE RATA FRAMEWORK

Resilience, and related concepts of adaptation (and adaptive capacity) and transformation (and transformability) are not easily quantifiable – the dynamic concepts upon which they are founded are not congruent with simple biophysical indicators such as land cover, or compound metrics such as gross domestic product. Additionally, highly synthesised compound indicators may have limited relevance for their particular system and may be very difficult to interpret, or use to support local or national decisions. Therefore we developed the Resilience Adaptation Transformation Assessment Framework, which can draw on existing indicator sets, and proposes that the relative levels of resilience and transformability, and changes in those levels, are an adequate basis for development of well-targeted interventions.

The draft approach was presented at a workshop in Sydney in November 2014 to evaluate the framework approach to assessing resilience, adaptation, and transformation for agroecosystems, suggest improvements, and explore potential applications and implementation pathways for the proposed approach. The Sydney workshop was attended by 50 experts and staff from GEF, STAP, the Conventions, research institutions etc. The workshop provided a vibrant forum for robust discussion and debate – and ultimately endorsement – of the proposed approach.

## THE PROPOSED RATA FRAMEWORK

The approach proposed in this report covers the set of concepts relating to the resilience, adaptation and transformation of agroecosystems, in the face of climate change, a range of slow drivers or shocks, to meet the objectives of maintaining or enhancing food production, livelihoods and/or other ecosystem services.




Overview of proposed Resilience-Assessment-Transformation Assessment Framework. The components with solid outlines are presented in this report. Dotted outlines indicate elements that require further work to develop and elaborate.

The core of the RATA Framework is the RATA Procedure (light blue box in Figure 1), a step by step iterative method for assessment. It is conducted at focal (sub-national) scale, ideally with multi-stakeholder engagement.

The RATA procedure is intended to complement and expand the scope of published guidelines and tools on resilience. The RATA procedure includes four elements:

- **Element A:** System Description
- **Element B:** Assessing the System
- **Element C:** Adaptive governance and management
- **Element D:** Multi-stakeholder engagement

The RATA Procedure provides an effective method to characterize a system, identify controlling variables, analyse the current state and future desired states of an agroecosystem and evaluate its condition with respect to resilience, adaptive capacity and transformability.

The Summary Action Indicators summarise the outcomes of the RATA procedure with respect to the need to adapt or transform, and provide broad guidance on appropriate actions.

The Meta-indicators quantify the coverage and quality of the application of the RATA Procedure.

The assessment of resilience, adaptation and transformation can be done in a range of ways and the methods presented here are intended as guidance, rather than prescriptions. The assessment process can be conducted with varying degrees of scientific rigour, ranging from conceptual to detailed quantitative analyses - or analytical models to support the understanding of system processes, controlling variables, thresholds and feedbacks. Assessments should be conducted in an iterative manner with increasingly more detail and effort as guided by an initial scoping assessment. For example, rapid assessments could be conducted to trial the approach and provide an initial overview and summary about where further effort could be best invested for more detailed analyses.

## WHO WOULD CONDUCT AND REPORT THE ASSESSMENT?

The following scales are relevant:

- Focal scale: scale at which the analysis is conducted and indicators gathered, probably sub-national and potentially sub-agroecosystem scale
- Reporting scale: the results or outcomes of the resilience assessments will be reported at the focal scale (sub-national) as well as at the national scale.

The RATA Framework has many different applications including:

- by groups of stakeholders at focal scale, to develop meaningful and informed storylines for their planning processes; to derive local meaning and value from the indicators that they measure and report; to strengthen community development.
- individuals or groups of researchers or consultants, utilising their own expert knowledge, and published studies. In such cases, without stakeholder involvement, the assessment should be limited to the System Description (Element A) and Assessing the System (Element B) because the findings are subject to the preconceptions, biases and knowledge limitations of those doing the work. While this can be a useful preliminary exercise, many elements of the assessment process (especially those related to adaptive governance and management, planning adaptation pathways) should be conducted with the involvement of local stakeholders in a robust participatory process. The implementation steps always require participation by stakeholders.
- national governments, to coordinate actions, including monitoring and reporting to international bodies (UNCCD , CBD, UNFCCC, OECD, FAO, Montreal process, SDGs etc) , and also for domestic policy development, such as climate change adaptation in all sectors, planning for food and energy security, disaster planning. It can create a basis for coordinating strategic planning and policy development, integrating between disciplines and sectors, to enhance effectiveness of interventions.
- international agencies and donors to help guide support programmes, streamline and focus effort in collating and reporting of indicators most relevant to any given system.

For groups at any scale – household to national – the framework provides an approach to:

- examine and develop shared understanding of the system, and vision for the future
- determine whether that envisioned future is resilient – and answer the question ‘Is this a sustainable pathway?’
- filter and select the most relevant indicators in which to invest resources in monitoring and reporting
- interpret the results of monitoring and reporting, to deepen understanding of the system and actions required
- inform decisions intended to improve livelihoods, food security, management of resources, and adapt to climate change.

## THE UTILITY OF THE PROPOSED APPROACH

An approach was proposed for assessing and reporting resilience, adaptation and transformation at the sub-national and national levels as relevant to the three Rio Conventions. The following criteria were used to guide the development of the proposed indicators:

- ensure clear and explicit statement of the intended purposes, and confirm that the indicators are fit for these purposes
- ensure that the indicators are consistent with the underlying theory and behaviour of the systems in which they are applied
- check the tractability of implementation, including skill required, repeatability, risk of operator bias, etc.

A brief self-assessment was conducted on whether the proposed approach to resilience indicators meets these criteria. The workshop also reviewed the approach and we reflect the views on where the strengths and challenges lie, and what the next steps might entail.

## CONCLUSIONS

The concept of resilience is an inspiration, and a clearly articulated aspiration, in the global discourse about sustainability and the future of the planet and its people. Despite the valuable body of research that has been conducted on resilience theory and practice it is apparent, however, that there are still enormous challenges to operationalizing the concept within an international, or national policy arena.

The RATA framework begins to address these challenges. It applies resilience theory as its conceptual basis, and proposes an iterative multi-stakeholder engagement approach to characterise the system, identifying socio-ecological variables and their interactions across scales. By focussing on proximity to thresholds for key controlling variables, it evaluates the adaptive capacity and transformability of the system. Based on the outcomes of this assessment, the procedure identifies the need to adapt within the defined system, or transform to a different system.

The RATA Framework is flexible, making it well-suited to different contexts. It is well able to accommodate the reality that what is vitally important in one system is irrelevant in another. For example, climate change will be an important consideration in some systems, but not all. The RATA framework is also readily applicable in situations of high uncertainty, high dispersion of power and highly ambiguous goals. Its flexibility makes it relevant beyond agroecosystems – indeed, it can readily be applied to any social-ecological system.

The RATA Framework is consistent with existing frameworks and can be used in conjunction with them. It has been informed by existing literature on resilience assessment, and contains key elements common to reviewed approaches: explicit system conceptualization; multiple scales; and acknowledgment and characterization of context (especially the specification of resilience of what, to what and according to whom).

The framework also brings to the fore the value of learning, innovation, experiments and openness to challenging the status quo as important attributes of a self-organized system. The RATA Framework enables mutual learning, fostering common understanding across stakeholders of different perspectives, interests and visions for their system, and development of narratives that provide meaningful interpretations of existing knowledge, datasets and indicators. The iterative nature of the framework and its emphasis on learning gives it some self-correcting capacity and scope for novelty.

The most prominent weakness of the RATA Framework is, in some ways, a consequence of one of its strengths. Its flexibility and utility across a range of contexts is accompanied by a high level of subjectivity in how it is applied. This is a strength as it enables participation and use across a wide range of settings, but it comes with a cost in that it limits the ability to compare across systems. Even though we stress that resilience is not a normative concept (i.e. it requires no value judgments claiming what is good and bad, or right or wrong), and is a system property, core aspects of the application of the concept within the RATA Framework are inherently normative judgments, including the choice of focal scale and how we frame what is in or out of the agroecosystem. It is for all these reasons that we have stressed throughout this report the need for multi-stakeholder engagement, inclusive adaptive management approaches and meta-indicators of the quality of assessment, and these aspects need to be strengthened in any application of the framework.

## NEXT STEPS

The proposed approach was developed as part of a small project, and requires further development and testing, preferably in an operationally applied environment. It must necessarily be an adaptive, learning process, and this needs to be built into the next steps. There are some intermediate steps that can be taken to prepare for a pilot or early stage implementation. Further steps to trial the RATA in a set of archetypal, contrasting agroecosystems from a selected set of candidate countries could be used in an adaptive learning environment, involving local expertise, local and national stakeholder interests, and technical expertise.

# Terms and definitions

| | |
|---|---|
| Adaptability (adaptive capacity) | The capacity of actors in a system to respond to shocks and to trends and (if known) the proximity of the state of the system to a threshold, and so to influence resilience. See General resilience. |
| Adaptation | A process of responsive change that improves the ability of a system to achieve desired goals, including by reducing vulnerability to disturbance or threats (including climate change). See Table 1 for further discussion about the use of the term in different branches of literature, and policy. |
| Adaptive governance | Institutional and political frameworks designed to adapt to changing relationships in society and between society and ecosystems. |
| Agroecosystem | Agroecosystems are one type of social – ecological system (SES): 'An ecosystem managed with the intention of producing, distributing, and consuming food, fuel, and fibre. Its boundaries encompass the physical space dedicated to production, as well as the resources, infrastructure, markets, institutions, and people that are dedicated to bringing food to the plate, fibre to the factory, and fuel to the hearth. The aggregate ecosystem operates simultaneously at multiple nested scales and hierarchies, from the field to the globe. ' |
| Forced transformation | An imposed transformation of a social–ecological system that is not initiated and guided deliberately by the actors. Also known as unintentional or autonomous transformation. |
| General resilience | capacity of all parts of the system to cope with all kinds of shocks and disturbances, and so be able to avoid crossing thresholds, known or unknown, to alternate regimes or systems. It is sometimes referred to as 'coping capacity' and in this report is used synonymously with 'adaptive capacity'. |
| Institution | A set of rules and norms that guide how people within societies live, work, and interact. Formal institutions consist of codified rules such as constitutions, organized markets, and property rights. Informal institutions consist of the rules which express social and behavioural norms of an individual, family, community, or society. |
| Intentional transformation | The deliberate transformation of a system to one with different defining variables and therefore a different identity (a new way of making a living), initiated and guided by the actors. |
| Regime | A set of states in a system that tend towards a single, particular stable state (an 'attractor'). Also known as a stability domain. |
| Regime shift | A change in the state of a system from one regime or stability domain to another. |
| Resilience | The ability of a system to maintain high-level objectives (e.g. sustainability, rural livelihoods, ecosystem services) in the face of unknown changes or disturbance.<br><br>The term resilience can be coupled with aspirational goals, or system futures which are seen as desirable or 'good' (e.g. maintain the resilience of ecosystem services), so long as it is clear that it is not the resilience per se that is desirable. |
| Social–ecological system | Integrated system of ecosystems and human society with reciprocal feedback and interdependence. The concept emphasizes the humans-in-nature perspective. |
| Specified resilience | Resilience of particular parts of a system to identified disturbances i.e. potential future occurrence is known or suspected, though their timing and magnitude may be a surprise. |

| | |
|---|---|
| **Stakeholders** | A stakeholder in a social-ecological system is any person actually or potentially affected by change in that system. A stakeholder may live within the geographical boundaries of the system – a farmer in an agroecosystem, for example, but may also live outside it - an agrochemical supplier or an urban conservationist perhaps. Most stakeholders have some ability to influence changes in the system, but people who are unaffected by changes in the system are by our definition, not stakeholders. We include governments among the stakeholders because they are responsible for the wellbeing of stakeholders in the SES, and are thus affected by changes in it. Resilience assessments are more likely to be accurate, and recommendations more likely to be effective, if stakeholders are engaged in the assessment. |
| **Threshold (aka critical transition)** | A level or amount of a controlling, often slowly changing variable where a change occurs in a critical feedback causing the system to self-organize along a different trajectory, that is, towards a different attractor. |
| **Transformability** | Transformability is the capacity for a system to be transformed to a different system. See Transformation. |
| **Transformation** | Transformation is physical or qualitative changes in form, structure, function or meaning. In resilience literature, transformation is the process of changing from one type of system to another with different controlling variables, outputs, structure, functions, and feedbacks ('identity'). Transformation can be intentional (i.e. driven by deliberate actions of people), autonomous (e.g. natural selection) or unintentional (forced) (transitions imposed from outside the system). |
| **Transition** | The course of the trajectory from one regime of a system to another, or from one kind of system to another (i.e. a transformational change). |

# Acronyms

| | |
|---|---|
| AC | Adaptive capacity |
| ACRIS | Australian Collaborative Rangelands Information System |
| CBD | Convention on Biological Diversity |
| COP | Conference of the Parties |
| DPSheIR | Driver-Pressure-State(human x environment)-Impact-Response |
| DPSIR | Driver-pressure-state-impact-response |
| FAO | Food and Agricultural Organization of the United Nations |
| GDOS | Global Drylands Observing System |
| GEF | Global Environment Facility |
| GR | General Resilience |
| GHG | Greenhouse gases |
| IPCC | Intergovernmental Panel on Climate Change |
| IRRI | International Rice Research Institute |
| M&E | Monitoring and evaluation |
| MA | Millennium Ecosystem Assessment |
| $NAP_1$ | National action programmes of the UNCCD |
| $NAP_2$ | National action plans of the UNFCCC |
| NAPA | National adaptation programmes of action of the UNFCCC |
| NBSAP | National Biodiversity Strategies and Action Plans (of the CBD, https://www.cbd.int/nbsap/) |
| NDVI | Normalized Difference Vegetation Index |
| OECD | Organization for Economic Co-operation and Development |
| PCI | Principle-Criteria-Indicator |
| RIMA | Resilience Index Measurement and Analysis |
| SDGs | Sustainable Development Goals |
| SDUDP | Systems dynamic-based understanding of desertification processes |
| SEPLS | Socio-Ecological Production Landscapes and Seascapes |
| SES | Social-ecological system |
| SLM | Sustainable land management |
| STAP | Scientific and Technical Advisory Panel of the Global Environment Facility |
| SR | Specified resilience |
| T | Transformability |
| UNCCD | United Nations Convention to Combat Desertification |
| UNFCCC | United Nations Framework Convention on Climate Change |

# 1 Introduction

## 1.1 Introduction

The concepts of 'resilience', 'adaptation', and 'transformation' have captured the attention of those who influence the global discourse on sustainability and the future of the planet and its people. The global policy arena has embraced the concepts and language of resilience thinking, planetary boundaries and a 'safe operating space for humanity' (Rockstrom et al., 2009b), adaptation and adaptive governance and management. The language permeates new policy directions, exemplified in the report The future we want (UN, 2012b) which aims to guide the formulation of the Sustainable Development Goals (SDGs) and the post-2015 development agenda. They are also prominent in Resilient People, Resilient Planet (UN, 2012a) which recognized that, in order to deal with the global food security crisis, the land production base needs to remain within the 'safe operating zone'.

Thus, these contemporary science approaches are gaining traction, and being translated into aspirational goals (O'Connell et al., 2013). There are some outstanding challenges, however, in taking the concepts beyond the stage of research and case-specific studies. Further effort is required to operationalize the concepts in the broader global policy and management domains, and for on-the-ground decision-making, planning and investment.

This report was commissioned by the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF). The STAP has identified ecosystem resilience as a common objective across the three Rio Conventions (the United Nations Convention to Combat Desertification, UNCCD; the Convention on Biological Diversity, CBD; and the United Nations Framework Convention on Climate Change, UNFCCC). The STAP considers that indicators of agroecosystem resilience could complement the UNCCD progress indicators on land cover and productivity, and could be shared with the UNFCCC as a measure of land-based adaptation, and the CBD as a measure of ecosystem resilience. Furthermore, these indicators are pertinent to the emerging SDGs, and the GEF land degradation focal area and GEF's integrated approach on Sustainability and Resilience for Food Security in Sub-Saharan Africa. The STAP anticipates that the development of common indicators of resilience (which covers the related concepts of adaptation and transformation) represents an opportunity to align approaches and common objectives, contribute to integrated strategies, and support common reporting between the Rio Conventions.

The purpose of this effort is to synthesize the scientific understanding of resilience in agroecosystems, and, if feasible, propose indicators that could be applied by nations at the appropriate scale.

The report will contribute to the following purposes:

i) enhancing UNCCD's and the GEF's efforts to assess progress in fostering ecosystem resilience
ii) reinforcing the coherence between the UNCCD's monitoring of its 10-Year Strategy and the GEF's monitoring of the land degradation focal area strategy
iii) identifying a joint indicator between the UNCCD, UNFCCC and CBD as a measure of both land-based adaptation and ecosystem resilience.

The full Terms of Reference are listed in Appendix 1.

The STAP commissioned a draft version of this report as a Discussion Paper, and convened a workshop in Sydney in November 2014 to:

i) Discuss, evaluate, peer review and suggest improvements to the proposed conceptual framework for approaches to resilience (adaptation, transformation) for agroecosystems
ii) Obtain clarity on the purpose(s) and common objectives and strategies across the three Rio Conventions and the GEF more broadly
iii) Explore potential uses and implementation pathways for the proposed approach to resilience (adaptation, transformation) indicators.

The Sydney workshop was attended by 50 people (list of attendees in Appendix 2). The workshop provided a vibrant forum for robust discussion and debate – and ultimately endorsement – of the proposed approach.

During the course of the project, the project team held several discussions with the Project Steering Committee to better understand the needs and operational mechanisms of the UNCCD and the GEF, reviewed a wide range of scientific literature and policy documentation across the three Rio Conventions to better understand unmet needs, and the mechanisms for achieving the overall purpose, such as aligning approaches and objectives and contribute to integrated strategies and common reporting between the Rio Conventions. This, combined with the emergence of a more clearly shared understanding of the purpose of this project, and the proposed approach which was elicited through the workshop process, led to some expansion and change of scope in this revision of the report. For example, the proposed approach deals with the related set of resilience, adaptation and transformation concepts, rather than the previous focus on 'resilience' alone (which tacitly included adaptation and transformation, but was confusing for many (see section 1.3)).

The workshop identified additional requirements to facilitate implementation of the framework. These are described in Chapter 4, but are not fully developed because they were outside the scope of this consultancy. They will be developed in future steps.

## 1.2 The purpose of indicators for resilience of agroecosystems for the UNCCD, other Multilateral Environmental Agreements and the GEF

In any effort to develop, or implement, indicators it is critically important that the purpose and application of the indicators are clearly articulated, and that their efficacy is evaluated against this purpose and application. We discuss the rationale for this in detail in Chapter 2. We have therefore placed some emphasis on gaining a clear articulation of the purpose and potential application of the indicator(s). The STAP has provided the following guidance.

This paper explores a common practical approach to land-based adaptation indicators and integration frameworks which could be applied within reporting processes of the Rio Conventions, drawing on existing methods, global data sets and reporting processes; thus improving opportunities for collaboration and enriching reporting processes, to serve the long-term goals of the Rio Conventions/GEF and support a more harmonized approach to sustainable development (Project Steering Committee, 2014).

Enhancing resilience in agroecosystems through sustainable land management is a priority for the GEF over the next four years. Targeted actions include:

i) improving agricultural management to enhance agroecosystem resilience and manage climate risks
ii) fostering resilience of ecosystem services for food security in Sub-Saharan Africa through a new integrated approach.

The STAP holds the view that a focus on resilience in social-ecological systems, and the assessment and reporting thereof, may stimulate practical collaboration among the Rio Conventions, as well as potentially contributing to the SDG framework (to be agreed at the seventieth United Nations General Assembly in September 2015).

The purpose of resilience indicators from the view of STAP is to encourage and support integration in strategic planning and implementation of actions to meet environmental objectives. Additional aspirations include providing a basis for prioritizing, monitoring and communicating adaptation policies, practices and their outcomes (Project Steering Committee, 2014).

The UNCCD parties have agreed an approach to Monitoring and Evaluation (M&E) that parties will use to track progress in meeting the agreed strategic objectives (UNCCD 2013a CST/2). The Ad Hoc Advisory Group of Technical Experts (AGTE) recommended to UNCCD CoP 11 an approach to M&E, consisting of three modules (ICCD/COP(11)CST/2 UNCCD, 2013a; ICCD/COP(11)/23/Add.1 UNCCD, 2013b):

a. Indicators, both global and national/local
b. A conceptual framework that allows the integration of indicators
c. Indicator sourcing and management mechanisms at the national/local level.

The AGTE articulated some clear needs and makes a range of recommendations for the UNCCD M&E approach (UNCCD, 2013a), including:

- Development of coherent narratives or storylines at a local scale, i.e. the documented history of successes and failures experienced at sites threatened by desertification and related processes; to provide the information and knowledge required to understand the dynamics of desertification, land degradation and drought processes. The production of storylines should be supported by a coordination system across spatial and governance levels, backed up by sufficient resources to feed local understanding of the land degradation and desertification processes, to plan local mitigation and adaptation policies, and inject fresh ideas and concepts to enable the adaptive evolution of the approach, including the necessity of new indicators.

- Application of a set of common, global progress indicators, to be complemented with formal and narrative indicators at national/local scale that could be sourced from predominantly local storylines, and could provide more detailed information on the level and characterization of land degradation that are specific to each context.

- Development of a new indicator integration framework to track progress and report at multiple scales, explicitly including human-environment interactions. This framework should aim to:

  – Enable the upscaling/downscaling feedback loop that allows synergy between the local and global levels

  – Draw storylines able to integrate the work of national action programmes, help countries to solve their own problems, and characterize the ‘hot/cold spots’ for areas at risk of desertification, land degradation and drought

  – Provide countries with conceptual and functional support to their chosen indicators sets, which improves their capacity to interpret them

  – Help the formulation of research and action projects.

- Recognition that M&E should not be done simply as a mandatory reporting exercise, but should be incentivized through the benefits that it can bring to local/national development. Reporting on indicators should therefore involve the local assessment of the outcome of the M&E process, and should be driven by the local/national need for the data, rather than the global reporting obligation. It is recognized that land degradation and human well-being are intrinsically linked, but that environmental interventions and development efforts are not always conducted in a synergistic manner. It recognized that participation in indicator selection and reporting at the local level gives the capacity for the resultant M&E data to inform decision-making intended to improve livelihoods and overall well-being, and strengthen community development activities.

There are also aspirations that the indicator(s) or Monitoring and Evaluation (M&E) framework(s) for agroecosystem resilience will be used to:

- Target and prioritize policies and measures to build adaptive capacity to a range of drivers or shocks.
- Establish baselines to monitor the effectiveness of adaptation interventions and their impacts on reducing vulnerability to climate change, and the links between adaptation and sustainable development.
- Communicate effectiveness and outcomes of adaptation projects to policy and decision makers and other stakeholders.
- Compare adaptation progress and achievements across sectors, regions and countries (Project Steering Committee 2014).

In Chapters 2 and 3 we lay out the logic behind our proposed approach (presented in Chapter 4). The approach includes an assessment process, a 'conceptual framework to allow the integration of indicators', as well as Summary Action Indicators to capture the outcomes of the assessment and provide guidance on appropriate responses. We apply the approach in a partial manner in Chapter 5 (full application can only take place in a multi-stakeholder, applied environment), and evaluate the utility of the proposed approach against these articulated purposes and broader needs in Chapter 6.

In summary, the purpose of the development of resilience indicators was:

- operationalize resilience concepts
- develop methods to monitor progress in enhancing resilience that are applicable at multiple scales, including national
- harmonize the UNCCD's, CBD's, and UNFCCC's efforts on monitoring and reporting of agroecosystem resilience and climate adaptation
- support the GEF's objective to foster cross-disciplinary projects, and develop tools to monitor progress towards this goal.

## 1.3 Three related concepts: resilience, adaptation and transformation

In this section, we introduce the three related concepts underpinning this report: resilience, adaptation and transformation. These three words, as well as 'sustainability', abound in the goals and objectives of all of the Rio Conventions, in the emerging SDG's and many other arenas. Here we briefly introduce and explain the key terms, as used in this report. A more complete list of terms is in the Terms and Definitions.

The terms resilience, adaptation and transformation, are used in popular culture as well as by governments, business, aid organizations, and international organizations such as United Nations. In this context they are invariably framed in a positive light, as desirable attributes; often as aspirational goals (such as 'maintain the resilience of ecosystem services'). Within the scientific and technical discourse, all three terms are used in a more specific manner. For example, 'resilience' as a system property is independent of value judgements: it is neither 'good' nor 'bad'. The aspect that is value-dependent (or 'normative', in the literature) is the judgement on whether or not a particular state is desirable. The scientific use of terms such as resilience, adaptation and transformation must be neutral and objective, and the utility should be assessed with respect to reaching explicit sustainability (or other) goals that are developed through a social process.

Even within the scientific discourse, the terms resilience, adaptation and transformation are not always used consistently between different scientific communities, and this can lead to confusion. The key terms and their usage in both popular culture and the scientific literature, are further described in Table 1. The concepts themselves are explained in more depth in Chapters 3 to 5.

In this report we view resilience, adaptation and transformation as a set of closely related concepts. This is consistent with the resilience literature, where the capacity to adapt and transform is considered to be part of the framing of resilience thinking. We acknowledge the differences in epistemology and usage in different academic arenas of resilience, climate change, etc. (each of which is also rapidly evolving). Our use of the terms and concepts accommodates these different approaches, while meeting the practical objectives of developing an approach which is relevant across the three Rio Conventions and beyond.

**TABLE 1 SOCIETAL AND TECHNICAL USE OF THE KEY CONCEPTS OF RESILIENCE, ADAPTATION, TRANSFORMATION AND SUSTAINABILITY**

| TERM | WHEN USED AS A SOCIAL GOAL | TECHNICAL USAGE |
|---|---|---|
| Sustainability | Definitions abound, but a 'universalist definition' uses the central notions of the planet and its people enduring in perpetuity, while maintaining health, prosperity and well-being. This is commonly translated into a concept of three interdependent 'pillars' of sustainability, i.e. maintaining environmental, social and economic health.<br><br>Sustainable development is 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). There is increasing recognition that in order for human related goals to be met, there are prerequisite ecosystem functions that need to be maintained. | Resilience and system dynamics help to explain processes relevant to sustainability. High resilience contributes to sustainability when it is desirable to maintain a system in its current state, but works against sustainability when transformation is desirable.<br><br>Adaptation and adaptive capacity both contribute to (and may be necessary for) sustainability where a system is under threat or is running down crucial assets or system functions.<br><br>Cross-scale interactions are critical in considering higher level sustainability objectives. For example, in the face of climate change sustainability of overall human well-being in a large river basin may require transformation in parts of it from irrigated to non-irrigated land-use. |
| Resilience | The ability of a system to maintain high-level objectives (e.g. sustainability, rural livelihoods, ecosystem services) in the face of unknown changes or disturbance.<br><br>The term resilience can be coupled with aspirational goals, or system futures which are seen as desirable or 'good' (e.g. maintain the resilience of ecosystem services), so long as it is clear that it is not the resilience per se that is desirable. | The ability of a system to absorb disturbance and reorganize so as to retain its 'identity' – the same function, structure, and feedbacks.<br><br>Resilience can be distinguished into<br><br>• 'specified' resilience – resilience of particular parts of a system to identified disturbances i.e. potential future occurrence is known or suspected, though their timing and magnitude may be a surprise<br><br>• 'general' resilience – capacity of all parts of the system to cope with all kinds of shocks and disturbances, and so be able to avoid crossing thresholds, known or unknown, to alternate regimes or systems. It is sometimes referred to as 'coping capacity' and in this report is used synonymously with 'adaptive capacity'.<br><br>Resilience is a value-free property: it is neither 'good' nor 'bad'. A system can have a high level of resilience (i.e. able to maintain the same identity despite shocks) whether it is in a desirable state (e.g. healthy, productive, profitable farmland) or an undesirable state (desertified landscape without capacity to produce food or livelihoods). |

| | | |
|---|---|---|
| Adaptation (and adaptive capacity) | A process of responsive change that improves the ability of a system to achieve desired goals, including by reducing vulnerability to disturbance or threats (including climate change).<br><br>In common or policy usage, adaptation is usually seen as intentional (driven by deliberate action of people), and viewed as driving towards a desirable goal, system or future.<br><br>Adaptive capacity is generally used as a positive term, relating to the ability of actors in the system to intentionally change the system to achieve desired goals. | This term is used slightly differently in different branches of science.<br><br>Adaptation can be in response to slow trends or drivers (e.g. climate change), or response to shocks.<br><br>Adaptation can be intentional (i.e. driven by deliberate actions of people), or autonomous (e.g. natural selection, or forced transitions to another regime or system).<br><br>Some use a narrower interpretation of adaptation which excludes transformation – for example, restricting it to responses that can maintain prevailing societal objectives, or the current system 'identity'. If these can no longer be achieved then 'limits to adaptation' have been reached, and transformation occurs. Much of the resilience literature separates adaptation and transformation in order to ensure consistency with an early narrow definition of adaptive capacity, namely 'the capacity of actors in a system to influence resilience'.<br><br>In climate change literature, the term adaptation also encompasses transformation, and is sometimes called transformational adaptation.<br><br>'Adaptive capacity', as used in this report, is analogous to general resilience. |
| Transformation (and transformability) | Transformation is physical or qualitative changes in form, structure, function or meaning.<br><br>Transformability is not widely used in popular parlance; it is usually covered by the term 'adaptive capacity' | In resilience literature, transformation is the process of changing from one type of system to another with different controlling variables, outputs, structure, functions, and feedbacks ('identity').<br><br>Transformation can occur in the biophysical world (e.g. novel ecosystems), or in social systems (e.g. reformed governance arrangements).<br><br>Transformation can be intentional (i.e. driven by deliberate actions of people), autonomous (e.g. natural selection) or forced (transitions imposed from outside the system).<br><br>Transformability is the capacity for a system to be transformed to a different system. |

## 1.4 Defining 'agroecosystem' for this study

Cabell and Oloefse (2012) define an agroecosystem as: 'An ecosystem managed with the intention of producing, distributing, and consuming food, fuel, and fibre. Its boundaries encompass the physical space dedicated to production, as well as the resources, infrastructure, markets, institutions, and people that are dedicated to bringing food to the plate, fibre to the factory, and fuel to the hearth. The aggregate ecosystem operates simultaneously at multiple nested scales and hierarchies, from the field to the globe.'

Humans are integral to this definition of agroecosystem, and it is consistent with the broader use of the term social – ecological system (SES) which is used throughout the resilience literature.

Typically a nation will have within it multiple agroecosystems (e.g. rain-fed annual systems, rain-fed perennial, irrigated, mixed grazing-cropping, extensive grazing etc.). These will operate at different scales, and are nested in part in global markets and institutions as well as being interlinked at national and sub-national scales. It may be sensible to define the systems spatially/bioregionally, and note there are links between subsystems operating in different bioregions.

Agroecosystem resilience, for the purposes of this report, is defined as 'the ability of an agroecosystem (a particular type of SES) to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks – to have the same identity'.

It is beneficial to build resilience of systems that are in a desirable state, so building agroecosystem resilience equates with enhancing the ability to cope with shocks and continue to maintain the well-being of humans that depend on that system for food and other valued outputs (which may include a range of valued outputs and ecosystem services outside the actual site of food production per se).The approach proposed in this report covers the set of concepts relating to the resilience, adaptation and transformation of agroecosystems, in the face of climate change, a range of slow drivers or shocks, to meet the objectives of maintaining food production, livelihoods or any other ecosystem services.

## 1.5 The structure of the report

In Chapter 1, we present an introductory overview with the objectives of the study, and the intended purposes(s) behind the effort to develop for resilience indicator(s) applicable to the UNCCD and the GEF, and potentially to the CBD and UNFCCC, as well as other emerging global policy discourses and instruments such as the SDGs.

In Chapter 2, we present and discuss the development, application and utility of complex, compound indicators for concepts such as vulnerability, adaptation and resilience. We also provide a brief review of the literature on 'resilience indicators', with a particular emphasis on those indicators or approaches that we employ in our proposed approach.

In Chapter 3, we present an overview of resilience theory and implementation. This is not intended to replace the many peer reviewed papers and books on the topic written since 1973. Rather, it is a quick guide for those who are less familiar with the concept, intended to provide a basis for navigating the subsequent chapters.

In Chapter 4, we present the core of this study. We describe the rationale for a conceptual approach to meet the overall objectives of the study. We suggest that a Resilience, Adaptation and Transformation Assessment Framework could be used as an integrating approach, at a sub-national scale. The initial rapid assessments could be summarized as Summary Action Indicators to provide first estimates of the prospects of the agroecosystem for coping with shocks while continuing to maintain ecosystem services (including food production), the well-being of humans that depend on it, and the need for particular types of interventions (in UNCCD-specific terms this is stated as preventing, halting or reversing desertification, land degradation and mitigating the effects of drought in agroecosystems). We suggest meta-indicators, to quantify the overall trends, the coverage and quality of assessment.

In Chapter 5, we apply the approach suggested in Chapter 4 to two case studies in differing agroecosystems. We present only a summary in this chapter; the full case studies are presented in an accompanying report *Resilience assessment case studies in Thailand and Niger (Grigg et al., 2015)*. Our intention in choosing the case studies was to span the concerns of the three Rio Conventions – climate change, land degradation and desertification, and biodiversity. The Sahelian system is dry, infertile, has relatively low dependence on external fertilizer and agrochemical inputs, and has a high dependence on ecosystem functions. Climate change scenarios are unclear. It is a system undergoing rapid social change, with associated impacts on land use, ecosystems and livelihoods. The Thailand system is wet, relatively fertile, heavily dependent on fossil fuels and agrochemicals, the use of which threatens ecosystem functionality. The Thailand system is especially vulnerable to climate change. Between them the case studies span the foci of the Rio Conventions as well as a range of agroecosystems to which resilience indicators may be applied.

In Chapter 6 we provide a preliminary evaluation of the utility of our proposed approach in terms of the purposes of resilience indicators. We conclude with a summary of the approach we have put forward. We suggest further steps that may be required to operationalize the concepts. We consider this study to be in the scoping stage and invite wider discussion, critique, further ideas and testing of the framework.

# 2 Indicator development and application

In this chapter, we start by providing a snapshot of the current approaches to indicators in the global policy instruments most relevant to this report: UNCCD, CBD, UNFCCC and the developing SDGs. Since the original Terms of Reference for this report focused on the development of 'resilience indicators', we focus on what should guide the development of indicators – particularly compound indicators of relevance to capturing dynamic system behaviour inherent in resilience, adaptation and transformation. Given the burgeoning lists of indicators globally and the burden imposed upon those who measure and report them, any development of new indicators needs to be approached with critical caution and very clear intent. We review the emerging literature on resilience indicators, and conclude that there are no existing approaches which would meet all of the needs expressed in section 1.2.

## 2.1 The utility of indicator sets relevant to UNCCD, CBD, UNFCCC and other national or global efforts

### 2.1.1 UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD)

The primary objectives of the UNCCD are to halt and reverse desertification and land degradation, and mitigate the impacts of drought. There are three strategic objectives relevant to the scope of this report in the 10-year strategic plan (2008–2018):

1. To improve the living conditions of affected populations.
2. To improve the conditions of affected ecosystems.
3. To generate global benefits through effective implementation of the UNCCD.

The UNCCD has, over the last couple of decades, developed a sound understanding of the use of different types of biophysical and socioeconomic indicators related to desertification and the monitoring of change, within nested hierarchies of scales (e.g. Reynolds et al. 2011). Frameworks and architectures have been developed and/or proposed for the use of these different scales and types of indicators within various types of integrated assessment models, providing interpreted knowledge and information for policy and land management (e.g. Sommer et al. 2011, Reed et al., 2011). Such systems have been operationalized in some countries – for example the Australian Collaborative Rangelands Information System (ACRIS) in Australia (Bastin et al., 2009), while a global drylands observing system (GDOS) has been scoped and proposed by many (e.g. Verstraete et al. 2009, Reynolds et al., 2011).

The UNCCD has adopted a Monitoring and Evaluation (M&E) framework and a set of indicators to track progress towards these strategic objectives. The recently approved M&E framework includes a set of six socioeconomic and biophysical indicators, two for each strategic objective. These indicators, their metrics/proxies and potential data sources are provided in Appendix 3.

As part of their reporting obligations, affected country Parties are requested to submit qualitative and quantitative information on these indicators every four years. Reporting is mandatory only if standardized global data sets to measure these indicators exist. This new approach, based on a broader use of readily available global data sources, aims at decreasing the reporting burden on Parties by limiting data-collection efforts at national level and putting greater emphasis on data quality improvement and interpretation. The identification of appropriate data sources is currently ongoing at the level of the UNCCD Secretariat in collaboration with numerous partners (Project Steering Committee, 2014).

### 2.1.2 CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

The Strategic Plan for Biodiversity 2011–2020 (Nagoya, Japan 2010) (http://www.cbd.int/decision/cop/?id=12268), is the framework for action for all stakeholders including the biodiversity-related Conventions, and has been adopted by the United Nations system at large. The 20 Aichi Biodiversity Targets support the plan. CBD Parties have committed to regularly report on progress towards the Aichi Biodiversity Targets, which are also to be set nationally through national biodiversity strategies and action plans.

A set of indicators operable at the global level has been identified by the Ad Hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011–2020 and ongoing work is supported by the Biodiversity Indicators Partnership. This work of continues and a follow up meeting of the Ad Hoc Technical Expert Group on Indicators will be held late 2015. Decision XI/39 contains an indicative list of these agreed global indicators (as of 2012) that provide a starting point for assessing progress in the achievement of the Aichi Targets at various scales taking into account different national circumstances and capabilities; although reporting using these indicators is voluntary. A criterion for the adoption of these agreed indicators was degree of availability of global data sets and monitoring frameworks for them.

The indicators that are most relevant for purposes of this current study are listed in Appendix 3. Some of these might be considered direct measures of ecosystem attributes that contribute to resilience; others might refer to supporting mechanisms (e.g. policy frameworks) that contribute to resilience. These data sets could potentially be drawn on in the Resilience, Adaptation and Transformation Assessment Framework proposed in this report; many of the indicators are defined as 'trends', which is a useful step forwards in assessing system dynamics. For the purposes of resilience assessment, however, another step may need to be taken – namely, defining critical thresholds in these trends. Conducting iterative resilience assessments may also assist countries to prioritize which of the many proposed indicators are the most critical in their agroecosystems, so that they can then invest effort on characterizing those variables which are most useful in understanding and managing resilience.

### 2.1.3 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The primary objective of the UNFCCC is to stabilize atmospheric greenhouse gas concentrations at a level which would prevent dangerous anthropogenic interference with the climate system (Article 2 of the Convention). This objective specifies that this level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. UNFCCC Parties have affirmed that adaptation must be addressed with the same level of priority as mitigation (Project Steering Committee, 2014).

The 2010 Conference of the Parties adopted the Cancun Adaptation Framework, which invited the Parties to undertake, among others, 'Building resilience of socioeconomic and ecological systems, including through economic diversification and sustainable management of natural resources'. An Adaptation Committee was established to promote the implementation of enhanced action on adaptation in a coherent manner under the Convention. The initial three-year workplan of the Adaptation Committee includes work on the monitoring and evaluation of adaptation. In this context, the Adaptation Committee organized a workshop in 2013 to consider how monitoring and evaluation could facilitate enhanced implementation of adaptation. The workshop addressed policy questions including:

(i) how, given the diverse set of indicators that currently exist to measure and evaluate adaptation, communities, countries and development/ adaptation agencies can build a common understanding of the goal of climate resilience; and

(ii) how individual assessments can be linked with national level assessments to broaden the focus from the means of achieving the outcomes (individual interventions) to the desired end result (countries becoming less vulnerable and having more adaptive capacity).

In addition to the Adaptation Committee, the Cancun Adaptation Framework established the National Adaptation Plan (NAP) process. Reporting, monitoring and reviewing of adaptation activities is an essential element of the process and the guidelines that have been developed in this context (UNFCCC LDC Expert Group, 2012). The NAPs offer an opportunity to develop information, indicators and/or M&E frameworks on land-based adaptation under appropriate sectors. This information could be used when reporting on the process.

There has been a large volume of research and reporting by IPCC and all of the agencies which feed into the IPCC assessment process, and many indicators and global data sets generated through this process could be drawn on or modified in the Resilience, Adaptation and Transformation Assessment Framework proposed in our report (Chapter 4).

### 2.1.4 SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals, with associated targets, indicators and metrics, are currently under development. They have been proposed by a range of organizations, and are currently expressed as a list of aspirational goals which include many references to resilience and adaptation (UNOWG, 2014), for example:

- Proposed Goal 1. End poverty in all its forms everywhere
  - Goal 1.3 by 2030. Build the resilience of the poor and those in vulnerable situations, and reduce their exposure and vulnerability to climate related extreme events and other economic, social and environmental shocks and disasters
- Proposed Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
  - Goal 2.1 by 2030, end hunger and ensure access by all people, in particular the poorer in people and vulnerable situations, including infants, to safe, nutritious and sufficient food, all year round
  - Goal 2.3 by 2030, double the agricultural productivity and incomes of small-scale food producers, particularly women, indigenous peoples, family farmers, pastoralists and fishers, including through securing equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment
  - Goal 2.4 by 2030, ensure sustainable food production systems and implement resilience agricultural practices that increase productivity and production, that help maintain ecosystems, strengthen capacity for adaptation to climate change, extreme weather, droughts, flooding and other disasters, and that progressively improve land and soil quality
- Proposed Goal 6. Ensure availability and sustainable management of water and sanitation for all
  - Goal 6.6 by 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- Proposed Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Proposed Goal 11. Make cities on human settlements, inclusive, safe, resilient and sustainable
- Proposed Goal 13. Take urgent action to combat climate change and its impact (acknowledging that the UNFCCC is the primary international, intergovernmental forum from negotiating the global response to climate change)
  - Goal 13.1 strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries
  - Proposed Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
  - Goal 15.3 by 2020, combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world.

During the first half of 2015 there will be an intensive international effort to finalize these proposed goals and their associated targets (probably mostly accepting the current words), as well as developing the indicators and metrics to underpin them through 2016. Given the multiple references to resilience, adaptation and related concepts, the approach proposed in this report has clear relevance.

In section 2.1 we have briefly outlined the frameworks of indicator reporting for the three Rio Conventions and alluded to what will be required to support the SDGs. There are many other indicator sets that have been devised – for example, those used by the GEF, and the OECD that have not been reviewed here, but which include indicators that may have relevance to the assessment of resilience, adaptation and transformation. These indicators, may be used in the application of the assessment procedure described in Chapter 4.

## 2.2 Simple and compound indicators

### 2.2.1 SIMPLE INDICATORS AND METHODS FOR MEASUREMENT

Relatively simple indicators, based on the observation of singular characteristics (e.g. pH, soil phosphorus levels, and infant mortality) are able to capture key aspects of linked social-ecological systems. If well-specified and validated to capture key system characteristics and outcomes, they can reflect essential ecosystem functions as well as human values associated with that function. Methods for measuring such indicators are well understood and mature.

Methods to measure other, more complex indicators, however, are still under development. They may have a high measurement cost or very complex underlying conceptual models – especially when the scale and local context are critical (O'Connell et al., 2013). For example, it is challenging and expensive to survey biodiversity across space and time and at different scales. Because it is difficult to express biodiversity in simple units, various proxies have been developed (e.g. habitat hectares (Parkes et al., 2003)). Interpretation of biodiversity data is very scale-dependent – an action that results in a poor biodiversity outcome in a small patch of land, as reflected in the metric, may have little overall effect on biodiversity at a broader scale – and it depends on the management of the landscape as a whole and the dynamics of the population under threat. Spatial linkages can also add to, or detract from the biodiversity value of a particular area of land. Indicators for the social attributes in agroecosystems likewise vary from single easily understood measures, such as levels of education and average income, to more complex aspects such as trust and leadership.

Well-specified and adequately measured simple indicators are critical inputs to almost all forms of sustainability assessment, from key variables/parameters in simulation modelling through to the formal Principle-Criteria-Indicator (PCI) schemes. There is a vast literature, beyond the scope of this report, on indicators relevant to various disciplines, including the use of surrogates and proxies and their predictive capacity for the more difficult to measure parameters, including their spatio-temporal variation.

### 2.2.2 COMPOUND OR COMPLEX INDICATORS

There are now many sets of compound indicators (e.g. see those reviewed in O'Connell et al., 2013) developed by different groups for different purposes, and they are deployed in many formal schemes across different levels, sectors and accounting systems. There is a wealth of literature on the development and application of complex indicators, as well as on typologies or classification schemes for the arrays of indicators that now exist (e.g. as reviewed by Singh et al. 2009). There are, however, some serious limitations to the effectiveness of highly synthesized indicators for sustainability assessment and decision-making.

A common problem with the use of compound or complex indicators is that the underlying theory, structure and dynamics of the system, and therefore relevance of the indicators, are not understood by the users or explicitly described by those devising the indicator. There is a trend to develop and apply complex or compound indicators, which may summarize multiple complex processes in a simple single metric, or indeed attempt to provide 'measurement' of entities which do not physically exist as such; they are actually concepts (e.g. vulnerability, resilience). A detailed critique of the indicators of climate change vulnerability and adaptive capacity (Hinkel, 2011) provided a rigorous conceptual framework for vulnerability indicators, and then analysed both the scientific arguments for developing such indicators, as well as their purpose and application in vulnerability assessments. The following six purposes were identified:

1. identifying mitigation targets
2. identifying vulnerable entities
3. raising awareness
4. allocating adaptation funds
5. monitoring adaptation policy
6. conducting scientific research.

Hinkel concluded that vulnerability indicators are not an appropriate tool for five of the six purposes, and that they may only be appropriate to identify vulnerable people, regions or sectors at local scales when systems can be narrowly defined and deductive arguments are available for selecting indicators, and inductive arguments are available for aggregating. For all the other purposes, either vulnerability is not an adequate concept, or indicator-based approaches are not an appropriate method.

The logic, analysis and recommendations of Hinkel (2011) are sound, and applicable to the evaluation of any high-level compound indicators, including the review of indicators relevant to resilience, adaptation and transformation. Employing this rigour more widely in the development of compound indicators would very likely reduce the burgeoning number of indicators under development, reduce the confusion and increase the utility of the approach.

## 2.3 A brief review of the 'resilience indicator' literature

### 2.3.1 INDICATORS TO REFLECT THE DYNAMIC BEHAVIOUR OF SYSTEMS: THEORIES AND MEASUREMENTS

Indicators are used to track past changes, the present state, and as far as feasible to estimate the probability and magnitude of future changes in systems. They cannot do so unless their selection and application is based on a theory of the system that as far as possible represents actual system behaviour. Most indicators have until recently been based on the assumption that an economic or ecological system has a single stable configuration, or regime, to which it can be returned quickly by internal feedbacks or human interventions following a shock. The ‘invisible hand’ of markets and the ‘balance of nature’ are metaphors for such behaviours, and are applied in mainstream economics, much of ecology and in their influential offspring, environmental economics.

Ecologists working in climates that vary widely in time and space, or are strongly perturbed by other shocks, discarded the idea of systems with a single stable state. Resilience theory (outlined in the following Chapter 3), which underpins the indicators proposed in this report, is based on the recognition that ecosystems and social-ecological systems tend to have multiple stable configurations separated by threshold levels in controlling variables. If a threshold is crossed, the system can be irreversibly changed. This is explained more fully in Chapter 3. *Measures to manage and live within such systems accept their intrinsic uncertainty, inherent variability, and potential to transition to a different and often irreversible state*. They do not seek to stabilize a system that is intrinsically variable, because to do so may threaten the processes that support its recovery from shock.

The application of resilience theory to integrated social-ecological systems was driven by this realization, and indicators derived from it will differ from those originating in assumptions of a single stable regime characterized by predictable and reversible linear change.

### 2.3.2 EMERGING RESILIENCE INDICATORS AND THEIR UTILITY

There is an emerging literature focused on resilience indicators per se (see Appendix 4). We reviewed the literature and assessed whether the indicators and approaches therein met the purposes outlined in Section 1.2.

The literature is diverse and in places inconsistent. In the same way as for other indicators, e.g. biophysical or other social or economic indicators, many publications comprise long lists of indicators and their rationale, origins and definitions, methods for estimating them and sometimes an applied context for their use (e.g. Bennet et al., 2005; Cumming et al., 2005; Cork, 2011). The resilience indicators may be organized into a taxonomy, or hierarchy, (e.g. Cabell and Oelofse, 2012, Ifejika Speranza et al., 2014) or some other framework for application (e.g. Plummer and Armitage, 2007, Ostrom et al., 2007, Ostrom, 2009, Chapin et al., 2009, Walker and Salt, 2012, Walker et al., 2014, Limnios et al., 2014, Abel et al., in review).

The Resilience Alliance hosts an online database on Thresholds and Regime Shifts in Ecological and Social-Ecological systems (http://www.resalliance.org/index.php/thresholds_database) (Walker and Meyers, 2004) and an online Regime Shifts Database is an active initiative of the Stockholm Resilience Centre (http://www.regimeshifts.org/). While this is an extensive and growing resource, it is specific to particular studies and does not provide high-level or universally applicable indicators.

Compound indicators do exist for resilience – for example, the FAO has developed a resilience framework over some years, based on developing a Resilience Index for households. It is made up of six dimensions, four of them direct measures of income and food, services, assistance and assets, and two, more complex, estimates of adaptive capacity and stability. It has been incorporated into an econometric approach, the Resilience Index Measurement and Analysis (RIMA) model, which is used to compare household livelihood groups. It is a useful tool for the intended purposes but for the approach being developed in this report the single (household) scale is too limiting.

The *Toolkit for Indicators of Resilience in Socio-Ecological Production Landscapes and Seascapes* (UNU-IAS Bioversity International IGES and UNDP, 2014) presents a participatory ‘assessment workshop’ approach, involving discussion and scoring of 20 indicators designed to capture the communities’ perceptions of factors affecting the resilience of their landscapes and seascapes. The participation of local community and stakeholders allows them to evaluate current conditions and reach agreement on priority actions. This approach appears promising at local scales, but only partially meets the needs outlined in section 1.2.

Several common themes emerge from our review of the literature. All authors give strong reasons for not seeking to measure resilience with precise metrics, or attempting to prescribe universal indicators of resilience. Instead the consensus is that a more appropriate requirement is for ‘rules of thumb’ and ‘surrogates’ that have been derived from conceptualizing the system in ways that recognize complex system properties (e.g. nonlinearities, feedback loops, cross-scale interactions, self-organization). Furthermore, point measurements of system attributes are insufficient, and many recommended indicators are intended to be used to infer rates and relationships between variables.

Similarly, all authors warn that social aspects of social-ecological systems are most overlooked and are critical to the assessment and management of resilience in social-ecological systems. Ostrom’s SES framework (Ostrom et al. 2007 and Ostrom 2009) is the most thorough and comprehensive for highlighting the social and governance processes that need to be considered when building conceptual models.

A strong theme of 'learning' is apparent in both the recommended indicators themselves, and in the approach used to elicit appropriate resilience indicators. Not surprisingly, various notions of 'buffer capacity' formed another common attribute across these recommended approaches.

Finally, implicit in all these approaches is a conceptualization that is also central to the proposed Sustainable Development Goals: that of livelihoods nested within ecosystems.

We conclude from the review of published indicators that although there is a rich discourse on various indicators, proxies or surrogates useful in resilience assessment, there are no published indicators (or indicator sets), which will meet the defined purpose of this study. Many of them may be useful and necessary, but they are not sufficient. Many of the resilience indicators covered in the literature will be useful in supporting a resilience assessment; however no single indicator will provide any useful information about resilience, adaptation or transformation without further analysis.

## 2.4 The process of developing useful indicators, and criteria for their selection

Indicator sets are very often a product of a committee of experts, each member of which has their own favourite indicator. The apparent simplicity of specifying indicators often appears attractive and tractable to non-technical stakeholder or implementation groups tasked with their development. However, a lack of understanding of the critical characteristics of effective indicators frequently leads to some very ineffective indicators being developed (e.g. some of those for bioenergy sustainability, see Lewandowski and Faaij 2006). In order to 'keep the peace and equity' within committees, often a range of suggested indicators are included, even though the theories and systemic assumptions behind them are not clearly expressed, and may be incompatible. In many cases, these indicators are not used or useful for their intended purpose (and sometimes the purpose itself is not clearly specified) (Hinkel, 2011, Moldan et al., 2012). There is a tension between scientific accuracy, cost and effort and the need for practical and adoptable indicators that create a real incentive and empower the users. Developing and measuring indicators is not, therefore, as simple as many claim – and the process is ideally developed by experts in consultation with local stakeholders.

When development of indicators is intended to inform policy, it is important to evaluate and recognize the needs of the policy system, the key leverage and access points of information, and what types of indicators are appropriate for effective learning and utilization (de Sherbinin et al., 2012).

Although the approaches to monitoring desertification in the UNCCD (reviewed briefly in section 2.1.1) focus on desertification, their framing in terms of understanding trends, fast and slow variables and use in nested hierarchies with both bottom-up and top-down approaches, and an integrated assessment and modelling approach is consistent with resilience theory, adaptation/transformation approaches (see Chapters 2 and 3).

We conclude, however, from our review of published indicators (Section 3.3) that there is no existing adequate indicator or indicator set that can meet the needs outlined in Section 1.4. We propose, therefore, a different approach in Chapter 4, building on the substantial knowledge base that exists. We adopt the ethos of Hinkel (2011), and use the following criteria to guide the development of proposed indicators:

1. ensure that the intended purposes are clearly and explicitly stated, and check that the indicators are fit for these purposes

2. ensure that the indicators are consistent with the underlying theory and behaviour of the systems the indicators are intended to provide information about

3. check the feasibility of implementation, including data availability, replicability, potential for operator bias and level of skill required, among other factors.

We provide an evaluation of the efficacy of our approach and preliminary indicators in Chapter 6 of this report

# 3 An overview of resilience, adaptation, transformation theory and application

In this chapter, we present some of the basic concepts, theory and practice for resilience, adaptation and transformation. There is a wide and deep literature on the topic, comprising several discrete bodies of work, which we will present very rapidly, focusing mostly on those concepts that we draw upon in the framework proposed in Chapter 4.

We start with focusing on resilience which describes the state and characteristics of the system (section 3.1), then move to an overview of adaptation and transformation which describes transitions to changes in those systems (which may be intentional and desired, if they are moving towards broader sustainability goals) (sections 3.1.1 and 3.1.2). We then provide a very brief overview of pathways to achieve adaptations and transformations, intentional and desired, and avoiding those which are unintentional and/or not desired and sustainable (maladaptive) (section 3.2). We present an illustrative example for a grazed rangeland in section 3.3.

## 3.1 The basic concepts underpinning a resilience approach

Resilience is defined as 'the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks – to have the same identity' or in simpler terms 'the ability to cope with shocks and keep functioning in much the same kind of way' (Walker and Salt, 2012). It has four defining characteristics:

- the amount of change the system can undergo and still retain the same functions and structure – in other words, its ability to remain within the same stability domain, or 'regime'
- the degree to which the system is capable of self-organization
- the ability to build and increase the capacity for learning and adaptation
- the capacity to transform part or all of the system into a different kind of system when the existing one is in an irreversibly undesirable state.

There is a deep literature on resilience theory (itself evolving) and emerging experience with its application. In this chapter, we introduce basic concepts, and provide material sufficient to frame the development of resilience indicators (Chapter 3), and explain the approach to a Resilience, Adaptation and Transformation Assessment Framework presented in Chapter 4.

### 3.1.1 SPECIFIED RESILIENCE AND GENERAL RESILIENCE (ADAPTIVE CAPACITY)

There is a clear distinction between

- General Resilience: The capacity of the system to cope with all kinds of shocks and disturbances, and so be able to avoid crossing all thresholds, known or unknown, to an alternate regime or system. This is analogous to the term 'adaptive capacity' used in some literature.
- Specified Resilience: Resilience of a specified part of a system to identified disturbances – i.e. potential future occurrence is known or suspected, though its timing and magnitude may be a surprise.

Thresholds ('tipping points') mark the boundaries between one set of states the system can be in (called a system regime) and an alternate set. System dynamics and feedbacks can allow systems to self-organize to stay within a bounded space of states, and this space is referred to as a regime. When subject to shocks these dynamics and feedbacks can be altered such that the system reorganizes into a different regime. In any situation, it is important to clarify the focus of the assessment: the resilience 'of what' (the particular variable of concern that has a threshold) and 'to what' (the kind of shock or disturbance that can cause the threshold between the regimes to be crossed). Specified resilience refers to how much the system can change in a particular way before it crosses a threshold (such as the amount of grass cover on the soil, or the amount of phosphate in the water of a lake) into a different 'regime' of system states (substantially different vegetation cover, or from a clear to a turbid, eutrophic lake), or perhaps to a different system altogether (remembering that a different regime of a system is described by different levels of the same set of variables, while a transformed system is described by a different set of variables). Specified resilience can be assessed where there is a relatively small number of controlling variables that mark the boundaries between one regime and another.

To portray the concept of resilience, it is helpful to use the 'ball-in-a-basin' metaphor, where the state of the system is indicated by the position of the ball, and the basins represent alternate regimes the system can be seen in Figure 1. The size of basin indicates the overall resilience of the system regime, and the position of the ball in relation to the edge of the basin indicates its specified resilience – how close it is to a threshold.

The dimensions of the state space in which the basin lies (two dimensions in Figure 1) are determined by the number of critical state variables that characterize the system's 'identity'; they are the variables that are needed to represent the dynamics of the things that people value in the system (e.g. crop production, animal production, clean water, or a range of other ecosystem services which may be outside of the direct 'food production' land, but are critical to the maintenance of food production). For example, the identity of a livestock system may be determined by livestock stocking rates, type of vegetation cover and income to debt ratio for farmers. The identity of a rice agroecosystem may be determined by rice (yield, variety, agronomic practice), soil health, water for irrigation and availability of fossil fuels. The case studies in Chapter 5 deal with these two examples in more detail.

The position of the black ball indicates the state of the system at a point in time and the dotted lines indicate the threshold positions of the system's two alternate basins of attraction.

Some system attributes, like human health or social capital, build general resilience to a broad range of shocks. Therefore, a high level of a range of these attributes (inferring high general resilience) enables inferences about the capacity of a system to cope with all kinds of shocks and disturbance, and so be able to avoid crossing many thresholds, known or unknown, to alternate regimes. A common term in the literature on sustainability and resilience is 'adaptive capacity'. Many of the attributes of general resilience are the same as those that confer adaptive capacity on a system, and the two terms are not distinguished clearly in the literature. Here we take the view that general resilience is analogous to high adaptive capacity. General resilience is sometimes referred to as 'coping capacity' and in social-ecological systems, including agroecosystems, it is strongly determined by social attributes. A recent comparative assessment of five regional agroecosystems in Australia came up with 12 indicators of general resilience, including diversity, connectivity, reserves, social capital (e.g. governance, agency) and 'economic capacity' (Walker et al., 2014). The attributes of agroecosystems conferring ability to rehabilitate landscapes in sub-Saharan Africa are examples of general resilience (Blay et al., 2004), while our Thai lowland rice case study (Chapter 5) proposed 19 indicators of general resilience at focal and national scales, covering governance, knowledge and learning, monitoring and feedback, diversity and emergency reserves. Section 3.3 reviews other work on indicators of general resilience.

As we introduced in section 1.3, specified resilience is neither 'good' nor 'bad', it is a property of a system. It is the state of the system itself which is desired or

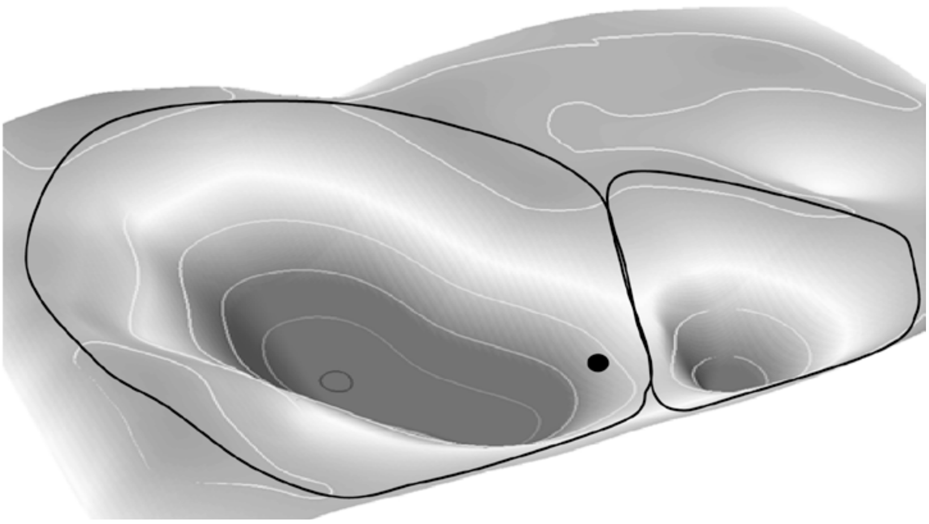


**Figure 1: A conceptual metaphor for resilience: the ball-in-a-basin diagram**

**The system can cross from one basin into another either by the state of the system changing (the ball moves) or by changes in the positions of the thresholds (Walker and Salt 2012).**

undesired (or is in a desired or undesired regime of states) – for example, we may perceive a system as desirable (e.g. a well-functioning productive landscape growing high yielding crops), and another as undesirable (a salinized degraded landscape unable to feed people).

In this sense, a system in an undesired state (e.g. highly salinized soils) can be very resilient – i.e. if it is far from the threshold that would allow it to change to a desired (e.g. fertile and productive) regime, it can be very difficult, if not impossible, to change. A high level of resilience of a system in an undesired state is sometimes referred to as 'resistant' (Folke et al., 2010).

This kind of situation with a high level of specified resilience is easy to understand; but when it comes to general resilience the literature is less clear. In the sense of coping capacity, a system in an undesired biophysical regime (e.g. a eutrophic lake) may still have high general resilience (for example, there may be capacity to change the land management system of the land surrounding the lake to prevent ongoing nutrient leakage, or high levels of investment to rehabilitate the lake) and therefore good prospects for crossing back into the desired biophysical regime. However, a high level of general resilience may also confer 'resistance', keeping a system in an undesired regime. For example, an important component of general resilience is leadership, and situations may arise where the leadership group is strong and, in its own interests, wishes the system to stay in a state which may be 'desired' by that small leadership group, but 'undesired' by others, i.e. not in accord with broader sustainability goals.

The time frame of such considerations is critical – over a long historical timespan (many hundreds of years), a high level of general resilience of the 'resistant' type may be assessed differently (in terms of persistence, consistency with broader societal goals, desirability of regime etc.) to how it is viewed within the time frame of a single generation, or the time frame of a policy mechanism, for example.

Resilience theory proposes that high general resilience confers upon a social-ecological system the capacity to remain in its current regime. If transformation would in the long term be moving the social-ecological system towards a high level 'desired' system (as defined by a social process to set such goals), high general resilience can in some cases serve to prevent it (e.g. worldwide dependence on fossil fuels has a high level of general resilience, and if societal goals shifted towards a future which reduced that dependence, the high level of general resilience of the energy system could inhibit transformation to alternatives). However, general resilience shares many of its component attributes with transformability, so high general resilience and high transformability (section 3.1.2) are not mutually exclusive. This is discussed further in the section 3.1.3.

### 3.1.2 TRANSFORMATION AND TRANSFORMABILITY

Transformation is defined in Table 1 as the process of changing from one type of system to another that has different controlling variables, outputs, structure, functions, and feedbacks ('identity'). Most transformations are the unintended consequence of shocks, exceeding critical levels in strong trends in key variables, or of lowered thresholds, and can occur at all scales, from the household, to region, to industry, to national. The aggregate consequence is systemic transformation, and the process is well documented. Intentional transformation on the other hand can be beneficial, and maintaining or increasing human well-being in a world already stressed by resource overuse will require transformation of many agroecosystems at some scale.

A degraded resource base commonly obliges people to seek external help such as famine relief, while those able to get work will migrate to towns or mines and secure alternative incomes that subsidize or in many cases exceed the value of agricultural production, as in some households in the Sahel case study. This is an example of an unintentional bottom-up transformation (next section) of an agroecosystem into an agro-urban or agro-mining-system. These systems are common in southern Africa (Maphosa, 2007) and elsewhere (Davis et al., 2010). In some cases local capacities can be deployed to rehabilitate the landscape – i.e. return it to the desirable regime. It was demonstrated in 14 cases from sub-Saharan Africa that this requires among other factors local empowerment, a favourable policy and political environment, clear resource use rights, equitable sharing of benefits and costs, participatory planning and implementation, use of local knowledge and capacity-building (Blay et al., 2004). This is an example of 'general resilience' being deployed to avoid an unwanted transformation.

When the current dynamics of a system indicate that shifting across a threshold into an undesired regime or transforming to a new and undesirable system is inevitable, or has already occurred and seems irreversible, one option is to promote intentional transformation of all or part of the system. The difficulty of doing this is indicated by the system's transformability – the capacity to transform. Intentional top-down transformation is well documented in the case of major infrastructure projects such as dams, where residents may be relocated with or without consultation or compensation. Some bottom-up transformations happen without deliberate widespread planning (for example massive changes in communication practices through the widespread adoption of mobile phones around the world). Deliberate bottom-up transformation is uncommon and not well understood, but research is beginning to identify potential indicators of transformability (Olsson et al., 2006, Kahan et al., 2011, Leach et al., 2010, Pelling, 2010, Wilson et al., 2013, O'Brien, 2012, Wise et al., 2014), including:

1. willingness to change values and seek agreement on the need for change among a sufficiently high proportion of influential individuals and groups. If specified resilience is high and the system perceived as satisfactory by its stakeholders, transformability will be low, growing if specified resilience declines
2. the feasibility and attractiveness of alternative resource uses
3. effective social networks open to change and linking across scales and stakeholder groups
4. distributed governance able to empower local scale groups to initiate and implement change
5. social processes for negotiating agreements over equitable distribution of the benefits and costs of change
6. potential for leaders at several levels of governance to promote radical change
7. processes that link new local, scientific and interdisciplinary knowledge and learning
8. opportunities for developing and resourcing unconventional ideas
9. capacity to change rules, especially those governing resource use, so as enable novel uses
10. capacity to divest from the status quo and invest in change.

### 3.1.3 RELATIONSHIPS BETWEEN GENERAL RESILIENCE, SPECIFIED RESILIENCE, AND TRANSFORMABILITY

The terms 'adaptive capacity 'and 'general resilience' are both used in the literature on resilience, often interchangeably. Adaptive capacity tends to emphasize social and economic attributes of the system, but these are also included in the wider consideration of general resilience. Though there may be a few instances where it is useful to differentiate between them, to avoid complicating this discussion it is assumed that the attributes that confer adaptive capacity are included in the set that confer general resilience.

There are overlaps and some differences between the attributes of general resilience (GR) and transformability (T) (Figure 2). Specified resilience attributes are of a different kind to those of general resilience or transformability. However, if a system is (or is made to become) resilient in a number of different, specified ways it will, *ipso facto*, possess many of the attributes that confer resilience, in general.

Though transformability is necessarily assessed at the scale at which management and policy are implemented (the 'focal scale'), it is strongly determined by cross-scale effects, and in most cases transformation will require investment and political commitment from higher scales. These connections also provide capacity to undertake the experiments and novel actions that need to be trialled at the finer scales (it is generally either too dangerous or impossible to attempt transformation at the whole focal scale at once).

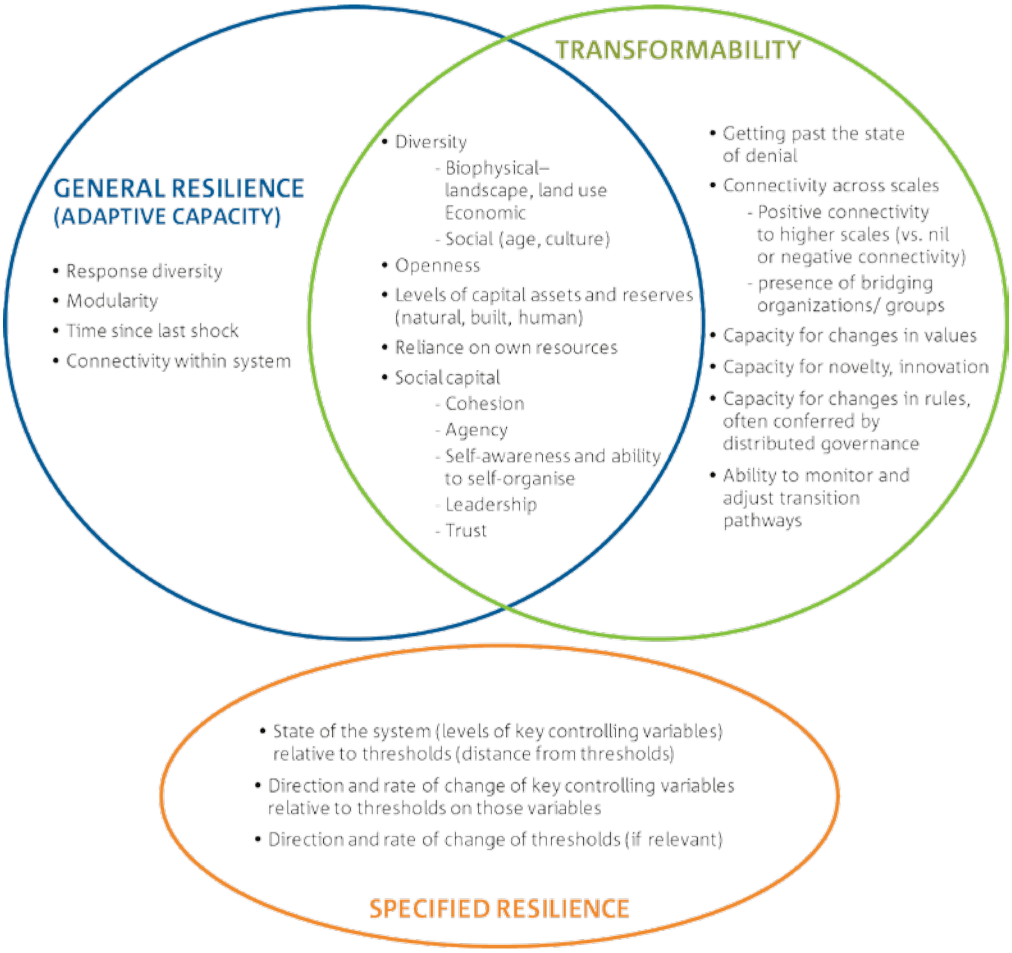



**Figure 2: Attributes which contribute to General Resilience (Adaptive Capacity), Transformability, and Specified Resilience**

**These attributes can be used to guide choice of relevant input indicators for the assessment process. Note that although no intersections with Specified Resilience attributes are shown, this is only because there are no intersections universal to all systems. In any one system there will of course be overlaps between SR, GR and T. For example, SR controlling variables can be levels of capital assets (e.g. human capital) which are also attributes of GR and T. There can be many SR assessments for a system (e.g. resilience of crop production to droughts, resilience of crop production to disease, resilience of household income to crop failure, resilience of transhumance practices to agricultural encroachments due to population increase, or resilience of water availability to climate change) and so SR assessments may range from low to high in the one system. More generally, one way to infer GR attributes is from meta-analysis of SR assessments.**

## 3.2 A brief introduction to adaptive management, adaptation and transformation pathways

There is a strong emerging literature and practice around how to make decisions about adaptation and transformation, particularly in response to climate change, and other drivers of global change. It is outside the scope of this report to review the literature in this area, but we provide a quick overview of some of the approaches, remembering that resilience describes the state and characteristics of a system, and adaptation and transformation describe transitions to system changes (which may be intentional or forced, and to more or less desirable systems or states). The pathways literature is about how to achieve these changes in an intentional way which is in accordance with sustainability goals.

Global change can have profound implications for how long-term effects of decisions to adapt transform need to be conceptualized. Risk assessment and cost-benefit analysis are used routinely by government, industry and other organizations to guide decision-making about future actions. These tools are applicable to situations where risk is simple, singular and well-characterized and where non-market values and broader societal issues do not necessarily need to be accounted for. However, these tools are not designed to aid decision-making in circumstances with rapidly-changing, multihazard, multi-stakeholder risk, such as those that characterize the complex and dynamic interactions of resilience, adaptation and transformation goals. Other approaches are needed, which we outline below.

### 3.2.1 ADAPTIVE MANAGEMENT

Adaptive management ('learning by doing', Walters and Holling, 1990), is based on the opportunity to learn from the outcome of an action (e.g. where the monitored outcome identifies a failure to meet a sustainability goal), and to use this to formulate an effective response or adaptation of that action. The use of adaptive management is well-recognized as a way of dealing with uncertainty (Kenward et al., 2011, McCook et al., 2010), and provides a clear and well-tested approach to progressively improving sustainability outcomes.

An organization is more likely to provide optimal responses to addressing issues within complex systems when higher forms of learning (often referred to as 'double-loop' or 'triple-loop' learning approaches), are used in this process. In its simplest form, adaptive management uses the 'single-loop' learning process to directly address only the changes necessary to meet the specified goal within the current context, assumption and rules of an organization. In many situations, this approach is sufficient, and will lead to appropriate adaptation and a satisfactory outcome. However, as discussed below, active adaptive management and adaptive governance embrace both double-loop learning (where the underlying assumptions and rules are also considered and may be changed), and triple-loop learning (which includes the consideration of a diversity of issues (context) using decentralized governance mechanisms), or a ground-up approach, for broader learning outcomes that can lead to transformative change (e.g. Chapin et al., 2009).

Adaptive management has been advocated for, and tested in, several domains of natural resource management including forestry (Raison et al., 2001), wildlife conservation (Nichols, 2006, Brainerd, 2007), and management of fisheries and marine parks (Grafton and Kompas, 2005, McCook et al., 2010). The recognition of adaptive management as a way of dealing with uncertainty in the management of a range of complex ecosystems has seen the inclusion of new terms such as 'active' and 'strategic' applied to modifications of the basic process:

- 'Active' adaptive management adds an active research component – the data derived from monitoring are used to build and calibrate response models to provide information on long-term responses to management practices (Walters and Holling, 1990). Wintle and Lindenmayer (2008) (in addressing wildlife conservation and sustainable forest management), have proposed the addition of risk analysis to this active adaptive process through the use of several competing models that reflect different hypotheses as to how forest systems will respond. The testing of the models and their associated management proposals through regular updating of data and the comparison of model predictions with outcomes, demonstrates which hypotheses/models are credible, allowing confidence in moving towards the implementation of improved forest management practices (Wintle, 2008).
- 'Strategic' adaptive management relies on a two-tiered approach with a subset of identified high-risk management issues subject to a more rigorous process such as a combination of those proposed by Walters and Holling (1990) and Wintle and Lindenmayer (2008). This strategic approach has been successfully implemented in South Africa (e.g. Kingsford et al., 2011).

A short review such as this cannot do justice to the wealth of literature on the topic, but we introduce it here to provide some support and background for the approach we propose in Chapter 4.

### 3.2.2 ADAPTATION PATHWAYS

Adaptation has been promoted in the past as consisting of a relatively simple set of decisions to be made by the end of a project or strategic planning activity. One set of challenges relates to sequencing sets of interrelated decisions, in order to maintain adaptation and transformation options for future decision makers (Haasnoot et al., 2013). Another set of challenges relates to dealing with the societal processes that play out over the long term such as cultural, institutional, political, technological and economic path dependencies (Wise et al., 2014).

Wise et al. (2014) proposed a broad conceptualization of the 'adaptation pathways perspective' that allows decision makers to explore the need for and the implications of societal transitions and transformation. This conceptualization emphasizes five critical dimensions to adaptation that are currently poorly integrated in research and practice:

1. the acknowledgement that adaptation is not separable from the cultural, political, economic, environmental and developmental contexts in which it occurs and is therefore only part of a range of societal responses to change

2. changes that cross spatial scales, sectors and jurisdictional boundaries, and that can lead to threshold effects, can be exacerbated if responses to changes are not coordinated

3. inter-temporal processes involving positive feedback loops and system inertia may be manifest as path-dependency (i.e. where future pathways are pre-determined by historical events) and 'lock-in' and are difficult to change

4. it is difficult to measure, monitor and understand what trajectory the social-ecological system is on because of the many emergent properties of complex adaptive systems as they respond to change

5. societal processes of change are enabled or constrained by prevailing rules, values and knowledge cultures and their interdependencies. Understanding how these interdependencies can be mobilized to enable adaptation is particularly important for disadvantaged and politically marginalized people whose vulnerability to global change may be perpetuated by existing power relations, norms and institutions.

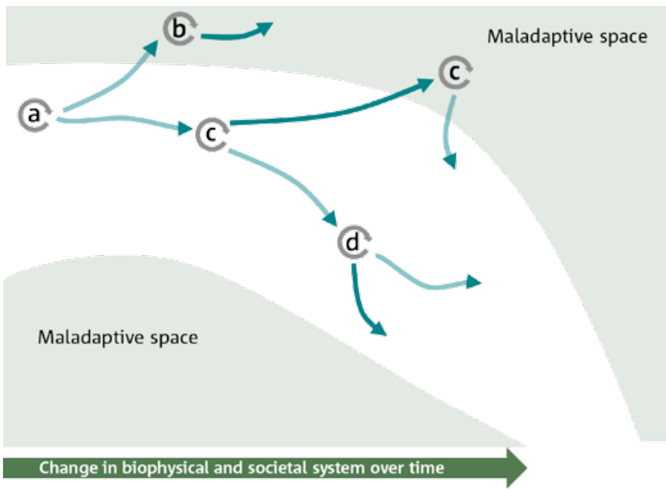



**Figure 3: A conceptualized set of adaptation pathways**

**The state of the biophysical system interacts with the state of the societal system to limit or enable options. The sequencing of decisions into the future can take the system into 'maladaptive' space where no future adaptive options exist (pathway b), or they can be returned from maladaptive to adpative space (pathway c) or they can remain in adaptive space (pathway d). (Modified after Wise et al., 2014).**

The adaptation pathways approach can help address the challenge of global change within a series of deliberative, adaptive decision-making processes. The adaptation pathway concept of Wise et al. (2014) focuses on the decision processes of the social-ecological system, including its social and biophysical dynamics. Changes in the biophysical system are caused by exogenous drivers but are also influenced by the decisions at focal scale. Boundaries between 'adaptive space' and 'maladaptive space' are determined by the social and biophysical state of the social-ecological system (Figure 3). Maladaptive space is where future decision makers have no options available to keep the system on an adaptive pathway.

Pathways can be thought of as means for the strategic analyses of how current decisions affect both the social and biophysical context of future decisions. Pathways can be thought of as means for the strategic analyses of how current decisions affect both the social and biophysical context of future decisions. For example pathway (b) represents a situation where adaptation decisions can be made in the present and the near future but because the societal system is not amenable to change, it will not be adaptive in the longer term. In contrast, pathway (d) moves the social system into a place where effective decisions can be made over a wider range of likely future conditions. Pathway (c) may avoid maladaptation in the short term but results in changes to the societal system that subsequently preclude adaptive decision-making leading to 'maladaptive space', that then requires a subsequent adaptive response in the future.

An adaptive pathway would, unlike these examples, retain the ability to adapt into the future, including the ability to prepare for and enact regime shifts or transformations when needed.

## 3.3 Application of resilience theory

There has been a wealth of scientific development applying resilience theory across a very broad range of linked social-ecological systems, including lakes (e.g. Carpenter and Cottingham, 1997); marine systems (e.g. Acheson et al., 1998); coral reef systems (e.g. Hughes et al., 2013); semi-arid rangelands used for livestock production; irrigated agricultural systems (e.g. Walker et al., 2009); forests (e.g. Bodin et al., 2006; floodplains and wetlands (e.g. Colloff and Baldwin, 2010) and urban systems. A selection of case studies appears, for example, in Walker et al. (2006), as well as on the Resilience Alliance website (http://www.resalliance.org).

### 3.3.1 AN EXAMPLE OF RESILIENCE ASSESSMENT

To illustrate our proposed approach to a resilience assessment and its indicators we introduce a simple example: a grazed rangeland controlled by a single agent. In Chapter 5, we present two more complex and realistic case studies to test the approach that we propose in Chapter 4.

This case study is presented in more detail in Walker and Salt (2012). This is a summary which is not intended to replace the deeper papers and discussion, but aims to present a simple example to describe the development and application of the Resilience, Adaptation and Transformation Assessment Framework, and Summary Action Indicators.

Rangeland agroecosystems include humans who graze animals for meat and fibre. They can exist as areas of grassy woodlands, or grasslands with shrubs, or grasslands. All rangelands are semi-arid, but they exist across a spectrum of rainfall. We use a rangeland system at the drier end of the spectrum as our example here.

In this rangeland example, infiltration of rainwater into soil is around 10 times higher under grass and litter, than into bare soil (Kelly and Walker, 1976). There is a critical amount of grass cover below which infiltration rate is insufficient to replenish soil moisture, so grass growth is reduced, cover declines and infiltration rate is reduced further. Decreased infiltration and ground cover combine to cause run-off to increase and erode the soil, reducing soil moisture storage capacity. At some point the grassland cannot restore itself, even if grazing and other pressures are removed. There are complex spatial dynamics relating to that landscape patterning of cover and infiltration; we acknowledge the complexity which is well described in the literature, but focus here on the simple aspects for the purpose of illustration, as depicted in Figure 4.

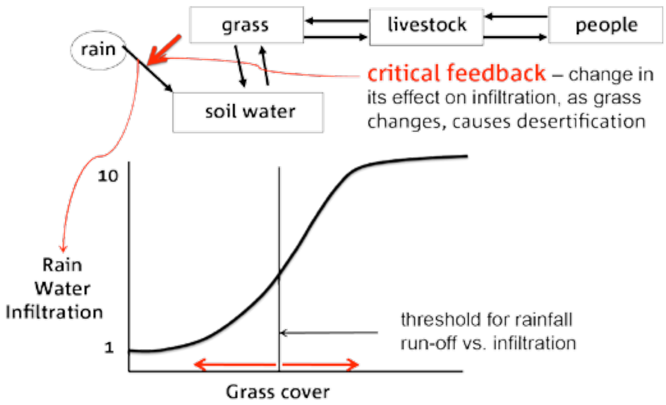



**Figure 4: Feedbacks and thresholds in desertification of arid rangelands (adapted from Fernandez et al., 2002).**

The biophysical controlling variables (grass cover, soil water infiltration) and their critical thresholds are well understood. The critical effect is the role of grass cover in influencing rainfall infiltration into the soil and hence soil water content, which influences grass growth and hence the amount of water taken out of the soil through evapotranspiration. The role of livestock (stocking density) is the key variable that determines what happens to the grass that is produced – whether grass cover is maintained or declines below the critical infiltration threshold. People decide how many livestock there are, though in many 'desertified' parts of the rangeland they have little choice.

The processes in Figure 4 can be depicted in a simple 'State-and-Transition' model (Westoby et al., 1989) of this rangeland system, shown in Figure 5.

There are three possible regimes this arid rangeland system[1] can be in (in the sense of the basins illustrated in Figure 1), and all states of the system within a regime are the same in terms of being: (i) productive, (ii) less productive with mainly annual grasses but still a viable

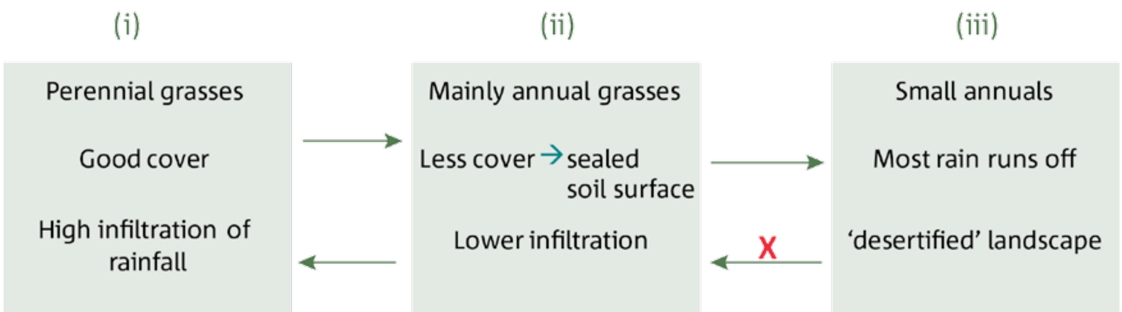



**Figure 5: State and transition model for arid rangelands (adapted from Westoby et al., 1989).**

1 The grassland described here is dominated by perennial species in the desired regime, unlike our Sahel case study where the desired regime is for climatic reasons dominated by annual grasses.

social-ecological system, and (iii) desertified. What are the possible transitions between these regimes, or archetypal system states? They are depicted by the arrows, and the 'X' on the arrow from regime (iii) to (ii) indicates that once in regime (iii) the system cannot return to regime (ii) on its own under normal conditions; it will require mechanical intervention or an exceptional run of above average rainfall for grass cover to get above the critical threshold, and so allow a transition back to regime (ii) and then regime (i).

The biophysical threshold is not the only important one that governs the system dynamics of the agroecosystem. Overgrazing leads to declining grass cover; and overgrazing is in turn governed by economic pressures on people, such as income: debt ratio. In northern Australia when equity ratios drop below about 80%[2], debts become extremely difficult to service and the grazing manager has no choice but to run as many cattle as possible to maximize short-term income to service the loan. The state of the rangeland can therefore be summarized by two variables representing the linked social-ecological system: grass cover, and some index of economic pressure, indicated here by income: debt ratio.

When the grass cover is high, and income: debt ratio is high, the system is in a desirable and resilient regime of high productivity states. As long as the enterprise doesn't cross the biophysical threshold, or the economic threshold, it can continue to operate safely (see Figure 6, where quadrant A envelops the 'safe operating zone'). If one of these thresholds is crossed, however, the system is then in an alternate stability regime and begins to move towards the stable state of that regime (the bottom of the basin, in Figure 1). The further it moves beyond the threshold, the harder it will be to return. The important point to note is that crossing one threshold strongly increases the chance that the other will also be crossed; i.e. *the controlling variables are linked*. If there are too many grazing animals and the grass cover threshold is crossed, declining productivity will cause enterprise losses and debt levels are likely to rise. On the other hand, if the economic threshold is crossed the grazier will be forced to run more grazing animals to try and service the debt, which makes it more likely that the grass threshold will be crossed.

This conceptual model makes it easy to envisage the safe operating space (Quadrant A in Figure 6). The system will vary within this space from year to year, and remain in a safe operating zone, and the particular state of the two controlling variables within this space will vary from year to year as climate and markets vary. This continues so long as the thresholds are not crossed. Just as Quadrant A may be thought of as a safe operating

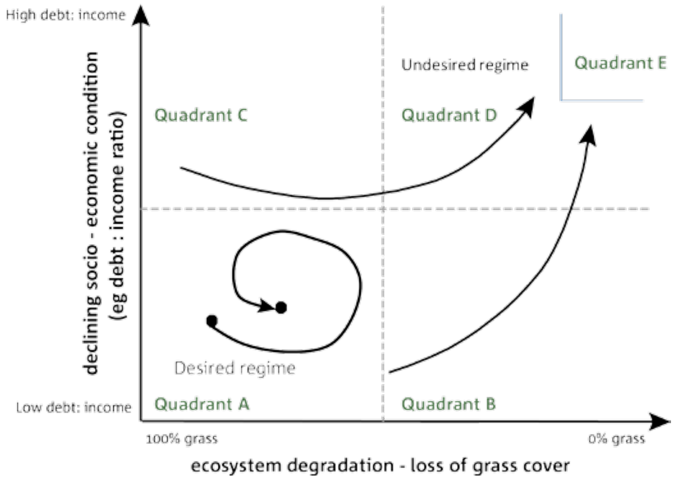



**Figure 6: Graphic showing two controlling variables in the rangeland system, each with a threshold between alternate regimes**

**The arrows depict trajectories through the overall state space of the system. (Adapted from Fernandez et al., 2002; and Walker and Salt, 2012.)**

space, Quadrant D (and eventually E) may be thought of as a doubly defined desertification trap, from which it may be difficult or impossible to escape. The only option in this situation may be transformation to a different sort of system (for example, mining or tourism).

Thresholds can be moved and/or managed. For example, one way of lowering the income: debt threshold is by having more off-farm income. The less the welfare of the household depends on income from a rangeland, the higher the debt level it can manage and still be able to recover. With respect to biophysical thresholds, one way of decreasing the threshold level of the grass cover that triggers desertification (e.g. instead of becoming desert below, say, 30% grass cover, it can drop to 20% grass cover before shifting regime) is to keep as much of the grass in the form of perennial grasses (as compared with annual species) as possible. Perennial grasses have much stronger root systems and promote higher infiltration than annual grasses for the same amount of cover, and the production of perennial grass varies much less from year to year in response to rainfall variation. Therefore the threshold is at a lower level of grass cover with perennial grasses, and less chance that the system will be pushed across the threshold in a low rainfall year. Different grazing management systems (largely to do with the relative periods of grazing and resting the rangeland) significantly influence the perennial: annual grass ratio.

2 This figure has more recently been estimated at 85% in Australia MCLEAN, I., HOLMES, P. & COUNSELL, D. 2014. The Northern beef report 2013, Meat and Livestock Australia, Sydney, NSW.

Just as it is possible to increase the safe operating space through various adaptations, it is equally possible for it to shrink. For example, if interest rates are raised suddenly, or if there is an invasive plant species. Either way if the system is operating close to thresholds, it may, without warning cross a critical threshold because of factors which were not anticipated.

If the system were to move into the Quadrant E, the SES may be supported for example by subsidies to the grazier to remain on the land, but this is not likely to be a long-term proposition in many parts of the world. Therefore over the longer term, there is a strong likelihood of an intentional or unintentional transformation taking place place, e.g. graziers turning off from income, or the system moving to an agro-mining or agro-tourism system, or abandonment of the grazing system.

## 3.4 Ten things to know about resilience, adaptation, transformation

This chapter has covered a great deal of conceptual territory very quickly, in order to set up theory which is drawn upon in the next chapter. Here we briefly summarize ten important things to know about resilience, adaptation and transformation:

1. Resilience is about complex, dynamic, linked social-ecological systems (SESs, of which agroecosystems are one example), not the separate dynamics of social, economic and environmental systems.

2. Resilience is about how linked SESs self-organize in response to shocks/disturbances – their resilience determines the limits to that capacity.

3. Resilience, adaptation and transformation are neutral system properties when used in a technical sense. They are neither 'good' nor 'bad'. It is the system, or the state of the system, or the broader sustainability goal which defines a 'desirable' or 'undesirable' system or goal. Some undesired system regimes, such as degraded land, can be very resilient (at least within the time frame of a person's lifetime, or within the context of decision and planning that frames the objectives of this report).

4. Making a system very resilient in one way can cause it to lose resilience in other ways or at other scales – there are trade-offs in applying resilience.

5. Understanding and managing resilience requires consideration of 'specified' and 'general' resilience, adaptation and transformation:

   – specified resilience describes the resilience of particular parts of a system to particular kinds of disturbance

   – general resilience is the capacity of a system to absorb disturbances of any kind, including novel and unforeseen ones; it is related to adaptive capacity (adaptability) – the capacity of the system to manage specified resilience; either stop it crossing a threshold, or engineer crossing back into a desired regime.

6. No system can be understood or managed at a single scale – all systems function at multiple (nested) scales, and interactions across scales affect resilience at any particular scale, and therefore the set of interacting scales.

7. Many losses in resilience are unintended consequences of narrowly focused optimization and 'efficiency' drives that remove currently 'unused' reserves and 'redundant' functional capacities (further discussed in section 3.3.1).

8. Resilience is **NOT** about reducing variability or not changing. Trying to prevent disturbance and keep a system constant reduces its resilience. Probing the boundaries of resilience is necessary for maintaining and building resilience, including the capacity for adaptation and transformation.

9. Adaptation and transformation are complementary processes – managers often need to transform a lower scale of system in order that a higher scale can remain resilient (e.g. portions of the catchment might change the enterprise in order that the broader catchment remains viable). When an undesirable regime shift has happened or is inevitable it calls for intentional transformational change. The capacity to achieve this is called transformability.

10. An adaptation pathways approach helps inform the sequencing of decisions within long decision time frames and incorporates flexibility to enable social learning, co-creation, experimentation and iteration, scenario planning and livelihood innovation. It provides an appropriate framework in situations where goals are ambiguous, decision-making is contested, social-ecological systems are complex and highly dynamic and trajectories are unpredictable.

# 4 The Resilience, Adaptation and Transformation Assessment Framework

## 4.1 Conceptual approach for current task

### 4.1.1 RATIONALE

We outlined a 'wish list' of potential purposes for an approach to 'resilience indicators' in Chapter 1. Over the course of this study, it became apparent that the set of resilience, adaptation and transformation concepts was important to provide a set of unifying concepts with utility across the three Rio Conventions and beyond.

We summarized some key points of theory and practice underpinning resilience (adaptation, transformation) in Chapter 2. The literature on these topics is large and evolving, and there are many different strands to reconcile. We provided a summarized set of concepts to support our proposed approach.

Resilience, and related concepts of adaptation (and adaptive capacity) and transformation (and transformability) are not easily quantifiable – in Chapter 2 we explained why the dynamic concepts upon which they are founded, are not congruent with simple 'metric' types of indicators in the same way as, for example, land cover or compound indicators like Gross Domestic Product. We briefly reviewed some of the relevant indicator sets (e.g. UNCCD, CBD, UNFCCC) as well as the literature on 'resilience' indicators. We concluded that there were no existing approaches which could easily meet the purposes defined in Chapter 1. We also wished to avoid adding to the burgeoning list of highly synthesized compound indicators to be reported by countries, many of which may have limited relevance for their particular system and which may be very difficult to interpret or use to support local or country decisions, and are usually impossible to justify rigorously (Hinkel, 2011). We hope we will demonstrate, however, that the relative levels of resilience and transformability, and changes in those levels, could be assessed with adequate confidence to justify recommendation of well – targeted management and policy responses.

The presentation of our approach through the Discussion Paper presented at the Sydney November 2014 workshop provided further guidance to us, building on the decisions made by the COP (ICCD/COP(11)/23/Add.1 UNCCD 2013b), as well as the ongoing discussions with the Project Steering Committee. The approach we present here is an assessment framework comprising several modules, rather than a resilience 'indicator' as first envisaged by the STAP when they initially conceived of this work.

In this chapter, we propose a 'Resilience, Adaptation and Transformation Assessment (RATA) Framework' to operationalize resilience, adaptation and transformation concepts.

In Chapter 5, we conduct a rapid desktop application of application of the Resilience, Adaptation and Transformation Assessment Framework in two contrasting agroecosystems as case studies. We partially test the utility of the approach with the Chapter 5 case studies, and further evaluate it according to a number of criteria in Chapter 6.

### 4.1.2 SCALES OF ASSESSMENT AND REPORTING

The resilience of a system at any scale depends strongly on the connections with the system at scales above and below (i.e. embedded scales). A focal scale for analysis must therefore be defined as part of the analytical process – an agroecosystem in a river basin, for example – as well as the critical scales above (a nation, say) and below (a farm, perhaps). The definition of the focal scale is contingent on the problem being addressed, and the reason for the assessment. This needs to be considered in an iterative way. For example, the scale of the regions defined for natural resource planning and management by Australian agencies proved too coarse for meaningful resilience assessments and most regions have focused on scales within catchments or within their regional boundaries; see for example http://www.wheatbeltnrm.org.au/nrmstrategy for Western Australia, and http://weconnect.gbcma.vic.gov.au/ for the Goulburn-Broken region in Victoria where after an initial attempt focusing on the whole region they evolved to using six sub-regions which were Social-Ecological Systems (SES) which shared similar social and landscape characteristics. In other agroecosystems, the analysis might be stratified by household type based on attributes such as livestock or land ownership, levels of off-farm income, soil type, gender of household head, or size of family. The Niger and Thailand case studies demonstrate the importance of understanding the heterogeneity within an agroecosystem, because levels of resilience and consequent intervention responses will differ between household categories.

We therefore propose the following:

- Focal scale: scale at which the analysis is conducted and indicators gathered, probably sub-national and potentially sub-agroecosystem scale
- Reporting scale: the results or outcomes of the resilience assessments will be reported at the focal scale (sub-national) as well as at the national scale.

### 4.1.3 WHO WOULD CONDUCT AND REPORT THE ASSESSMENT?

Discussion about the specific modes of implementation is beyond the scope of this report. However, we envisage that the Resilience, Adaptation and Transformation Assessment Framework can be used and reported by many different groups including:

- groups of stakeholders at focal scale, in order to develop meaningful and informed storylines for their planning processes; to filter and select the most relevant indicators in which to invest resources in monitoring and reporting; to derive local meaning and value from the indicators that they might be asked to measure and report to international bodies; to inform decisions intended to improve livelihoods, food security, management of their resources; and strengthen community development. Many of these uses align directly with the stated aims of the UNCCD M&E integrating framework (section 1.2, Appendix 6)

- individuals, or small groups of individuals e.g. researchers or consultants working independently on the basis of expert knowledge, published studies (as illustrated in the case studies conducted by the authors in Chapter 5 – system description and assessment) ; consultants /researchers based on literature with some engagement with stakeholders – eg through facilitating a workshop process; or empirically based transdisciplinary studies closely involving researchers and key stakeholders in a full multi-stakeholder engagement implementing the whole framework . If conducted by small groups of experts/researchers/consultants, however, the assessment should not go beyond the stage of System Description and Assessment of the System, because the findings are subject to the preconceptions, biases and knowledge limitations of those doing the work. It is clear that although a first rapid iteration of some elements of assessment is useful and possible in this mode of application, many elements of the assessment process (especially those related to adaptive governance and management, planning adaptation pathways) should be conducted with the involvement of stakeholders in a robust, transparent, salient and legitimate engagement process.

- national governments as is appropriate to the UNCCD and other international initiatives such as SDGs
- international conventions and donors to help guide support programmes, streamline collation and focus effort in reporting of indicators most relevant to any given system.

The assessment of resilience, adaptation and transformation can be done in a range of ways and the methods presented here are intended as guidance, rather than prescriptions. The assessment process can be conducted with varying degrees of scientific rigour, ranging from conceptual or mental models through to detailed quantitative analyses or analytical models to support the understanding of system processes, controlling variables, thresholds and feedbacks. Assessments should be conducted in an iterative manner with increasingly more detail and effort, as guided by an initial scoping level assessment. For example, rapid assessments could be conducted to trial the approach and provide an initial overview and summary about where further effort could be best invested for more detailed assessments (e.g. Chapter 5 case studies).

## 4.2 Overview of proposed Resilience, Adaptation and Transformation Assessment Framework

We propose a Resilience, Adaptation and Transformation Assessment Framework which comprises:

- At the core, the Resilience, Adaptation and Transformation Assessment Procedure (RATA Procedure) (light blue box), a step by step iterative method for assessment. It is conducted at the focal scale, ideally with multi-stakeholder engagement.

- The key attributes and controlling variables will be elicited by the iterative application of the RATA Procedure. The RATA Procedure will help the users understand which are the critical attributes and indicators for their system, so that effort and resources invested in measuring and reporting can be targeted at indicators of those key variables. There may be indicators for these attributes/controlling variables (yellow box) already reported in the UNCCD, CBD, UNFCCC or other databases, or in the literature, although some may need to be supplemented or modified. New indicators may need to be developed if they do not exist.

- Summary Action Indicators (magenta box) are outputs of the RATA Procedure, and provide broad guidance on the types of actions or interventions that may be appropriate in response to the results of the assessment.

- There are two types of indicators to report on the application of the RATA Procedure (green box): a simple Coverage of assessment to provide information on how widely the RATA Procedure has been applied; and Quality of assessment indicators to describe the robustness and replicability of the procedure.

An overview of the Resilience, Adaptation and Transformation Assessment Framework is shown in Figure 7. The indicator components with solid outlines are presented in Chapter 4. Those with dotted outlines are not dealt with in detail in this report because they emerged from the Sydney workshop, and further work is required to develop them.

At the focal scale of analysis (blue box): The core of the Resilience, Adaptation and Transformation Assessment Framework is the Resilience, Adaptation and Transformation Assessment Procedure (RATA Procedure), a step by step iterative method for assessment. It is conducted at focal scale, ideally with multi-stakeholder engagement.

The key attributes and controlling variables will be elicited by, and used by the iterative application of the RATA Procedure. There may be indicators for these attributes already reported in the UNCCD, CBD, UNFCCC or other databases, or in the literature, although some may need to be supplemented or modified (dotted yellow box). New indicators may need to be developed. In turn, the RATA Procedure will help the users understand which

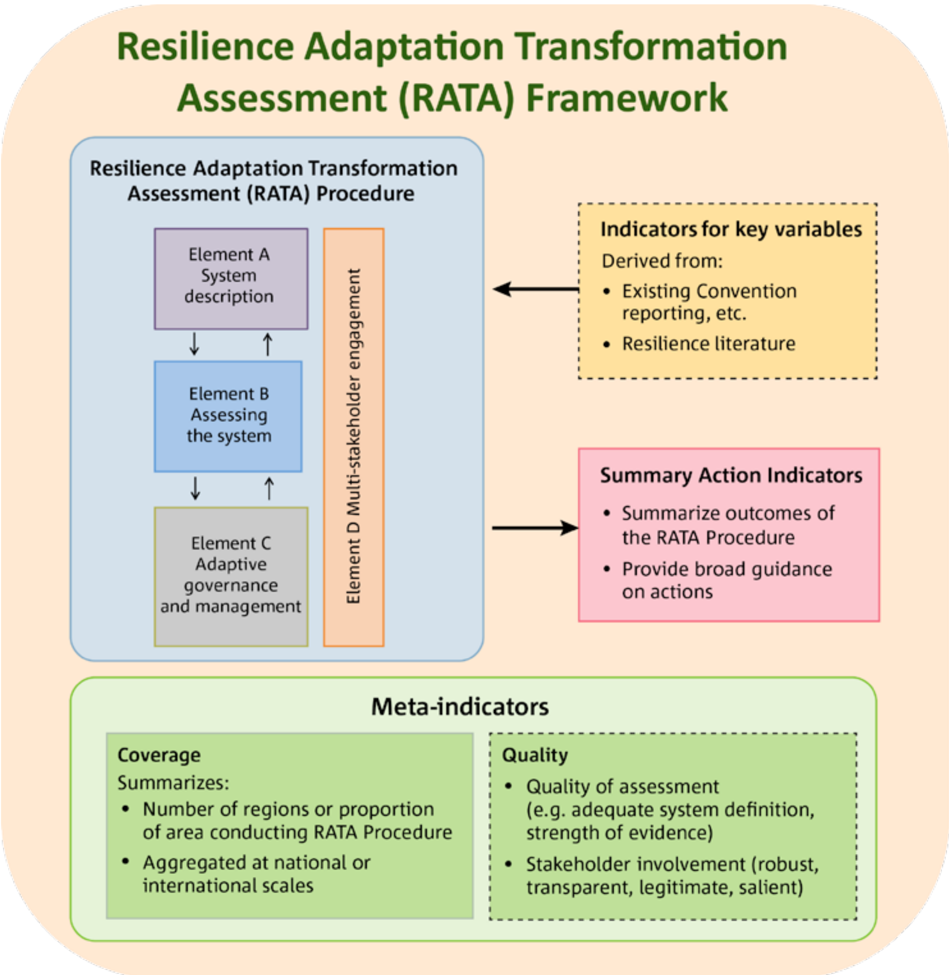



**Figure 7: Overview of proposed Resilience, Adaptation and Transformation Assessment Framework**

**Components with solid outlines are covered in Chapter 4. Those with dotted outlines are not covered in detail herein, as further work is required to develop them. At the focal scale of analysis (blue box): the Resilience, Adaptation and Transformation Assessment Procedure (cf. Figure 8 for details), is an iterative method for assessment, conducted ideally with multi-stakeholder engagement. Summary Action Indicators are outputs that provide broad guidance on the types of appropriate actions. The indicators for key variables or attributes in RATA Procedure (dotted yellow box) will be elicited via the iterative application of RATA Procedure. Some indicators already exist, others will need to be modified or newly developed. The RATA Procedure will help users reveal these critical attributes and indicators for their system, so that measuring and reporting efforts and resources can be refined and targeted. The meta-indicators to report on the RATA Procedure (green box) include a Coverage to provide information on how widely the RATA Procedure has been applied; and Quality indicators to describe the robustness, repeatability and other aspects of the multi-stakeholder engagement.**

are the critical attributes and indicators for their system, so that any effort and resources invested in measuring and reporting can be targeted more appropriately.

Summary Action Indicators (magenta box) are outputs of the RATA Procedure, and provide broad guidance on the types of actions that may be appropriate as a result of the assessment.

There are two types of indicators to report on the RATA Procedure (green box): a simple Coverage to provide information on how widely the RATA Procedure has been applied; and Quality indicators to describe the robustness and replicability of the procedure. The meta-indicators aggregate the results to higher scales in a nested hierarchy with levels of confidence that justify recommendations of well-targeted interventions.

The components with solid outlines are presented in Chapter 4. Those with dotted outlines are not dealt with in detail in this report because they emerged from the workshop, and further work is required to develop them.

## 4.3 Indicators for key attributes or variables

Early iterations of the RATA Procedure will help define which attributes are most relevant or useful for any system being assessed. Some of the attributes may be quite amenable to measurement or estimation as simple or compound indicators, and some of these may already be reported and readily available at country or finer scale. In Chapter 3, we provided a brief review of some of these indicator sets, with some further detail provided in Appendix 3.

Indicators for these key attributes may then be sourced from existing indicator reporting processes and databases (e.g. UNCCD, CBD, UNFCCC, OECD) (see for example section 2.1 and the references therein). Indicators on biophysical or economic attributes may be especially useful for Specified Resilience, especially if information about their trends and thresholds are available. Detailed discussions and reviews of many of the indicators which may have particular relevance, as well as suggested architectures for nested hierarchies across local – global scales, are covered by Reed et al., 2011, [Sommer here] Sommer et al., 2011, Verstraete et al., 2011. Some of the indicators in existing databases (e.g. Appendix 3) may need to be supplemented or modified to suit the needs of the assessment.

Indicators relevant to general resilience (adaptive capacity), and transformability may be guided by the resilience literature (sections 2.3 and 3.1.3, Appendix 4). Some of the individual attributes may be reported in existing databases available by country or globally, but this is less likely. In some cases, new indicators may be developed.

The RATA Procedure will help to elicit and define the indicators of critical importance for the assessment of the system; the corollary is that it will also clarify where the effort is best invested in obtaining improved information on attributes and indicators, especially for the large lists of voluntarily reported progress indicators. Implemented systems such as the Australian Collaborative Rangelands Information System (ACRIS) (e.g. Bastin et al., 2009) have already made substantial progress in systematically selecting (and providing guidance on) which indicators, at what scale, from which data source/providers support which kinds of decisions. They propose an information architecture for indicators which is potentially complementary to what may be useful for the RATA Framework proposed in this report.

The November 2014 workshop in Sydney recommended that further work on reviewing the GEF, UNCCD, and other existing reporting frameworks and databases be conducted, and more clarity be provided about the potential utility of these existing indicator sets. This will be undertaken as future work.

## 4.4 The Resilience, Adaptation and Transformation Assessment Procedure (RATA Procedure)

Resilience is a way of thinking about how complex adaptive systems change at multiple interacting scales. It can be applied in many different ways. Practical guidelines and methods focusing on resilience, with less focus on adaptive pathways planning, have been provided by:

- Walker and Salt (2012), which takes useful steps in linking theory to practice
- the Resilience Alliance Workbook Version 2 (http://www.resalliance.org/workbook/) which outlines methods for assessment, with worked examples
- The Toolkit for the Indicators of Resilience in Socio-Ecological Production Landscapes and Seascapes (SEPLS) (UNU-IAS Bioversity International IGES and UNDP, 2014), which has a useful emphasis on indicators for landscape/seascape diversity and ecosystem protection, biodiversity, knowledge and innovation, governance and social equity, livelihoods and well-being. It also provides for preparation, running and follow-up of workshops.

The procedure presented here is intended to complement and expand the scope of these sources. We do not advocate a prescriptive 'recipe'. Instead, we summarize the main steps in a Resilience, Adaptation and Transformation Assessment Procedure:

- System Description (Element A)
- Assessing the System (Element B)
- Adaptive Governance and Management (Element C)
- Multi-stakeholder Engagement (Element D)

The implementation of the System Description (Element A) and Assessing the System (Element B) are demonstrated in this report (expanded further in Section 4.4.1 and 4.4.2). Outputs include a detailed description of the system, an assessment of its general and specified resilience, potential alternate regimes, thresholds, governance structures, adaptive capacity and transformability. We also propose that this is summarized as a set of Summary Action Indicators (Section 4.5).

The steps listed under Adaptive Governance and Management (Element C) are about the interventions that are informed by the assessment procedure. We cannot demonstrate this adaptive assessment in our examples – that is clearly not possible in this report – this is a collaborative, iterative process that cannot be demonstrated through a desktop exercise – but it is an important aspect of the assessment framework, enforcing the iterative process that the assessment demands.

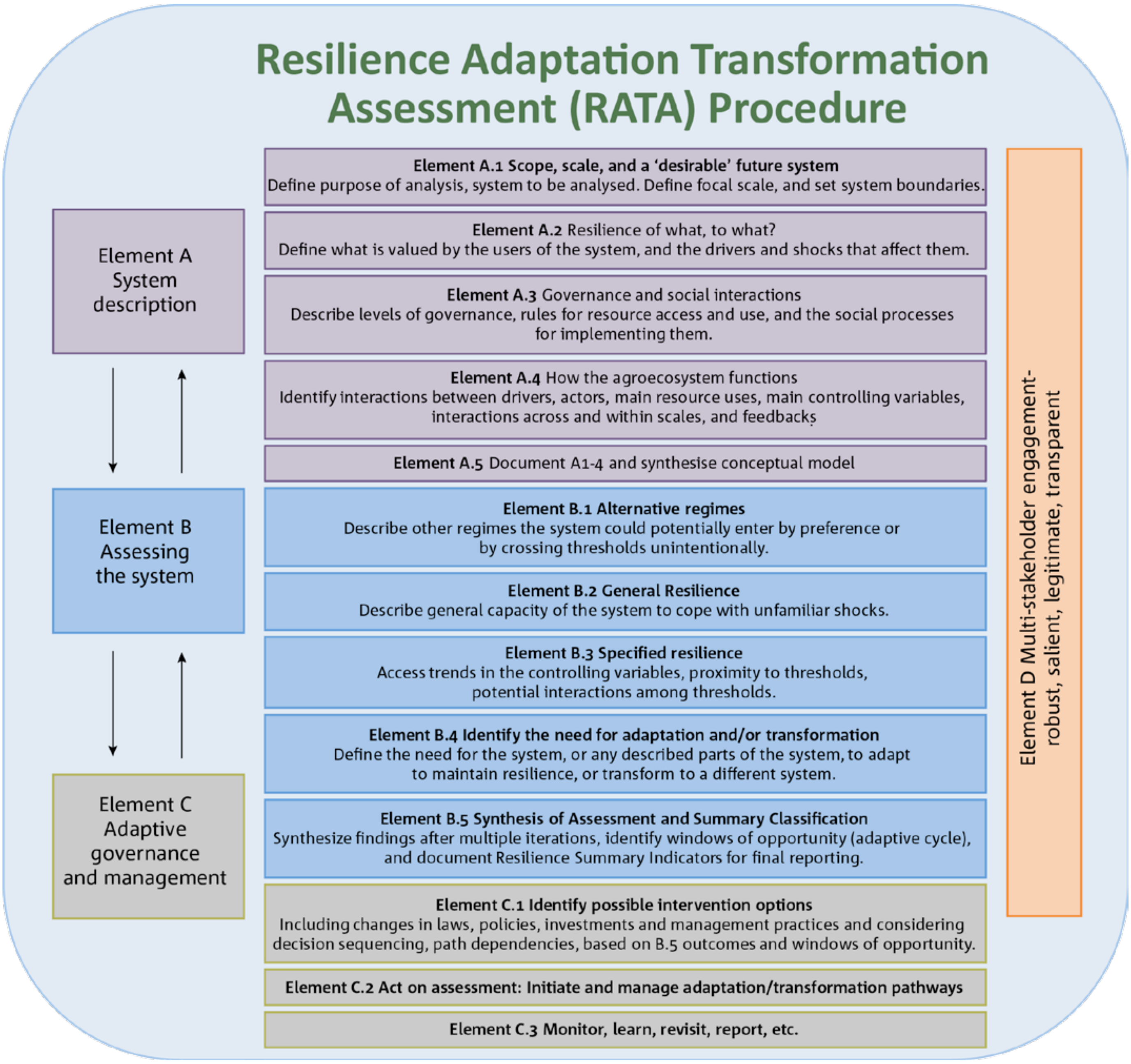



**Figure 8: Overview of the Resilience, Adaptation and Transformation Assessment Procedure (RATA Procedure)**

**Elements A (System Description) and B (Assessing the System) are applied in the case studies in Chapter 5, but it is not possible to illustrate C and D within the scope of this report.**

The entire approach would be most successfully conducted within a Multi-Stakeholder Engagement process (Element D), outside the scope of this report. However, it is possible to conduct system description and assessment (Elements A and B) without robust multi-stakeholder engagement i.e. by individuals as in our case studies or by expert groups (Rockstrom et al., 2009a, Rockstrom et al., 2009b); Adaptive Governance and Management (Element C) is, however, entirely reliant upon a robust multi-stakeholder engagement.

These steps need to be dealt with in an iterative way; each will inform the others.

This section provides details around the steps in Figure 8. However, as the process is iterative, it is not necessary that the steps are started and completed in the order shown in Figure 8.

### 4.4.1 SYSTEM DESCRIPTION (ELEMENT A)

Element A.1 Scope, scale, envisaging a 'desirable' future system and defining goals

- Define the purpose of the analysis, and the scale(s) at which the resilience assessment is to be used (e.g. local region, with summary indicators perhaps flowing into reporting to international or national programmes, policies or development projects).
- Determine the focal scale and boundaries of the agroecosystem, including the biophysical and social components (e.g. a catchment, a river basin, a wheat growing region, a mixed farming region, the sorts of households and businesses and livelihoods), as well as the significant, influential scales above and below.
- Envisage a future desirable system. Is the system currently in a 'desirable' state? Envisage what a future 'desirable' system (or regime) might be, and compare to the expected future system, based on understanding the current trajectory. By iterating through A1 – B5 and C1, check that the 'desirable' future system is itself, resilient and sustainable, and that the actions outlined are logically consistent with reaching that state.
- Define the goals of the assessment on the basis of the above (e.g. if the system is currently in a desirable state, 'maintain resilience of ecosystem services, especially food production and rural livelihoods' might be appropriate; whereas if it is in a currently undesirable state, 'transform to a system which has a different source of rural livelihoods' may be a more relevant goal) (see section 1.3 and 3.1.3).
- Outline the major issues affecting the system at the focal scale, for example declining water tables, deforestation, growing poverty, the positive or negative impacts of the system beyond the focal scale, and so on.

#### Element A.2 Resilience of what, to what? (see section 3.1.1)

- Identify the values that people expect to get from the system now and in the future (e.g. grain, milk or hides that are marketed or consumed, an unpolluted river and its fish, securely held land on which to raise children) and the drivers that affect or might affect these valued system properties or products. Common drivers are markets and technologies, national and international policies, and (latterly) climate change.
- Identify past or potential 'shocks' that might hit unexpectedly, such as a new crop disease, a sudden collapse in a market, a flood, a drought, a major policy change etc.

#### Element A.3 Governance and social interactions

- Describe the levels of governance, the extent of decentralization of power, formal and informal rules for resource access and use and the social processes for implementing them.
- Identify conflict resolution processes, and assess levels of public trust in the governance system, its openness to criticism, and the ability to change laws if circumstances require it.

#### Element A.4 How the agroecosystem functions

- Analyse the social structure of the system, and if necessary stratify into relatively homogeneous groups (e.g. farm household types). Describe their livelihood strategies, their interests and influence, as well as the variables that control the system outputs they value, such as the cover of grass or dry-season fodder trees, the depth of soil on arable land, or distance to permanent water, social cohesion (iterate with A.2, resilience 'of what' above). Some of the literature and indicators reviewed in Section 3.2 and 3.3 may be useful.
- Describe how these variables interact in producing valued outputs (i.e. the dynamics of the biophysical, social and ecological processes), and how these interactions are mediated by governance and management.
- Describe interactions within and across scales – e.g. between land-use and catchment hydrology; between the focal system and other agroecosystems (e.g. the

interaction of pastoralists with crop farmers), and the top-down/ bottom-up interactions of the focal system with systems at national and international scales.

### Element A.5 Synthesize conceptual models from Steps A.1 to A.4

- Effective resilience practice is about creating a process where the conceptual models of the system are used to foster shared understanding of the system among the key stakeholders rather than creating one 'right' system description. In order to be implemented effectively, conceptual models should be regularly updated and shared and be used to inform adaptive management and governance.
- Although there is no single right way to develop and document a conceptual model, it needs to contain core elements amenable to resilience assessment. These include:
  - drivers and shocks
  - actors
  - main resource uses
  - valued components and products of the system
  - controlling variables of these valued component and products
  - system dynamics (e.g. stabilizing and destabilizing feedback loops, non-linear interactions)
  - cross-scale interactions – connections and feedbacks between the focal scale and the scales above and within the focal scale.

## 4.4.2 ASSESSING THE SYSTEM (ELEMENT B)

### Element B.1 Alternate regimes

- Refer back to the desired future systems explored in Element A1. Describe known and possible alternative regimes the system can potentially be in, either by preference (through a planned transition), or by crossing thresholds unintentionally.
- Determine whether the system as a whole, or particular social groups within it, are in a desired or an undesired system or regime.

### Element B.2 General resilience

- Assess the probable effectiveness of the agroecosystem in adapting to expected and unexpected shocks. Dealing with probabilities and likelihoods could be done via a simple ranking method e.g. very effective, effective, somewhat effective, ineffective or very ineffective; or a detailed quantitative analysis, depending on the effort, resources and data with which the assessment is being conducted.

### Element B.3 Specified resilience

- Taking the level of general resilience into account, for each social group, or the agroecosystem as a whole if sufficiently uniform, assess trends in controlling variables, proximity to thresholds, and the likelihood of crossing them in the short, medium or longer term (see previous note re levels at which this could be conducted – simple ranking through to quantitative analysis).
- Considering interactions among controlling variables, their closeness to thresholds and the level of general resilience, assess how likely it is that transgressing one or more thresholds could cause the agroecosystem or a social group to undergo an unwanted regime shift or transformation in the near, medium or longer term (this can be done in a simple way with a ranking systems e.g. very likely, likely, possible, unlikely, very unlikely; through to using analytical models with quantified uncertainties).

### Element B.4 Identify the need for adaptation and/or transformation

- Analyse the need for the system as a whole, or of particular components (e.g. social groups) to adapt in order to remain within the existing regime, transition to a different (preferred) regime, or to transform to a different kind of system (see section 3.1.3).
- If the system or social group is in a desired regime, and:
  - the chance of an unwanted regime shift or transformation is judged to be sufficiently low for the chosen timespan and goals defined in Element A.1, then investing in the mix of specified and general resilience measures judged to maintain the regime is a prudent strategy; or
  - the chance of an unwanted transformation or regime shift within the chosen timespan is judged to be too high, then an additional option is to invest in intentional regime shift or transformation to a different, desirable more resilient system.
- If the system is locked into an unwanted regime by, for example, land degradation, over-population or land tenure rules, and is unable without external intervention to shift to a preferred regime, then options include seeking external investment in a shift to the desired agricultural regime, for example through land rehabilitation, land tenure

changes and the establishment of local industries, or investing in transformation to a new system.

- Describe the adaptive capacity, and the set of options for alternative regimes, and whether the transitions are likely given the trends in drivers and likely shocks identified, and thus whether the situation is resolvable through adaptation. This step may dovetail with other existing tools that may have been used in the past, for example social impact assessment.
- Where the situation is not resolvable, assess the transformability of the system (e.g. using attributes listed in section 3.1.3) and transformation options (section 3.2). Where, and at what scales, is transformation needed? What options exist? What is needed to build transformability? (see C3 below).

#### Element B.5 Synthesis of assessment B.1–4, and summary classification

- Develop a text summary of the resilience assessment including documenting the steps, and conclusions.
- Use the stages of the adaptive cycle to identify windows of opportunity for intervention.
- The outcome of the resilience assessment can be summarized, indicating the kinds of options to be pursued under various combinations of the regime the system is in and the levels of its general and specified resilience – the Summary Action Indicators – see Section 4.5.

### 4.4.3 ADAPTIVE GOVERNANCE AND MANAGEMENT (ELEMENT C)

The steps listed in Elements C and D could not be conducted in the case studies for this report, because they are inherently reliant upon multi-stakeholder engagement processes. Further development of these modules to provide more detail will need to be developed in future work, within an implemented context, with stakeholders. Brief summaries of relevant activities are provided here.

The assessment of the system in elements A and B provides a narrative about the need and potential for deliberate intervention in order to change system behaviour. This narrative provides the motivation, justification and focus for an adaptation initiative.

Any intervention also needs an underpinning theory of change describing how the adaptation initiative may help enable this change. This involves

- how the social system will adapt to external drivers of change in the absence of intervention and identification of desirable and undesirable system features
- articulation of how an alternative social system response may lead to different, preferable outcomes and how an adaptation initiative enables these
- analysis of feedback processes that maintain this system (e.g. power relationships that entrench some interests and exclude other issues and interests from existing social processes)
- if the societal dynamics preclude short-term controlled change, the narrative also needs to include how this adaptation initiative provides a strategic step towards the desired system (e.g. by establishing resourcing for ongoing adaptation efforts)
- analysis of the inherent limitations of an initiative to influence the societal system forms the basis of the development of a strategy ( e.g. limited duration of funding, limited local legitimacy and systems understanding, limited ability to influence the social system at different scales).

The motivating narrative and theory of change needs to be open to critical revision. This is challenging, given their role in motivating and coordinating activities and in structuring in the face of accountability and project reporting requirements.

#### Element C.1 Identify potential intervention options and their utility in achieving desired futures and articulated goals

- The science and logistics of sequencing possible decision pathways to future desirable states is complex, and evolving. There is no one correct way to do this, but section 3.2 and the references therein provide some examples.
- Include changes in laws, policies, investments and management practices and taking into account path dependencies and the need for

decision sequencing, according to the resilience assessment and windows of opportunity.

- Use complementary processes for visioning alternative future scenarios, and back-casting through the potential intervention options to test whether the desired futures and articulated goals will have been achieved by taking such actions, or whether taking such actions may reduce the options for adaptive responses in the future, thus taking the system into maladaptive space

#### Element C.2 Act on assessment: Initiate and manage adaptive or transformation pathways (refer section 3.2.2).

- There is no one correct way to do this, but section 3.2 and the references therein provide some examples.

#### Element C.3 Monitor, learn, revisit, report, etc. (refer section 3.2.1)

- set up a process for RATA to be embedded in an adaptive management cycle, in which outcomes of interventions are posed as hypotheses to be tested, so that as the outcomes unfold this ensures a learning process of how the agroecosystem functions.

### 4.4.4 MULTI-STAKEHOLDER ENGAGEMENT

#### Element D Multi-stakeholder engagement

A complete RATA Procedure requires all four elements A, B, C, D to be implemented. Ideally all elements would be conducted within a multi-stakeholder context; however we understand that there are many situations where some parts of the analysis might be conducted by an individual, or a group of experts/scientists/consultants. Local multi-stakeholder engagement, however, is mandatory if Element C is to be implemented.

The November 2014 workshop in Sydney recommended that further work should be conducted into defining Element D, including:

- development of a methodological multi-stakeholder systems approach (with tools) that can then feed into evaluation tools and indicators (see section 4.6) , where best practice is gathered and then fed back for broader learning. The method needs to specifically cover issues; robust, transparent, legitimate and saliency for the application. Some example tools include: critical systems heuristics, systemic interventions.
- preparation of a 'Practitioner Guide to Multi-stakeholder Engagement for the RATA Framework'. This should be based on best practice in application as well as currently known processes for legitimate, transparent, robust and salient multi-stakeholder engagement. These should draw on existing literature and work, rather than re-invent the wheel.

## 4.5 Summary Action Indicators (Element B.5)

### 4.5.1 INTENTION OF THE SUMMARY ACTION INDICATORS

We describe Summary Action Indicators as an output of the RATA at the focal scale. They can be 'scaled up' to a national reporting process as proposed for the meta-indicators (Section 4.6).

We provided a draft version of this at the Sydney November 2014 workshop. The aim of these indicators was viewed by workshop participants as an important and useful way to report across regions in a way that allowed for flexibility of application of the approach at a focal scale, but could provide a more systematic or consistent overview of the state of agroecosystems at the level of the Rio Conventions. But the applicability in the case studies showed lower utility than hoped due to the uncertainties of a 'binary' style of classification used in the draft version presented to the workshop. In addition, feedback from participants about the draft scheme presented at the Sydney November 2014 workshop was that it was too complex, and difficult to understand and use. In the light of this feedback we have revised the approach and present it here. We advise caution as this revised approach is tentative, and has not yet been subject to the peer review process through workshopping and, unlike the RATA Procedure, has not been field-tested. For the Summary Action Indicators to be meaningful in different contexts, their derivation should itself be part of the multi-stakeholder engagement process.

For all these reasons, these proposed indicators are preliminary in nature, provided only to illustrate the concept. The summary action indicators therefore require further testing and development during an implementation phase with multi-stakeholder engagement, including participation of the GEF and other agencies interested in using the reported indicators, to ensure that it meets their needs.

### 4.5.2 LOGIC OF THE SUMMARY ACTION INDICATORS

Envisaging and describing future 'desirable' systems, and translating this into specific goals forms an early framing step of Element A1 of the RATA Procedure. Describing the current system function is conducted in Elements A2-A4, and assessing the properties of specified resilience, general resilience/adaptive capacity, and transformability of the current system is dealt with in Elements B1–B3. Assessing whether the current system needs to maintain its current identity, or transform to a different system (or regime of current system) in order to reach the future 'desirable' state, is conducted in Elements B4 and B5. Identifying intervention options if required, and planning and initiating adaptation/transformation pathways is dealt with in Element C.

In this section we develop Summary Action Indicators that synthesize what is considered necessary to reach the future 'desired' state of the agroecosystem (compared to the current state), by identifying policy or management responses for GR, SR and T. If this system is currently in a 'desired' state, and there is a low likelihood of an unintentional transformation, then options to manage resilience and adaptation to maintain the current system identity are indicated. If, however, the system is in a state which is 'undesired' (as discussed in Element A1), or on a trajectory towards an 'undesired' state, then clearly options around adaptation or transformation are indicated.

As the focal scale of the assessment increases, it will probably be increasingly heterogeneous, socio-economically and biophysically, leading to variation in resilience and transformability within the system, as in our Niger and Thailand case studies (Chapter 5). For the rest of this section we discuss illustrative agroecosystem cases assuming that their resilience and transformability is internally uniform, but if that does not hold the examples would apply to subsystems or categories, rather than an agroecosystem as a whole. We begin with systems that are currently in a desirable regime, then discuss options for systems that are already in an undesirable one.

### 4.5.3 SYSTEM CURRENTLY DESIRED, AND IN A DESIRED STATE OR REGIME

Figure 9 depicts the relationship between SR, GR and T in the case of an agroecosystem or parts of a system currently in a desired regime, and is to be referred to in conjunction with Table 2. It builds on the discussion in Section 3.1.3, along with the Venn diagram showing the overlap between attributes in SR, GR (adaptive capacity) and T. We emphasize that although the cube is represented with orthogonal axes, they are not truly orthogonal in reality. This is because many of the attributes of each of these are in common, and not independent (in a mathematical sense) because there is a correlation between variables. Furthermore, any of the points depicted will always have large uncertainties associated with them, and are best considered as uncertain distributions rather than discrete points. There is uncertainty around each controlling variable, uncertainty about the effects of interactions among them (e.g. the 'domino effect'), and further uncertainty about the potential effects of unexpected shocks and unidentified thresholds in other parts of the system. There are also large uncertainties in the estimation of general resilience and transformability. As explained previously, these are concepts that cannot be measured and so their characterization rests on appropriate heuristics and surrogates. With these caveats, the cube is a useful simple way to visualize the construction of the Summary Action Indicators.

System A has high SR and GR. Bearing in mind that an SR assessment estimates current resilience in terms of the likelihood of an unintended regime shift or transformation within some specified time frame. GR is an estimation of the effectiveness of the system in coping with expected, and unexpected, shocks (Sections 3.1.1 and 4.4.2); therefore, there is currently little need to transform. Although the system may have some or many of the attributes of T, we assume the likelihood of a transformation is low because communities and government will not perceive a need to transform – there will be no drive to shift values, no leadership promoting transformation, no incentive to change rules or disinvest from the current regime (Section 3.1.2).

System B has high SR to all assessed shocks, so by the same arguments there is no need to transform and the likelihood of it doing so is probably low, based on what is known about the system's resilience to identified disturbances. However, low GR leaves it exposed to unidentified shocks, and the priority is to invest in building GR to move it towards the location of system A.

The future of system C is precarious despite its high GR because it is likely to cross thresholds in the given time-horizon. The obvious option is to rebuild SR, for example through land rehabilitation supported by changes in resource use rules. If rebuilding SR is not feasible it may need to transform, which would need high investment in T from outside the focal scale of the system (e.g. government or external agencies) or reallocating resources within the system to build on GR. An example is coastal agroecosystems facing rising sea levels, which points to the third option – end efforts to maintain the regime and invest instead in alternative livelihoods for the population or other measures that support change.

D has such low SR and GR that it is likely to be either:

- in transition to an undesirable regime – for example an agroecosystem with very degraded land. Options for transforming are limited (for example there are biophysical constraints which limit other land-use or livelihood options)
- intentionally or unintentionally transforming to a new system – a widespread example of the latter is transformation to an agro-urban or agro-mining system in which some household members remit off-farm incomes which commonly exceed the contribution from agriculture. If external resources are being used to hasten the move towards D1 in a deliberate or planned way, then the transformation is intentional. Often, however, focal scale transformation is driven incrementally and unintentionally from household scale as people find livelihoods outside the system. At household scale, those with members able to earn off-farm incomes have high T. To put differently, where dynamics at the focal scale may once have been able to be characterised without reference to external sources of income, an increase in households exercising this option has effectively changed the system to one that requires new state variables (e.g. external remittance incomes) to characterise the dynamics. Unintentional focal scale transformation may be more costly (socio-economically and environmentally) than intentional transformation. For example, incremental urbanisation without intentional planning leads to more difficulties in providing public services such as reliable sewerage, electricity and water supply systems. Hence, building transformability (via higher-scale interventions) could be explored to see whether it is the better option.

### 4.5.4 SYSTEM CURRENTLY UNDESIRED, OR IN AN UNDESIRED STATE OR REGIME

Figure 9 addresses only cases where the current regime is deemed desirable. When the regime is undesirable (e.g. the land cannot maintain human well-being), or is on track to becoming undesirable, then adaptation or transformation options are more relevant than those used to maintain the current undesired system identity or regime.

With one exception policy responses to assessed levels of SR, GR and T would be similar to those for systems C, D or D.1 in Figure 9, the aim being to shift back to the desirable regime, or transform. However, if the agroecosystem is far from the thresholds that separate it from the desirable regime (as in quadrant E of the example given in Figure 6 in Section 3.3.1), its SR is rated as high (resilience being neither good nor bad). Unless a large investment is made in shifting the system back to a desirable state, then transformation, intended or otherwise, would be very likely to follow; and if it is unintended, investments in emergency measures may be needed.

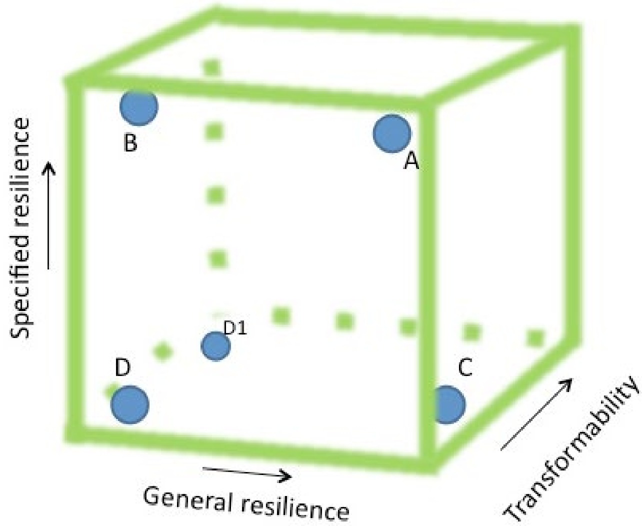



**Figure 9: Estimating the GR, SR and T for a system in a DESIRED regime. The Resilience Adaptation Transformation Assessment procedure is used to provide Summary Action Indicators**

**Although the cube is represented with orthogonal axes, they are mathematically not orthogonal (see Section 4.5.3). This remains, however, a useful simple way to visualize the construction of the Summary Action Indicators. Each blue ball represents a group of points.**

**TABLE 2 SUMMARY ACTION INDICATORS FOR DIFFERENT COMBINATIONS OF GENERAL RESILIENCE (GR), SPECIFIED RESILIENCE (SR) AND TRANSF ORMABILITY (T) REFLECTED IN THE POSITIONS A, B, C AND D IN FIGURE 9**

<table>
<tr><th></th><th>GR LOW</th><th>GR HIGH</th></tr>
<tr><td colspan="3">Desirable regime</td></tr>
<tr><td>SR high</td><td>B. High SR to shocks that have been assessed therefore little or no motivation to transform. But low GR leaves it exposed to shocks, especially unexpected ones. Likely that actions at higher scale are needed to boost GR to enable maintenance of high SR, and if feasible to boost T.<br><br>Interventions:<br>• Invest in general resilience. Higher scale actions may be necessary<br>• Urgency = medium<br>• Intervention priority = medium to high<br>• Scale of intervention = focal scale or above</td><td>A. The system is far from identified thresholds to undesirable regimes and the capacity of the people to manage the system is high, so currently no need to transform. Although the system may have many of the attributes of T, if communities and government do not perceive a need to transform they are unlikely to initiate it. If something such that they do wish to transform, whether or not they could so then depends on their transformability.<br><br>Interventions:<br>• Monitor and maintain SR and GR<br>• Urgency = low<br>• Intervention priority = low or zero<br>• Scale of intervention = N/A</td></tr>
<tr><td>SR low</td><td>D. System is close to thresholds and with low GR the likelihood of an undesired regime shift or transformation is high. It may be in transition (e.g. agroecosystem with increasing degradation of land) or transforming to a new system (e.g. agro-urban or mining) in which some households have off-farm incomes. Depending on the levels and options for T, external resources can be used for intentional transformation (move the system towards D1 by increasing the capacity to transform), or it may be driven incrementally and unintentionally from household scale as people find livelihoods outside the system.<br><br>Interventions:<br>• Build GR and SR; will likely need higher scale support<br>• If the ‘low/low’ combination makes a shift to ‘undesired’ inevitable, then build transformability; will need higher scale support<br>• Urgency = high<br>• Intervention priority = high if feasible<br>• Scale of intervention = focal scale, and scales above<br>• If above options not feasible, prepare for crises such as famine relief.</td><td>C. Future is precarious despite high GR because it is close to thresholds or approaching them fast. Need to use the high GR (adaptive capacity) to move the state further away from the threshold (increase SR). However, if the likelihood of being able to do this is low (strong drivers taking the system towards the threshold), then intentional regime shift or transformation may be necessary<br><br>Interventions:<br>• Use the high adaptive capacity (GR) to manage and build specified resilience<br>• If rebuilding SR not feasible, invest in transformability (note that G and T share many attributes) or intentional regime shift<br>• If above options fail, prepare for crises such as famine relief<br>• Urgency = depends on trend and closeness to thresholds<br>• Intervention priority depends on urgency<br>• Scale of intervention = mainly focal for building SR, but definitely cross-scale if regime shift or transformation sought</td></tr>
</table>

<table>
<tr><th></th><th>GR LOW</th><th>GR HIGH</th></tr>
<tr><td colspan="3">Undesirable regime</td></tr>
<tr><td>SR high</td><td colspan="2">SR high and system is far from the thresholds that separate it from the desirable regime (as in quadrant E of Figure 6)<br><br>• Investigate options and feasibility of shifting system back to a desirable regime<br>• If this is not possible, look at options for transformation to a different system<br>• If an intentional transformation is feasible and desirable, it may be easier if GR is also high<br>• If GR low, it will need higher scale support<br>• If it is not feasible, investments in emergency measures may be needed<br>• Urgency = depends on level of poverty etc.<br>• Intervention priority = high if feasible<br>• Scale of intervention = focal scale, and scales above</td></tr>
<tr><td>SR low</td><td colspan="2">• If the system is close to thresholds that could take it back into a desired regime...then same as D / D1 above<br>• If the system is moving away from these thresholds quickly, with little chance of reversal to a desired regime and a low T (i.e. into a state of high SR ‘lock-in’ of undesirable state) then investments in emergency measures may be needed<br>• If system is close to/moving towards thresholds where T is high and options to transform to another desirable or at least useful system, explore/build adaptive pathways towards that option</td></tr>
</table>

### 4.5.5 DEALING WITH UNCERTAINTY AND AMBIGUITY IN THE SUMMARY ACTION INDICATORS

We have used examples from extremes of SR and GR in order to illustrate the implications of high-level resilience indicators. Many assessments in real cases will not be clear cut; a lot of systems will be placed part way along the axes, or have large irresolvable uncertainty ranges giving little indication of what interventions to recommend. In such cases investment in the type of resilience that is closest to triggering an undesirable regime shift is a pragmatic solution, bearing in mind that there is no such thing as a ‘unit of resilience’, and that SR and GR are not commensurable. But there will also in practice be ambiguity in the locations of the various agroecosystems in the SR-GR-T space. Sources of ambiguity include uncertainty in data and their interpretation, the subjectivity and variation in skill levels of assessors, and shifts in resilience as drivers and controlling variables change. There will be substantial variation both over time and among assessors in the estimation of transformability, because it is strongly dependent on psychological, political and economic opportunities that arise rapidly and disappear just as fast, so the transformation pathway is likely to be marked by starts, stops and reversals as windows of opportunity open and close.

The RATA Procedure is to be conducted at focal scale, ideally in a multi-stakeholder engagement mode. We have aimed NOT to be overly prescriptive in this procedure, because:

- it should be sufficiently flexible to remain applicable in a range of situations (simple conceptual models as demonstrated in Chapter 5, through to highly quantitative analysis)
- the approach is preliminary and requires further testing and development in an implemented, multi-stakeholder environment.

There will therefore be a high level of heterogeneity in its application. In order to provide some high-level summary at higher scales (country level through to international convention level) about:

- a summary of the overall levels of GR, SR and T for any given system at the focal scale
- relevant actions – i.e. the types and scales of intervention options that may be applicable.

## 4.6 Meta-Indicators of coverage and quality of assessment

There are two types of indicators to report on the application of the RATA Procedure:

- a simple Coverage indicator to provide information on how widely the RATA Procedure has been applied. The outcome of the focal scale assessments, the Summary Action Indicators, could be aggregated to report on the proportion of area that, for example, is classed as 'High General Resilience, High Specified Resilience, High transformability' , etc., or change in proportion of area in each category. This additional Coverage indicator has not yet been developed, and is best done so in an applied environment.
- Quality indicators to describe the scientific robustness and replicability of the procedure.

### 4.6.1 COVERAGE OF ASSESSMENT

This indicator could be applied in a very simple way – for example the area, or proportions of regions within a country which have applied the RATA Framework. This was proposed to the Sydney November 2014 workshop, and well accepted.

However, there are many ways that the information obtained by application of the RATA Procedure and deriving the Summary Action Indicators proposed element B5 (section 4.5) could be 'scaled up' and/or summed to provide information. For example, focal scale assessments which show that the stakeholders view the system as being in a desired future system/state, and on a positive trend to achieving this (with or without interventions), can be summed or in some other manner scaled up to report at national scale. The ACRIS system architecture provides a clear demonstration of how this sort of information can be obtained from a range of appropriate measures at various scales, and aggregated to provide information on trends relevant to specific types of management decisions (e.g. Bastin et al., 2009). Although the ACRIS is not focused on resilience or adaptation/transformation assessment per se, many of its approaches to relevant to providing an improved specification of these meta-indicators. These include its approaches to multiscale data, synthesizing information across data types to integrate emergent higher order information relevant to decisions about future changes, and dealing with uncertainty and ambiguity.

Further work is required to specify these meta-indicators more clearly. This would ideally be conducted during an implementation phase, working with regional groups applying the RATA Procedure in a 'bottom-up' manner. It can also include those who manage reporting to UNCCD, CBD and UNFCCC to ensure consistency of the approach with reporting frameworks, and align decisions they require with information needs.

### 4.6.2 QUALITY OF ASSESSMENT

These meta-indicators provide a measure of the maturity and quality of any given application of the RATA Framework implementation, in terms of maturity and mode of application.

Valid applications of the RATA Procedure will be variable and flexible:

- At one end of the spectrum, as demonstrated in Chapter 5 of this report, early-stage iteration of the RATA Procedure may be conducted by scientists/experts/consultants applying only Elements and B, based on published information and conceptual models only, to scope the sorts of issues and roughly gauge SR, GR or T.
- At the other end of the spectrum, the RATA Procedure may be delivered through a sound multi-stakeholder engagement processes, draw heavily on a range of data and reliable quantitative modelling approaches, and take a robust approach to Element C in exploring adaptive pathways, and dealing with adaptive governance and management.

Meta-indicators can be developed to report on the strength and maturity of the application of the RATA Procedure (e.g. adequate system definition, strength and reliability of evidence), as well as the multi-stakeholder engagement (tracking whether it was legitimate, salient, transparent, robust).

This category of meta-indicators emerged from the Sydney November 2014 workshop. More work is required, at least some of which can be conducted as a desktop study prior to implementation, by drawing on the literature and applications which already have some maturity in similar domains.

## 4.7 Summary

In summary, the architecture for a RATA Framework has been proposed, comprising a number of components. At the core is the RATA Procedure, which can be applied in an iterative manner at local scale, and provide Summary Action Indicators. The RATA Procedure will draw on existing indicator sets and the literature, though it may also require additional indicators to be developed. A small set of meta-indicators has been proposed, which can be aggregated and summed to provide country-level or international information about resilience, adaptation and transformation for agroecosystems.

In the next chapter, we apply part of the RATA Framework to two contrasting agroecosystems in Niger and Thailand.

The RATA Framework has been proposed using desktop studies, and requires further development and testing in a pilot phase, prior to or in the early stages of full scale implementation.

# 5 Case studies in two agroecosystems: irrigated rice in Thailand and mixed farming in Niger

## 5.1 Overview

Sections 5.2 and 5.3 summarize the two case studies we used to develop and test resilience indicators. The full studies are reported in Grigg et al. (2015). We used them to test and contribute to the development of resilience assessment methods and indicators by applying them to two contrasting agroecosystems. One is the intensive production of irrigated rice in tropical Thailand, the other an extensive semi-arid agropastoral system in Niger. We selected these contrasting systems so as to span a range across three critical biophysical dimensions of agroecosystems: soil moisture, which depends on rainfall; naturally occurring soil nutrients; and level of external fertilizer and agro to chemical inputs. These characteristics can be described for any agroecosystem. Interactions among these variables are relevant to the Rio Conventions on desertification and degradation, climatic change and biodiversity, and so hold the potential to inform indicators relevant to all three Rio Conventions. They have profound implications for biophysical resilience because they are related to key controlling variables as we describe next:

- plant growth in dryland agroecosystems is limited mainly by water availability (Maasai pastoral system), nutrient availability (Sahel agropastoral and shifting agricultural systems), or both (Kenya highland mixed farming system)
- farmers motivated by the need for food or cash reduce these constraints with fertilizers, irrigation, or both. This favours crops as well as weeds and pests, so industrial fertilizer, herbicide and pesticide dependence are all increased
- low input systems depend on ecosystem functions such as soil fauna that maintains soil moisture storage capacity and predators that control pests, but those functions are partly substituted by irrigation, fertilizers and agrochemicals in high input systems
- external inputs tend to degrade ecosystem functions and reduce resilience through, for example, their effects on soil fauna and soil acidity, predators of crop pests and crop pollinators; they also pollute aquatic systems and affect fisheries, humans and other species.

Without climatic change the needs for food and money drive increased dependence on external inputs, decline in free, self-organizing ecosystem services, and consequent loss of resilience. Climatic change, and global change more generally, is likely to destabilize agroecosystems in some regions and increase the risk of degradation by shifting the relative scarcities of soil water and soil nutrients, thus affecting plant production and cover. These changes would also shift relative levels of dependence on external inputs versus ecosystem services, with consequences for agrochemical pollution and biodiversity. These descriptions emphasize the biophysical characteristics of agroecosystems. We reiterate that an agroecosystem is a social-ecological system and our assessment of these case studies includes social characteristics.

Our Sahel and Thailand examples were rapid desktop studies by two researchers unfamiliar with these agroecosystems. As such the cases had insufficient rigour or depth of knowledge, and did not use the multi-stakeholder assessment methods we would advocate for

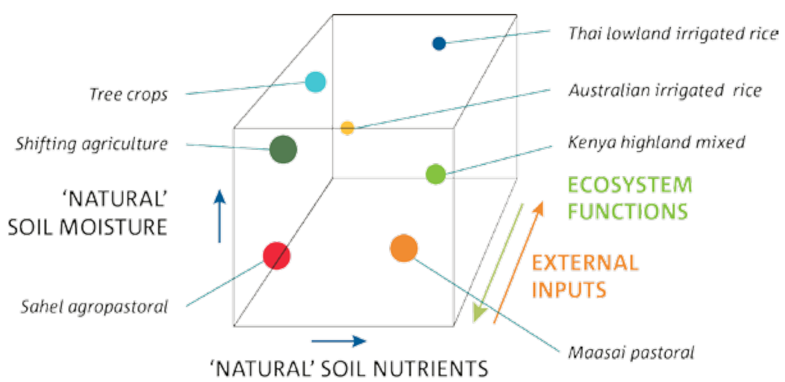



**Figure 10: Soil moisture, soil nutrients, external inputs and ecosystem functions**

**'Natural' soil nutrients refers to the nutrients available to plants in the absence of fertilizers or manure. 'Natural' soil moisture is the moisture available to plants without irrigation. External inputs are commercial fertilizers, herbicides, fungicides and pesticides. Ecosystem functions are processes such as predation on pests and maintenance of soil water infiltration rates that are performed by biota. They tend to decline with increasing external inputs because of toxins and other chemical changes.**

an assessment used to guide actual agroecosystem policy and management. The case studies were, however, useful tests of the methods and indicators we have proposed.

The case studies follow the assessment process described above, and the headings 'Element A1, A2' etc. are steps summarized in Figure 8.

## 5.2 Case study: the lowland irrigated rice agroecosystem on the Central Plain of Thailand – a summary

This case was informed from multiple sources. They are not cited in this summary, but are given in Grigg et al. (2015).

### 5.2.1 ELEMENT A. SYSTEM DESCRIPTION

#### Element A1. Scope of the resilience assessment

The irrigated lowland rice agroecosystem occupies around 35,000 km$^2$ on Thailand's Central Plain, which lies within the basin containing the Chao Praya River and its tributaries. The focal scale is the 158,000km$^2$ of the basin. Within it are upland catchments upon which irrigated lowland rice production depends. They contain dryland cropping and upland paddy rice agroecosystems. These are different categories of agroecosystem, so their resilience indicators would be estimated and reported separately. We analyse their interactions with the lowland rice agroecosystem on the Central Plain, and the consequences of this for its resilience.

Issues that have informed our resilience assessment include:

- climatic change, water becoming scarcer and competition for it increasing
- wet season flooding coupled with subsidence due to groundwater abstraction in Bangkok
- saltwater intrusion into the over-used aquifers under Bangkok
- navigability of rivers, a crucial part of the transport network, impeded alternatively by floods or by low water levels as water is abstracted for irrigation
- forest clearance for agriculture in the upper catchments affecting stream flow, water quality and dam capacity
- water pollution and greenhouse gas emissions from rice production.

These issues are discussed more in Element A2 (Resilience of what, to what?).

#### Element A2. Resilience of what to what?

**Resilience of what?**

We assess the capacity of the Central Plain to continue to contribute to future human well-being by providing food, water, income and quality of life needs despite economic and environmental shocks and trends. Philosophically it is human-centred – the consequences of rice production are judged only in terms of their direct or indirect impacts on human values. Indirect impacts result from loss of ecosystem functions, such as the unintended killing of pest predators by pesticides. The system produces both use and non-use values. Some use values such as marketed rice are monetary, others such as fish caught in paddies for direct household consumption are not. Non-use values include the intrinsic and existence values of cultural ecosystems and their biota, such as the rich birdlife, and the unquantifiable values of the options, such as uncommitted land or water resources, that the system retains for potential use if the regime shifts or the system is transformed.

**Resilience to what? Drivers and shocks**

Drivers of the irrigated rice agroecosystem are variables that cause the system to change but are unresponsive to feedback from the focal system. We identified the drivers and shocks summarized below.

*Climate change*

- Summer temperature will likely rise.
- Frequency of extreme heat events is projected to increase.
- The magnitude and frequency of extreme rainfall events will likely rise.
- Sea levels will continue to rise so that salt water will intrude further into coastal groundwater. The area of land permanently inundated will grow and the storm surge limit will continue to spread inland. The landward extent of storm surges is likely to be enhanced by increased intensity of tropical cyclones.

This is important because:

- temperature rise is expected to constrain rice production – dry season temperatures are already at the upper threshold of tolerance for current rice varieties
- potential impacts on rice production are flood damage to crops and infrastructure, and further yield reduction because drought is thought to enhance temperature sensitivity

- coastal agriculture will necessarily retreat from the sea, but the future of Bangkok itself, which has subsided because of groundwater extraction, will depend on the defensive and adaptation strategies chosen, and their effectiveness.

*Markets*

Important influences include:

- a shift of some land from irrigated rice production to the growing of vegetables, fruit and other commercial crops such as rubber
- commercialization of production, including the use of contract farming by 'outsiders' which is said to be weakening long-established collective water management institutions
- changes in input markets (especially fossil fuels and agrochemicals) could drive further changes in the agroecosystem (Element A4).

*Population change*

- The national rate of population growth was slowing in 2004, and the age structure shifting towards a higher proportion of economically active 15 to 65 year-olds.
- Despite this shift, the proportion of people working in agriculture continues to decline – and labour scarcity currently increases agricultural labour costs.
- Migration into the upper catchments by those seeking land drives deforestation that affects lowland irrigation (Element A4).

*Crop diseases and pests*

- Many are already established and are subject to feedbacks (Element A4), but new ones would shock the system.

## Element A3. Governance

The resilience of this agroecosystem can be enhanced or diminished by national laws, policies and investments, especially:

- policies aiming to reduce the use of scarce dry season water, manage pest risks, maintain soil quality and reduce rates of agrochemical use, and the inducements to comply with these including improved market access, and subsidies for high quality seeds, green manure use, and crop diversification
- national-scale governance which determines land tenure and water use rights, the construction and maintenance of public irrigation infrastructure, and levels of acceptability of water quality, national rice pricing, education and research policies, funding extension programmes for farmers, trade agreements that affect rice export levels, and internationally acceptable levels of greenhouse gas emissions
- international research organizations (e.g. International Rice Research Institute (IRRI)) which aim to influence the productivity of the lowland rice system through their research on genetic improvement, land and water management and pest and disease control.

## Element A4. How the lowland rice agroecosystem functions

We first identified the main variables and how they interact dynamically under the influences of governance, drivers and shocks. With this tentative understanding we then identified focal scale controlling variables in preparation for the resilience assessment (Figure 11).

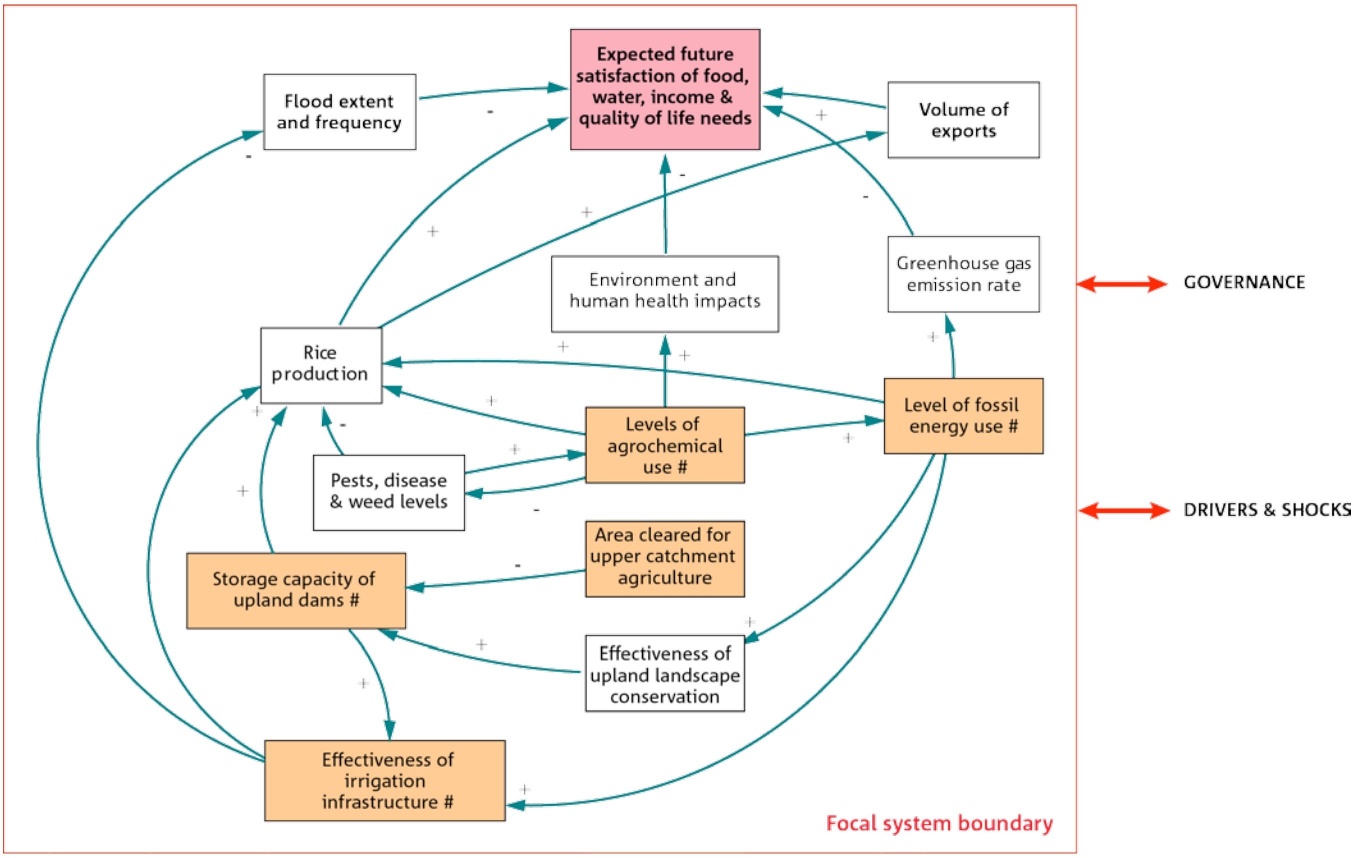



**Figure 11: Summary of the main interactions that generate well-being and affect resilience in the lowland rice agroecosystem. Postulated controlling variables are brown. Stabilizing feedbacks have a negative sign, and destabilizing ones are marked +**

## Stakeholders and roles

Stakeholders groups and their roles are:

- informal farmer groups, or formal cooperatives, or larger groupings; concerned with the dissemination of knowledge, better seeds and new technologies
- Thai Rice Farmers' Association; aims to influence government policies as well as providing market and production advice to farmers
- agricultural labourers; the opportunity of higher wages working in urban jobs makes them scarce and costly to rice farmers
- water users; form into groups to manage canals
- other actors such as rice traders, exporters and rice seed producers, machinery manufacturers, financial service providers, input suppliers; with various roles.

## Controlling variables

Table 3 lists the postulated controlling variables.

**TABLE 3 SUMMARY OF POSTULATED INDICATORS FOR SPECIFIED RESILIENCE OF IRRIGATED RICE**

| INDICATOR | RATIONALE & ASSUMPTIONS |
|---|---|
| Levels of fossil energy use and greenhouse gas emissions | • Trend in fossil energy use in the focal area<br>• Level of dependence on fossil energy<br>• Trend in national greenhouse gas emissions<br>• Proximity of national greenhouse gas emission rate to internationally negotiated target |
| Levels of agrochemical use | Fertilizers:<br>• Trends in use<br>• Threshold for tolerable water quality level. The impact reaches into the Gulf of Thailand where we assume it affects marine ecosystems<br>• Pesticide, herbicide, fungicides:<br>• Trends in use<br>• Threshold of tolerable pollution level |
| Effectiveness of irrigation infrastructure | • Modularity: shows the ability of the system as a whole to remain functional when parts of it are damaged. The many paddies, and the multiple lowland water storages are examples of modular subsystems, but the few large upland dams are much less modular, and the loss of one would have a severe impact.<br>• Redundancy: estimates the extent to which the functions of one damaged system component can be replaced by a different component. A hypothetical example is the effects of damage to flood control infrastructure around a city being mitigated by the use of irrigation infrastructure to divert floods.<br>• Reserves: measures the amount of spare capacity in a system under extreme conditions. Water resources are already at full capacity, and scarcity limits production during the dry season, with the potential for that scarcity to accumulate if a series of drought years alternates with lower wet season rainfall.<br>• The capacity of water management groups at different levels and locations in the system to coordinate their decisions.<br>• Existence of convincing and rehearsed emergency strategies |
| Area cleared for upper catchment agriculture | • Ten year trends in area cleared in catchments for all upland dams in the focal area. If trends are similar they can be aggregated, otherwise trends would need to be reported as separate classes.<br>• The area of annual crop above which run-off rate in extreme rainfall events is deemed unacceptable. Soil loss modelling would be needed. Again, if minimal cover thresholds vary significantly between catchments they would need to be reported separately<br>• Proximity to above area. |
| Storage capacity of upland dams | • Trend in storage capacity<br>• Acceptable threshold of storage capacity under modelled rainfall scenarios with longer droughts and more extreme events than are experienced under the current climate. We propose the use of rainfall scenarios rather than actual data because time would be needed to change storage capacity and to implement landscape conservation projects<br>• Proximity of storage capacity to above threshold. |

### 5.2.2 ELEMENT B. ASSESSING THE RESILIENCE OF THE AGROECOSYSTEM

#### Element B2. General resilience

Thus far we have identified the drivers we expect to impact the system and explored their potential effects, but if investment in building resilience is focused only on the expected impacts, the system may become more vulnerable to unexpected shocks. General resilience is the capacity of a system to persist through an unexpected shock or systemic change, such as the new diseases and social disruptions climatic change might bring. Our lack of knowledge prevents us assessing these attributes but we list some preliminary suggestions of indicators to illustrate the direction in which an assessment might proceed (Table 4 below).

**TABLE 4 POTENTIAL INDICATORS OF GENERAL RESILIENCE – CURRENT LEVELS AND TRENDS**

| INDICATOR | RATIONALE & ASSUMPTIONS | POTENTIAL SOURCES OF INFORMATION ON LEVELS AND TRENDS |
|---|---|---|
| Public trust in the integrity of governance | Intentional regime shifts and responses to crises will require sufficient levels of public trust in judicial, political and administrative processes | Existing social surveys; published international indices e.g. Transparency International |
| Ability to change laws when new circumstances require it | Significant adaptations and regime shifts would probably require changes in, for example resource access laws | Commissioned work to assess the flexibility of legislation |
| Openness to criticism and new ideas | When circumstances change and conventional solutions no longer work, leaders should accept criticism and be open to new ideas | Commissioned work to compare Thailand with other nations |
| De-centralization of power and the resources to govern | It is an assumption in resilience thinking that decentralized governance is more adaptable than a hierarchical system because monitoring, actions and resources are located close to the origin of problems | Commissioned work to assess the current governance structure |
| School educational levels | A sound education is assumed to make societies more adaptable | Published international indices, e.g. World Bank 2012 |
| Numbers of university graduates | As above | Published international indices |
| National research capability | Finding long-term solutions to declining resilience requires innovative thinking and the ability to generate useful information at the right scale for exploring and implementing options. | Commissioned work to assess capability |
| Integration of scientific and local knowledge | Local knowledge can be informative about local problems, while scientific knowledge is more widely applicable; integration can enhance both. | Commissioned work to assess the integration |

| INDICATOR | RATIONALE & ASSUMPTIONS | POTENTIAL SOURCES OF INFORMATION ON LEVELS AND TRENDS |
|---|---|---|
| Indicators well defined and linked to theory | This report makes the arguments in Sections 2–4. | Quick desk study |
| Indicators at time and spatial scales suited to system behaviour | As above | As above |
| Strong feedback to research, governance and management | Researchers, policymakers, resource users and managers need to learn about the system from the way it responds to drivers, shocks and previous interventions so that their activities are well focused. | Commissioned work to assess the effectiveness of linkages |
| Long-term funding for data collection and analysis | Effective monitoring requires long-term commitment of sufficient funds to realize and communicate the value in the data. | Size of budget relative to tasks, and duration of commitment |
| Land uses | A heterogeneous land-use pattern reduces the likelihood of a livestock or plant disease or pest spreading. | Develop an index of land-use diversity. Satellite imagery would produce data rapidly. |
| Input markets | Dependence on a few markets makes farmers vulnerable to risks outside their control | Data will probably be held by the Thai Government. |
| Output markets | As above | As above |
| Gender roles | A mix of genders makes for better quality decisions | Statistics probably available |
| Cultures | Cultural diversity is assumed to generate a similar diversity of ideas about the causes of problems and potential interventions | As above |
| Money | Savings at national or household levels can be used to recover from shocks or to enable transformation. National trust funds are best established soon because they are likely to be useful as climatic changes develop. | Statistics probably available |
| Energy | Reserves of fossil fuel would reduce the risks to imports from international crises. | As above |

### Element B3. Specified resilience

The current level of specified resilience depends on trends in levels of controlling variables, and proximity to thresholds (Table 3). In Table 5 we assess the likelihood of thresholds being transgressed within the next 25 years.

**TABLE 5 SUBJECTIVE ASSESSMENT OF LIKELIHOOD THAT A THRESHOLD ON A CONTROLLING VARIABLE WILL BE EXCEEDED IN THE NEXT 5, 10 OR 25 YEARS**

| SUBJECTIVE LIKELIHOOD | FOSSIL ENERGY USE LEVEL | AGROCHEMICAL USE LEVEL | INFRASTRUCTURE EFFECTIVENESS | UPLAND AREA CLEARED | DAM STORAGE CAPACITY |
|---|---|---|---|---|---|
| Very unlikely | | | | | 10 |
| Unlikely | 5 | 5 | 5 | 5 | |
| Possible | 10 | 10 | 10 | | 25 |
| Likely | | | | 10 | |
| Very likely | 25 | 25 | 25 | 25 | |

The level of fossil fuel dependence is high and growing. The most likely threshold that usage rates will meet is a greenhouse gas emissions cap, but threat of that may cause use to shift towards renewable sources proactively. Government may already be exploring an energy transition but we have not sought this information.

Levels of agrochemical use are also high and growing. Their water pollution impacts are acknowledged, but we have not detected any sense of crisis from our desks, nor do we have evidence of any intention to cap usage.

We speculate that intolerance of floods in general, and of Bangkok in particular because of extreme river flows interacting with a rising sea may reveal thresholds in the capacity of the infrastructure to store and divert water and manage flows. We do not speculate on when this might occur, but it is likely to reduce the effectiveness of transport networks as roads and bridges are cut.

The capacity of large dams in the uplands affects seasonal water availability for rice as well as unintentional flooding of rural and urban lands. Their capacity will matter more in future because both dry spells and flow volumes are projected to increase, but meanwhile sedimentation due to forest clearance for agriculture is reducing capacity even as the erosivity of rainfall is expected to increase sediment yields under climatic change.

We conclude from the information we have that this agroecosystem is becoming more vulnerable to economic and climatic shocks because it is trending towards potential thresholds on seven controlling variables. Meanwhile policy and research emphases are upon increased resource use efficiency rather than on building resilience for growing uncertainties. Our concern is that this agroecosystem may enter a time of unprecedented turbulence configured efficiently for circumstances that no longer exist.

### Elements B1 and B4. Assessing the need for and likelihood of regime shifts

This agroecosystem could conceivably be transformed unintentionally by major changes in the monsoon system, but the possibility of this climatic shift was not explored by the World Bank (2013), which was more concerned with the likelihood of greater extremes of dry and wet, and the inevitability of sea level rise. Depending on the magnitude and seasonality of dry and wet extremes, water scarcity and flooding – of Bangkok in particular – could drive a transition towards a technologically advanced regime using multiple sensors linked to computerized water storage and flow controls and much lower levels of water use. Water pricing could speed the process. Current concerns with pollution from agrochemicals may precede a comparable shift towards a farming system in which precise amounts of agrochemicals are placed robotically in the right place at the right time. This shift could be facilitated by the capping of greenhouse gas emissions which might drive irrigators away from paddy production with its high methane emissions, perhaps towards other crops. An emissions cap would also encourage a shift to renewable energy – solar, wind or biofuels. Demand for biofuels could see some land put to that use.

These changes could in theory see the integration of all these technologies into a new high technology agroecosystem. We speculate that it would be more efficient than the current human-controlled system, but also less resilient. However, from our desks we found it hard to envisage a uniform regime shift across the whole of this extensive and somewhat heterogeneous agroecosystem. Areas near busy roads and urban centres are already being transformed by the decisions of individual farmers to move out of communal paddy production by inundation and into individualistic cash crop production from their private wells, and this may be the beginning of a transition towards greater heterogeneity of land uses. Added to this, sea level rise and saline intrusions of groundwater are likely to transform the agroecosystem near the coast where production is unlikely to continue, so our speculations about potential regime shifts needs to be tempered by the knowledge that Bangkok City depends for the management of floods and saltwater intrusion from the coast on water management within the agroecosystem. With sea level projected to rise more than 50 cm above current levels by 2060, and by over a metre by 2090, some rice production may be sacrificed for the well-being of Bangkok's residents – 6.6 million of them currently and the population still growing. But unintentional regime shifts could also occur. Sea level rise is expected to drive people off floodplains in the South and South-East Asian Regions (World Bank, 2013), and the arrival of climatic change refugees may trigger unintentional transformation of the agroecosystem in ways we do not presume to explore. Investing in general resilience should increase the capacity to adapt to such shocks.

#### 5.2.3 CONCLUSIONS FROM RAPID RESILIENCE ASSESSMENT OF LOWLAND IRRIGATED RICE

We were not able to assess the general resilience of the agroecosystem in the time and with the resources we had, but our assessment of specified resilience suggests that in anticipation of climatic change and its associated impacts, it may be worth exploring the outcomes of possible shifts of policy and investment emphases towards general resilience and away from the current focus on production and resource use efficiency gains. Given our limited knowledge of the system we did not presume to explore a planned regime shift or transformational change, but the analysis indicates that there is currently a window of opportunity for Thai people to be exploring possibilities, options and transitional pathways.

## 5.3 Agropastoral millet/sorghum agroecosystems in south-west Niger

This case was informed from several sources (Fernandez et al., 2002, Hiernaux and Turner, 2002, Hiernaux and Ayantunde, 2004, Saqalli, 2008, Saqalli et al., 2010a, Saqalli et al., 2010b, Saqalli et al., 2011, Djaby, 2010, Malik, 2014) and more specific details and references are provided in the Case Studies report.

#### 5.3.1 ELEMENT A. SYSTEM DESCRIPTION

A more full description is provided in Grigg et al. (2015) and here only dot points are listed within each RATA category.

### Element A1. Scope and overview

- Agropastoral millet/sorghum agroecosystems in Niger, an example of subsistence agropastoral farming systems in the Sahel facing land degradation and other risks.
- Finest scale considered is individuals in villages in the Fakara canton, which is part of the Kollo Department in the Tillaberi administrative region of Niger (Figure 12).
- Several conceptual models have been published and we draw on a subset only to illustrate application of the resilience assessment framework.

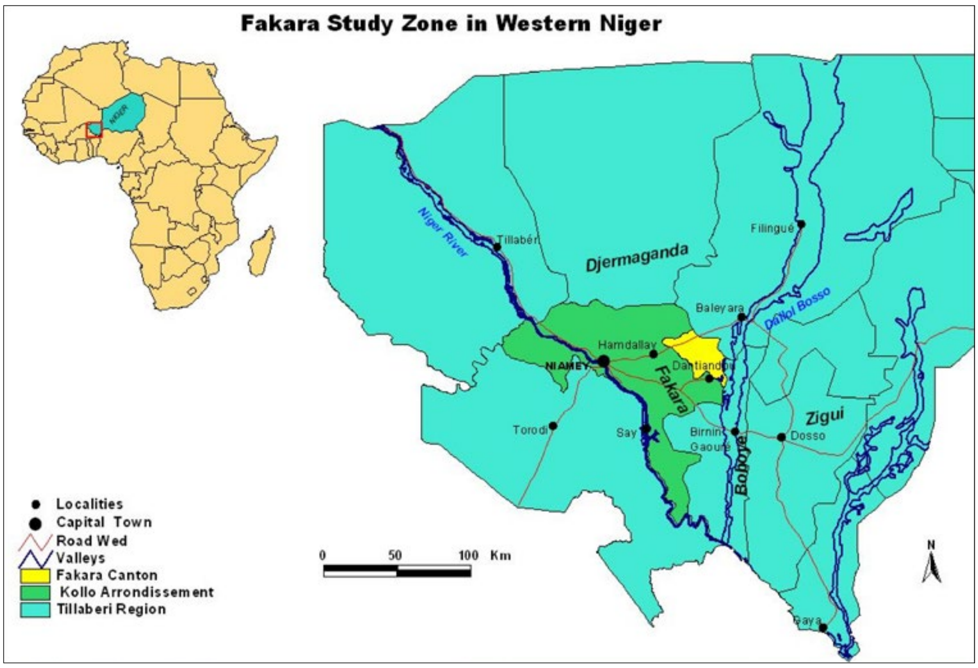



**Figure 12: The Fakara, Niger (figure reference Hiernaux and Ayantunde, 2004)**

**Climate, soils, hydrology and vegetation**

- Central Sahel bio-climatic zone, average annual rainfall is approximately 500mm on a steep North-South gradient, with rainfall reducing to the north.
- Semi-arid tropical climate, summer rainfall over a rainy season of 4 to 5 months (and shorter rain season to the North). Seasonal pattern of monsoonal rains is regular and predictable, but the actual spatial and temporal distribution is erratic and unpredictable from year to year.
- Soils: low fertility, weak structure, low organic matter content, low cation exchange capacity, acidic topsoils low in nitrogen and phosphorus.
- Soil nutrient deficiency is a limiting factor in determining rangeland and crop productivity.
- Vegetation: mostly annual grasses, scattered small trees and shrubs. The conditions select against perennial grasses, with annual grasses better adapted to severe, long dry seasons and poor fertility soils. Spatial and temporal heterogeneity in water and nutrient availability, fire and seasonal herbivory make for patchiness in the vegetation, as do the land use practices (grazing pressure, clearing, cropping, fallowing, manuring). The vegetation dynamics are highly adapted to droughts.

**Agriculture**

- Predominantly two agrarian cultures (with both cultures coevolving towards sedentary crop-livestock systems and exclusively pastoral households no longer exist):
  - village household (mostly Jerma people) crop farmers
  - camp household (mostly Fulani people) pastoralists.
- Crops and categories are:
  - staples (millet and sorghum)
  - secondary legume crops (cowpea, bambara nut, ground nut)
  - cash crops (sesame, sorrel).
- Mostly no-till practices, limited labour availability at times, and low-efficiency manual weeding contribute to limiting crop productivity.
- Traditional fallowing practices are changing from long (15 to 30 years) to short (3 years) or none at all if fertilizer inputs are being used.
- Livestock (cattle, sheep, goats) an important form of wealth. Livestock husbandry has a strong reliance on seasonal herd mobility, with herds moving north in the wet season. Reduction and fragmentation of grazing lands, with less access to communal resources such as water points and livestock tracks, and political unrest in the north, is resulting in the decrease of long-distance transhumances.
- Vegetable gardening is a dry season activity, requires access to groundwater, and is a mostly female activity.

**Population**

- Niger compared to other nations:
  - highest total fertility rate (approximately 7.6 infants per woman)
  - lowest Human Development Index value (HDI of 0.337)
  - one of the highest gender inequality index values
  - one of the lowest levels of income per capita (2011 ppp $873 per capita) of all nations
- Fakara canton:
  - population approximately 16,000
  - dramatic population growth since mid-1900s
  - population is far from stable and population demographics are a key driver of the evolution of agroecosystems.

### Element A.3 Governance and social interactions

- Inheritance hierarchies and conditions for accessing land, livestock and other wealth are evolving rapidly from a tradition of transferring property to eldest son to a local version of a Muslim inheritance systems (property transferred equally to heirs, but along gender-specific lines). Women typically do not own land.
- Village households have primary rights to cropping land, camp households need to enter into agreements (secondary usufruct rights) with village households to be able to use cropping land.
- Gender, social rank and season determine access to all social and economic activities.
- Men migrate to other countries looking for work in the dry season, depending on age and level of responsibility. This has implications for the definition of the spatial domain of the ecosystem given the reliance of many households on incomes from migration.
- Marriage and cultural traditions extremely important, and household expenditure on these (40%) is comparable to expenditure on food (48%) and exceeds investments into farm inputs (5%).

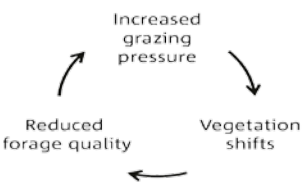
- Marital status determines social rank, and so access to other assets and activities.
- Limited institutions for stewardship of common, shared pastoral resources and unequal distribution of access to such resources.

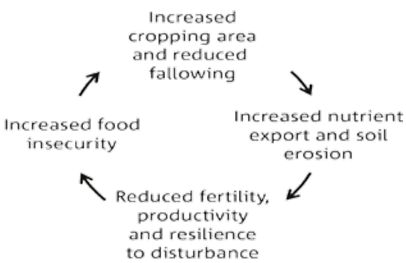
### Element A2. Resilience of what and to what

- Resilience of this agroecosystems' capacity to meet the health, well-being and livelihood needs of the populations dependent on them, now and into the future
- Resilience to internal and external stresses and shocks driven by several drivers and pressures contributing to both internal and external stresses and disturbances: population demographics, climate variability (which results in climate shocks), climate change (a trend in both average levels of rainfall and temperature and in the pattern of climate shocks), ecological constraints, health, governance (especially regarding access to resources) and social-economic conditions.
- Resilience to land degradation risks is of particular interest.

### Element A4. How the agroecosystem functions

- Abiotic conditions and increasing population and grazing pressures lead to a downward spiral of desertification.
- Positive (i.e. reinforcing) feedback loops identified include:




These positive feedback loops alone would lead to (a) ongoing agroecosystem shifts and (b) increased food insecurity due to lower crop and livestock productivity. These dynamics are strongest during the rainy season (high labour shortages, limited grazing resources, vegetation and soil at their most sensitive to pressures).

- Minimal household biophysical configuration for a neutral or positive nutrient balance, without which soil condition will degrade (e.g. proportion of land fallow and cropped, and number of livestock per capita). Livestock mobility and land tenure arrangements were identified as critical aspects that enable these minimal conditions.
- Three slow, controlling variables (two biophysical and one socioeconomic) and thresholds for these variables beyond which the system risks changing state are:
  - an index of sustainability with regard to soil fertility that is defined by fallowing practices
    - threshold: a household with no access to manure can maintain soil fertility only if it fallows at least 3/8 of the arable land it manages
  - an index of herbage intake
    - threshold: total herbage intake by resident livestock can be no more than 1/3 of the mass of palatable herbage at the end of the growing season
  - an index of economic sustainability
    - threshold: household needs exceed production.

The first and third indices are plotted in Figure 13. The lower-left quadrant of the diagram represents a sustainable regime where at least 3/8 of the land is fallowing and households produce enough to meet household needs. The diagram points to three groupings: (i) village farmers who are operating in an economically unsustainable way, (ii) village of mixed farmers and camp agropastoralists who are meeting both biophysical and economic sustainability criteria, and (iii) all farms within the village of Kodey which have unsustainable fertility practices. It indicates that livestock ownership enables economic sustainability, but increased livestock ownership also increases grazing pressure during the wet season, which risks taking farmers into the biophysically unsustainable bottom-right quadrant. The analysis highlights the heterogeneity in the system. Any attempt to place the agroecosystem as a whole into one of these quadrants would mask the variation across villages. Similarly, there is much variation between households and individuals within a village and between pastoralist and village communities. Such heterogeneity suggests caution is needed in presenting any aggregate summary of the system, and there is much to be learned from its diversity.

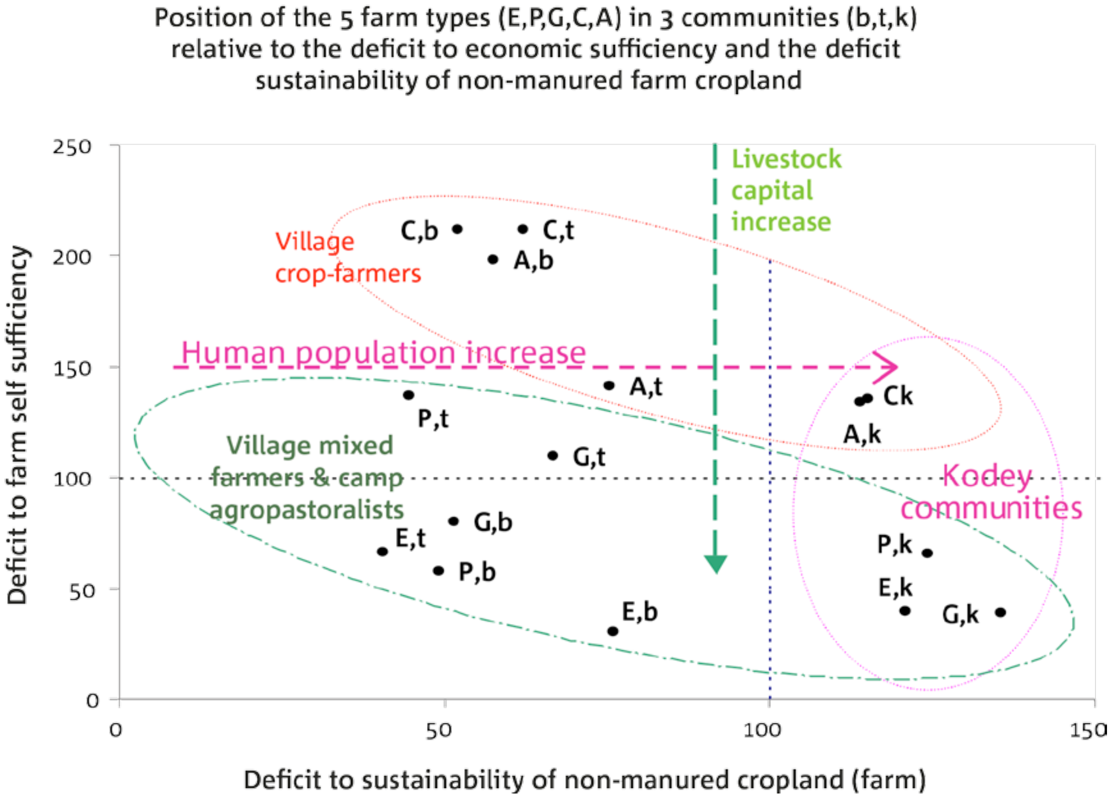



**Figure 13: Position of five farm types (E, P, G, C, A) in three communities (b, t, k) relative to index of farm self-sufficiency and index of sustainability (Hiernaux and Ayantunde, 2004)**

- Cross-scale linkages from households to other scales:
  - community rangelands mean that the amount and quality of forage for livestock per household depends on community livestock density and type
  - access to wet-season forage is strongly dependent on amount of fallow land made available by neighbours
  - access to cross-border rangelands is critical to transhumance activities, and so affects household production and well-being.

### 5.3.2 ELEMENT B. ASSESSING THE SYSTEM

#### Element B.1 Alternative regimes

- Figure 13 shows two alternative regimes, and transition pathways between them:
  - a biophysically sustainable and productive regime in which household/farm production exceeds the needs of the household
  - undesirable regime of decreasing agricultural productivity and socioeconomic security.

Crossing either the biophysical or economic threshold sees the system shift to the undesirable regime. Once this regime shift has occurred the pathways back are highly hysteretic and are likely to require higher scale interventions to occur.

- Transhumance/crop-livestock regime shift:
  - below a critical threshold of animals, pastoralists can no longer afford to live a mobile existence and must settle to secure enough food for their family. Once settled there are systemic barriers to building up a large enough herd to return to a mobile existence.
  - The reverse if possible: in some circumstances successful cash crops create the potential to invest in livestock and accumulate capital.
- Social change processes (e.g. changing inheritance structures) interacting with other demographic drivers and ecological conditions to lead to a similar shift:
  - no intensification, exporting wealth through off-territory cattle (transhumance activities) effectively allowing 'offshore savings'
  - strong agricultural intensification via better livestock-crop integration and more gardening.

Note that other potential regimes are likely to exist, in particular those relating to the viability of livestock systems.

### Element B.2 General resilience

**TABLE 6 POTENTIAL INDICATORS OF GENERAL RESILIENCE AT THE FOCAL SCALE – CURRENT LEVELS AND TRENDS**

| INDICATOR | RATIONALE AND ASSUMPTIONS | POTENTIAL SOURCES OF INFOMATION ON LEVELS AND TRENDS |
|---|---|---|
| Ecosystem diversity and productivity of native vegetation rangelands | Natural ecosystem enhances this agroecosystem's general resilience, and degradation trends are eroding that general resilience | Remote sensing, field measurement |
| Connectivity of transhumance routes | Loss of options for seasonal transhumance places more pressure on rangelands in the wet season, so reducing quality forage productivity and so general resilience | Household surveys and land use maps |
| Seasonal migration opportunities | Options to for dry-season migration relieve pressure on household food stores and bring in additional household income | Household surveys |
| Participation in farmer-led institutions | Farmer empowerment (for men and women) is a key way to strengthen the sharing of conceptual models (between farmers, and between farmers, researchers and development agencies), learning and experimentation, so building general resilience | Household surveys, institutional surveys, associations, political parties |
| Human Development Indicators and Gender Inequality Indices | These indicators are extremely poor at present, and improvements would indicate some lifting of human and social capital, which is a necessary underpinning for general resilience | UNDP, access to education, health, communication services |
| Capital reserves | Human, natural, social and built capital reserves all build options, and so general resilience | National accounts, availability of insurance/banking, grain stores, livestock census |
| Institutions governing access to shared resources | Good stewardship of shared resources increases general resilience | Household surveys, National laws, local policies |

### Element B.3 Specified resilience

**TABLE 7 EXAMPLE OF A SET OF SPECIFIED RESILIENCE INDICATORS TO REFLECT THE REGIMES SHOWN IN FIGURE 13**

| INDICATOR | RATIONALE AND ASSUMPTIONS |
|---|---|
| Index of sustainability with respect to fallowing | Evidence that it is a useful indicator of soil fertility, with a well-defined critical threshold (fallowing 3/8 of arable land) |
| Index of sustainability with respect to herbage intake | Evidence of a critical threshold if resident livestock have more than 1/3 of the mass of palatable herbage by the end of the growing season |
| Other indicators of farm-scale nutrient balance | If practices other than fallowing are involved for soil fertility, other indicators of farm-scale nutrient balance will be needed |
| Distribution of household economic self-sufficiency index | A clear threshold for unsustainability when household needs exceed production |

There is much scope for expanding the specified resilience assessment to identify relevant indicators beyond those identified in Table 7. In particular, indicators of livestock productivity and the quality of crop-livestock interactions (e.g. recycling through manure, crop residues) could be developed. Other specified resilience indicators could be derived from more detailed analysis of hypothesized alternate regimes and associated controlling variables and thresholds (e.g. resilience of transhumance practices to a sudden drop in connectivity).

Note that specified resilience assessments of this kind are best conducted at the focal scale, which leaves the question of how such assessments can inform national scale assessments.

### Elements B.4 The need for adaptation or transformation

Options for building adaptive capacity:

- Diversification of crop and livestock production, including trade-oriented commodities, dual-purpose legumes, poultry and small ruminants.
- Off-farm input (inorganic fertilizer, pesticides for cash crops, mineral feed supplement and vaccinations) have the potential for 'residual and snowball effects' on ecosystem productivity.
- Adapting agroforestry activities so they are better integrated with crop and livestock activities to provide ecosystem services such as shade, nutrient recycling.
- Enhancing farmers' animal husbandry skills, and improving crop-livestock integration (at both farm and higher scales).
- Farmer empowerment (including access to education, health, communication services and infrastructure).

These are just some of the options for building adaptive capacity and many more are possible. An equally important consideration is whether the likelihood of success in building such adaptive capacity is diminishing. If so, resilience theory would suggest it is sensible, perhaps necessary, to be building transformability. In this system, such options would draw on other aspects of these agroecosystems, such as options for off-farm income and other configurations that would emphasize activities that are currently not defining the system identity as conceptualized so far.

### Summary Action Indicators

The Summary Action Indicators (Section 4.5) provide high-level information to guide decisions towards appropriate actions and priorities, which depend on the need for adaptation, regime shift or transformation. This agroecosystem consists of different household types. Summary Action Indicators would be different for each type, depending on the level of general resilience for the agroecosystem as a whole, on whether that type is in a desirable or an undesirable regime, and on levels of specific resilience and transformability. Attributes such as natural vegetation and pastoral practices well adapted to a long history of shocks of many kinds certainly confer general resilience, as does the wealth of research that has developed multiple conceptual models and other forms of knowledge for the area. It is clear, however, that general resilience is weakening due to:

- pressure due to poor soil fertility, inherent and growing due to unbalanced nutrient fluxes (net export of nitrogen, phosphorus and mineralization of organic matter)
- changing markets (e.g. increased market for meat driven by demographic shifts and urbanization, less extensive market for millet, and irregular cash crop markets for cowpea, sesame and groundnut)
- rapid changes in landscape connectivity: reduced connectivity for grazing resources such as rangelands and fallow fields; increased connectivity due to the enhancement of gully run-off that increases the filling of ponds and recharging of the water table; increase in area cropped is increasing connectivity between fields with impact on gene pools, weed and pests
- reduced options for adaptation as population, poverty, health, education and other local pressures build (although such pressures can also drive innovations and ventures that seek out new opportunities)
- global scale pressures (e.g. climate change).

Summary Action Indicators depend on whether a regime is desirable or not. Only local people can determine this, and their answer would depend on what else is possible. The same engagement process needed to ask them could also assess the capacity to shift regimes or transform. However, to illustrate how the Summary Action Indicator approach might proceed, we will assume for now that groups whose activities are economically or biophysically unsustainable are in an unwanted regime. The procedure in Section 4.5.2., would then advocate these general recommendations:

- build general resilience for the agroecosystem as a whole (e.g. the biophysical, social and institutional requirements to support enhancing nutrient levels and recycling, crop-livestock interactions, agroforestry)
- for those with biophysically and economically sustainable livelihoods: invest in keeping away from identified thresholds
- economically or biophysically unsustainable farmers: invest in a regime shift or transformation (which can include off-farm activities)
- invest in education and health to enhance farmers' empowerment.

We have avoided specific interventions require local engagement and more knowledge than we have.

The important messages here are:

- a rapid desktop assessment such as this must not be a basis for decisions. It provides some guidance to future iterations to identify controlling variables and indicators, and where further efforts could be invested in improving understanding, information or reporting. The investment priority at this point would be in empowering stakeholders to build their capacity to explore and navigate these uncertain futures, not least by strengthening access to health, education, communication, financial and related supporting services.
- the Resilience, Adaptation and Transformation AssessmentFramework and its Summary Action Indicators have enable a clear characterization of uncertainties and trade-offs that would benefit from further exploration. In this case it has also highlighted where the system is dependent on links to geographically distant systems, suggesting revised conceptualization of system boundaries for any resilience assessment could be useful.

### 5.3.3 CONCLUSIONS FROM RAPID RESILIENCE ASSESSMENT OF SOUTH-WEST NIGER AGROECOSYSTEMS

The Resilience, Adaptation and Transformation Assessment Framework provided a useful lens through which to review existing knowledge of the system and identify system attributes relevant to resilience. The results of the assessment are limited and heavily influenced by the particular subset of literature selected for review, and would be strengthened by the inclusion of a more comprehensive range of knowledge of the system (including non-academic knowledge, and especially local knowledge). Questions of resilience 'of what, to what' and the identification of alternative regimes and options for transformation are particularly limited by the choice of system boundaries and the knowledge sources used to inform the assessment.

Our assessment suggests that the focal scale as defined would benefit from being reconceptualized. Rather than choosing a geographical area as the focal scale, it would appear that a system definition that reflects the important networks affecting system dynamics would make more sense. In particular, seasonal migration and transhumance destinations (and associated markets) could be included more specifically as important parts of the agroecosystem, despite being geographically distant. There are also ethical dimensions and sensitivities to be alert to when defining system boundaries, and again benefits from being informed by multiple perspectives of diverse stakeholders to reduce risks of excluding or marginalizing the concerns of particular groups via an overly narrow system definition.

Assessment outcomes are currently too premature and generic to be implemented. The assessment was carried out to help us develop resilience indicators, not to inform actions and polices in Niger, but what we present here is an appropriate starting point for iterative improvement guided by stakeholders in the system.

# 6 Conclusions and next steps

The scope of work evolved during the course of this project, as the project team reviewed and presented a wide range of relevant (and sometimes disparate) scientific literature and policy documentation across three Rio Conventions to better understand unmet needs. The project team worked in partnership with the Project Steering Committee, and received valuable feedback from participants at the Sydney November 2014 workshop. This resulted in an improved understanding of the role of indicators and assessment methods to meet the overall purposes - which was aligning approaches and objectives and contribute to integrated strategies and common reporting between the Conventions.

Resilience, adaptation (and adaptive capacity) and transformation (and transformability) are concepts which are not measurable or easily quantifiable – the dynamic concepts upon which they are founded, are not meaningfully expressed or interpreted with simple 'metric' types of indicators in the same way as, for example, land cover or population growth rates. A review of some of the relevant indicator sets (e.g. UNCCD, CBD, UNFCCC) as well as the literature on 'resilience' indicators showed that there were no existing approaches which could easily meet the purposes for which the study was commissioned (see Chapter 2). An early decision was made in this project to avoid adding another compound indicator to be reported by countries because, as discussed in Chapter 2, many of the compound indicators have limited relevance for their particular system and which may be very difficult to interpret or use to support local or country-level decisions. Instead, we propose that the relative levels of resilience, adaptability and transformability, and changes in those levels, can be assessed at focal (sub-national) scale.

We propose a flexible, iterative assessment procedure which has potential for being useful to local stakeholders. The flexibility means that there is a challenge to provide an aggregated, comparable, scaled up view of progress across multiple sub-national assessments which may have been applied in different ways. Therefore we propose reporting meta-indicators which aggregate the results to higher scales in a nested hierarchy, with levels of confidence that justify recommendations of well-targeted interventions. Indicators that are already reported can be drawn upon to support the assessment. Assessing and planning adaptation and transformation options and actions can be conducted with the application of adaptive management, and the emerging field of adaptive pathways science.

Thus, the proposed approach has drawn from many different threads of theory and literature, and blended them into a framework which can be practically applied and operationalized as relevant to the needs of the three Rio Conventions.

In this Chapter, we provide a preliminary assessment of the potential utility of the approach from the point of view of the authors, and feedback about the strengths and challenges of the approach from the Sydney November 2014 participants. We propose some next steps on the pathway to implementing the approach, and make some concluding comments.

## 6.1 The utility of the proposed approach – author assessment

We outlined in Section 2.4 the following criteria to guide the development of proposed indicators:

- ensure statement of clear and explicit statement of the intended purposes (Section 1.2), and check that the indicators are fit for these purposes
- ensure that the indicators are consistent with the underlying theory and behaviour of the systems the indicators are intended to provide information about
- check the tractability of implementation, including replicability, operator bias and competence required, etc.

### 6.1.1 DOES IT MEET THE INTENDED PURPOSE(S)?

**Purposes defined in the Terms of Reference**

The Terms of Reference state that the report will contribute to the following objectives:

i) enhancing UNCCD's and the GEF's efforts to assess progress in fostering ecosystem resilience
ii) reinforcing the coherence between the Convention's monitoring of its 10-Year Strategy and the GEF's monitoring of the land degradation focal area strategy
iii) identifying a joint indicator between the UNCCD, UNFCCC and CBD as a measure of both land-based adaptation and ecosystem resilience.

*Preliminary evaluation =>*

*We consider that RATA Framework provides a consistent, flexible and tractable approach to dealing with the concepts in resilience, adaptation and transformation. It has the potential to be relevant across all three Rio Conventions and beyond. The clear definition of a future 'desirable' system, translated to aspirational goals, may have different foci across the Rio Conventions (e.g. the focus on agroecosystems in the UNCCD; ecosystem services in the CBD; effective climate adaptation pathways in the UNFCCC).*

*We consider that the RATA Framework (once fully developed and implemented) has the potential to contribute to the following aspirational goals (outlined in section 1.2):*

- *target and prioritize policies and measures to build adaptive capacity where needed*
- *establish baselines to monitor the effectiveness of adaptation interventions and their impacts on reducing vulnerability to climate change, and the links between adaptation and sustainable development*
- *communicate effectiveness and outcomes of adaptation projects to policy and decision makers and other stakeholders*
- *compare adaptation progress and achievements across sectors, regions and countries.*

### The call for an approach to assessment and integration of indicators across scales

The UNCCD has called for a Monitoring and Evaluation approach which can track progress in meeting the strategic objectives (UNCCD, 2013a). They propose that it consists of three modules:

(a) indicators, both global and national/local
(b) a conceptual framework that allows the integration of indicators
(c) indicator sourcing and management mechanisms at the national/local level.

In addition to meeting the needs outlined above, the proposed framework meets many of the other needs and challenges outlined in UNCCD (2013a):

- It is a valuable way to develop and articulate a narrative, or storyline.

- It is amenable to selecting the most relevant indicators from existing databases/reporting requirements, and guiding the importance or utility of gathering other more locally specific indicators in accordance with the analysis and narrative. Using the Resilience, Adaptation and Transformation Assessment Procedure in this way will help to guide the choice of indicators and level of measurement/reporting effort, so that effort is expended on those indicators which are the most critical, meaningful or informative for any party conducting the assessment. This is consistent with existing approaches to monitoring land degradation and desertification for example (Bastin et al. 2009) recommended that ACRIS adopt a more hierarchical and nested approach that matches the scale of the data to the scale of the issue and doesn't attempt to monitor everything everywhere, and continuing the integration of data collected at different scales and working towards more nationally consistent approaches. A similar approach was recommended for GDOS.

- It could complement the call for a for a new indicator integration framework (UNCCD, 2013a) to:

  - track progress and report at multiple scales, explicitly including human-environment interactions
  - enable the upscaling/downscaling feedback loop that allows synergy between the local and global levels
  - develop storylines able to integrate the work of national action programmes, help countries to solve their own problems, and characterize the 'hot/cold spots' for areas at risk of desertification, land degradation and drought
  - provide countries with conceptual and functional support to their chosen indicators sets, which improves their capacity to interpret them
  - help the formulation of research and action projects.

- If implemented within a robust, transparent, salient and legitimate multi-stakeholder engagement process at local scale, or across nested scales from local through to national, it could meet the need for

  - engaging local stakeholders
  - harmonizing across reporting scales
  - realizing synergistic links between environmental interventions and development efforts.

The details of these are mapped to the clauses from the UNCCD (2013a) in Appendix 5.

*Evaluation =>*

*The Resilience, Adaptation and Transformation Assessment Framework has the potential to contribute to these purposes outlined here including the critically important role of the integrating framework discussed above, but*

- *will require systematic testing and further development, in an iterative fashion, within a multi-stakeholder engagement process (see section 6.3 discussing future steps)*
- *is reliant upon the other criteria (consistency with theory and observed system behaviour; tractability; replicability etc.) to be met.*

### 6.1.2 ARE THE INDICATORS CONSISTENT WITH THE UNDERLYING THEORY AND BEHAVIOUR OF AGROECOSYSTEMS?

The key characteristics defining linked social-ecological system behaviours, and the appropriateness of compound indicators to reflect them adequately was reviewed in Chapter 3, and illustrated in the case studies in Chapter 5.

The application of the Resilience, Adaptation and Transformation Assessment Framework in a very preliminary desktop manner in the case studies showed its potential utility in eliciting the most important indicators for any given focal analysis or scale of reporting. The focus on controlling variables, trends and thresholds has potential, if done with skill and supported by adequate data and multi-stakeholder engagement, to provide a robust insight into system dynamics and key points of intervention.

*Evaluation =>*

- *The proposed Resilience, Adaptation and Transformation Assessment Framework and related indicators used in each assessment (as illustrated in the case studies) have the potential in generic sense to be consistent with theory and behaviour of the system. But, whether or not it ACTUALLY meets the criterion will depend on how it is done, and by whom, and whether there is sufficient understanding of the system and data to support the assessment (see Section 6.1.3).*

### 6.1.3 IS THE IMPLEMENTATION TRACTABLE AND REPLICABLE?

As with any analysis of a complex dynamic system, it is not possible to codify a rigid formulaic approach. This means that every individual assessment will encounter issues of operator bias and competence, different mental models and varying value systems. This is not unique to resilience assessment – by analogy, it is well demonstrated that in soil survey work, no soil map by two surveyors is exactly the same, because everything from deciding where to sample, categorizing and describing soil classes and drawing lines on the map relies on a tacit understanding of landscapes which is rarely made explicit. We have tried to address this by listing elements in the Resilience, Adaptation and Transformation Assessment Framework which should prompt the operator(s) to include key components in their conceptual models of how the agroecosystem works, and make them explicit. However, the approach will still not be completely unambiguous and replicable as was clearly shown by the case studies. The Summary Action indicators and the Coverage and Quality meta-indicators are intended to provide a level of reporting which is comparative and consistent at higher scales.

*Evaluation =>*

- *The approach will, like any analytical approach, require some capacity-building. It has the potential not only to be tractable itself, but to enable nations to focus their efforts and resources more clearly by measuring or characterizing the most important controlling variables and interactions in the linked social-ecological systems. It can be implemented in an iterative manner, and can range from a very limited conceptual analysis relying on published data and expert knowledge from consultants/scientists (useful scoping), through to a multi-stakeholder engagement process supported by adequate data and quantitative analysis, conducting a robust adaptive pathways planning process.*

## 6.2 Assessment by Sydney November 2014 workshop participants

In this section, we reflect the feedback from the workshop participants. A first question asked by participants was: what additional benefits and insights are possible that are not already accessible via existing indicators and monitoring and evaluation systems? Much of the feedback from workshop participants addresses this question.

### 6.2.1 THE HOPE OR POTENTIAL INHERENT IN RESILIENCE PERSPECTIVES

A motivation for developing integrated approaches emphasising resilience is that it can recognise interconnections that are neglected in other approaches. For example, adaptation activities can sequester carbon (contributing to mitigation) as well as build resilient food security outcomes for communities. Where single objectives only are considered (in this example carbon mitigation or food security in isolation) some of these activities may be viewed as less efficient than other options and overlooked, but only because valuable interconnections are not adequately taken into consideration. Similarly, the failure to recognise declining resilience in agroecosystems is a failure to account for a key driver of expansion of agriculture into new lands taken from forests and wetlands, with consequences for the CBD in particular. This ability to integrate is also necessary to operationalize concepts such as land degradation neutrality and to find common land-based indicators that compare insights across $NAPs_{1,2}$ NAPAs, and NBSAPs and strengthen links between the three Rio Conventions.

The RATA Framework points to opportunities for greater coherence between the three Rio Conventions, for example via National Adaptation Planning processes, and leaves open the possibility that after several countries have applied the framework some common indicators for agroecosystem resilience could be identified. As outlined in this report, if operationalized using a transdisciplinary, adaptive management approach, the underpinning assumptions would become research hypotheses, the derived indicators would guide the monitoring of SESs, and the evaluation activities would together enable the kind of governance critical to adaptation and in particular transformation.

The RATA Framework complements the current approaches of the GEF. Indicators thus far have tended to be specific, independent lists – an integrating framework (SDUDP) has been proposed (UNCCD, 2013a) but not yet designed or implemented. Monitoring and evaluation is a serious challenge for the GEF, and the RATA Framework can be a basis for evaluation as it inherently articulates a theory of change, so implying criteria for monitoring and evaluation. Rather than adding to a list of indicators, there is much potential for it to make good use of existing data and indicators, allowing them to be interpreted in different contexts in a coherent way to better inform decisions and interventions.

There is potential for the RATA framework to inform, challenge and build narratives. Workshop participants highlighted several examples. For example, existing narratives have dwelt on all that is wrong (e.g. workshop participants spoke of ‘the sky is falling in’ narratives, and analysis efforts that provide results described as ‘an interesting epitaph for a dead river’). Resilience concepts provide the opportunity to look beyond measurements and narratives of degradation to consider options for healing and restoration. It is also useful for challenging the common ’poverty versus environment’ discourse because social-ecological co-dependencies are at its core, and livelihoods are deeply embedded in, and dependent upon, ecosystems. Participants pointed out that when combined with empirical evidence such as remote sensing, the resilience perspective can be helpful for drawing out more details on the ’story behind each pixel’.

Powerful narratives at a nation scale typically include metrics such as the GDP, despite its well known deficiencies (Costanza et al., 2014). Although GDP is an easily reported indicator, the system of national accounts underpinning its calculation is rich, detailed and requires globally agreed accounting methods. The RATA Framework in this report provides the basis for a systematic approach to assessing resilience in a way that it includes many aspects neglected in measures such as GDP, and so would enrich national narratives. Finally, we heard that in some social ecological systems it would be a strength to have the courage to consider possibilities of transformation, and the RATA framework offers that potential. For example, a resilience perspective will foster a fundamental shift away from policies that aim to rebuild after disaster in a way that puts things back the way they were, to policies that build adaptive capacity and transformability.

### 6.2.2 IDENTIFIED STRENGTHS AND UNIQUE QUALITIES OF THE RATA FRAMEWORK

The RATA Framework is flexible, making it well-suited to different contexts. It is well able to accommodate the reality that what is vitally important in one system is irrelevant in another. For example, climate change will be an important consideration in some systems, but not all. The RATA framework is also readily applicable in situations of high uncertainty, high dispersion of power and highly ambiguous goals. Its flexibility extends beyond agroecosystems, and can readily be applied to any social-ecological system.

The RATA Framework is consistent with existing frameworks and can be used in conjunction with them. It has been informed by existing literature on resilience assessment, and contains key elements common to reviewed approaches: explicit system conceptualization; multiple scales; and acknowledgment and characterization of context (especially the specification of resilience of what, to what and according to whom). It can readily work with existing frameworks. For example, the DPSIR framework (Gabrielsen and Bosch, 2003) is a well-used integrating framework developed by the European Environment Agency, and was one of the conceptual frameworks used in the GEF project on Land Degradation Assessment in Drylands (Biancalani et al., 2013). The DPSIR framework could be used when conceptualizing how the system functions in Element A of the RATA. The RATA Framework is also consistent with the UNFCCC NAP process principles of continuous, progressive and iterative processes that facilitate country-owned, country-driven action without being prescriptive.

The RATA Framework highlights system considerations that can be hard to accommodate in other approaches. Unique to this approach is the explicit recognition that multiple scales (both spatial and temporal), and interactions across those scales, need to be included. On the other hand, it offers useful guidance in the face of the challenge that if everything is connected to everything else, how is it possible to characterize the system in a useful way? This is the challenge of balancing the impossibility of considering everything with the dangers of naïve oversimplification. Central to the RATA Framework is the acknowledgment that it is useful to adopt the 'rule of hand', which is a heuristic informed by experience across social-ecological systems that key dynamics can be characterized by small sets of three to five key variables (Walker et al., 2006). Hence the focus on identifying controlling variables in specified resilience assessments.

The framework also brings the value of learning, innovation, experiments and openness to challenging the *status quo* to the fore as important attributes of a self-organized system. The RATA Framework enables mutual learning, fostering common understanding across stakeholders of different perspectives, interests and visions for their system, and developing narratives that provide meaningful interpretations of existing knowledge, datasets and indicators. The iterative nature of the framework and its emphasis on learning gives it some self-correcting capacity and scope for novelty. The inclusion of meta-indicators that review the coverage and quality of the application of the framework is useful for exposing weaknesses and informing improvements to the method. For example, a review of catchment management authorities that had used this approach found that none had considered transformation. This insight was exposed by the process and informed improvements to the RATA Framework.

### 6.2.3 WEAKNESSES OF THE RATA FRAMEWORK AND OPEN QUESTIONS

The most prominent weakness of the RATA Framework is, in some ways, a consequence of one of its strengths. Its flexibility and utility across a range of contexts is accompanied by a high level of subjectivity in how it is applied. This is a strength as it enables participation and use across a wide range of settings, but it comes with a cost in that it limits the ability to compare across systems. Even though we stress that resilience is not a normative concept (i.e. it requires no value judgments claiming what is good and bad, or right or wrong), and is a system property, core aspects of the application of the concept within the RATA Framework are inherently normative judgments, including the choice of focal scale and how we frame what is in or out of the agroecosystem. It raises questions of who is included in the process, who decides what is desirable or not and what to do about it, and who decides whether to enhance resilience or pursue transformation. The framework does not make clear how to handle multiple, conflicting desired regimes identified by different actors with competing interests and agendas, nor how manage the risk of outcomes being ad hoc or biased given that outcomes are highly dependent on who is or is not included. It is for all these reasons that we have stressed throughout this report the need for multi-stakeholder engagement, inclusive adaptive management approaches and meta-indicators of the quality of assessment, and these aspects need to be strengthened in any application of the framework.

The next key barrier to application of the RATA Framework is the resource requirements for deploying it effectively in practice. It is time consuming, complex, resource intensive and may not align with many existing planning, accounting and reporting requirements. In response, we note that such critique would have been equally relevant to outcomes of the Bretton Woods negotiations that recommended the system underpinning today's global financial relationships. Laying out the requirements for a resilience, adaptation and transformation assessment process that is supported by best practice knowledge and experience brings to light the ways in which our current governance systems are not structured and resourced to address the growing imperative to address global aspirations for sustainability and resilience. This in itself may be valuable evidence to support change.

Agroecosystems may not be the right object on which to focus resilience assessments, particularly if the intention is to foster good integration between the three Rio Conventions. Concerns with a focus on agroecosystems include the possible inference that we're prioritizing or promoting persistence with agriculture when other livelihood options may be better in some circumstances, or that by focusing on agroecosystems we are neglecting other ecosystems that are of particular interest to the CBD. Our response is that the RATA Framework is flexible, and that agroecosystems are an example of a linked SES to which the approach could be applied.

The assertion that resilience is a concept, and not a measurable quantity, is an uncomfortable one for some. We would not want the message that we cannot measure resilience to be heard as a view that measurement is irrelevant or unnecessary. It will require some care to continue to emphasize that while resilience itself cannot be measured, the framework can be used to elicit measurable system properties that are relevant and can be measured, monitored and used to inform assessments.

Better ways to highlight the time dimension in resilience assessments may be helpful, as for some it is not clear that system descriptions include information about the temporal dynamics of system variables. For example, some workshop participants suggested system conceptualizations risked being perceived as static representations and some suggested there was too much emphasis on shocks and not enough on rates of change that govern what dynamics unfold in a system. Without mathematical simulation there are limits to our ability to understand how interacting system dynamics will play out over time, and more mature system conceptualizations bring in mathematical simulation in order to explore those consequences more thoroughly.

## 6.3 Next steps

The proposed approach was developed as part of a small project, and requires further development and testing, preferably in an operationally applied environment. It must necessarily be an adaptive, learning process, and this needs to be built into the next steps. There are some intermediate steps that can be taken to prepare for a pilot or early stage implementation (as outlined in section 6.2). Further steps to trial the RATA in a set of archetypal, contrasting agroecosystems from a selected set of candidate countries could be used in an adaptive learning way, involving local expertise, local and national stakeholder interests, and technical expertise.

Different components of the RATA Framework are in different stages of development, and may require different approaches for implementing the next steps. We summarize these for each component, and for the framework as a whole. We summarise the maturity of each component of the framework, and further work, in Table 8.

**TABLE 8 SUMMARY OF STAGE OF MATURITY AND STEPS TO IMPLEMENTATION OF THE RATA FRAMEWORK**

| FRAMEWORK COMPONENT | STATE OF MATURITY | NEXT STEPS |
|---|---|---|
| 1. RATA Procedure – interim steps to prepare for implementation | Elements A, B, D of the RATA Framework are relatively well tested in a range of case studies around the world, and complementary to many other published resources.<br><br>Element C: Adaptive pathways, sequencing decisions, adaptive governance etc . is less mature in terms of tested case studies, but is developing rapidly and is ready to be further co-developed and tested with multi-stakeholder engagement in an implementation phase. | A. Improve articulation and description of the RATA Framework, with an increased emphasis on Element C, tailored for country climate adaptation planning implementation pathway. Tailoring would be based on desktop studies, interviews with range of stakeholders and decision makers, expert knowledge and experience from a diverse range of countries and potential users.<br><br>B. Through further discussions with a range of GEF, UNCCD, CBD, UNFCCC and other agency staff, develop a clearer articulation of<br><br>i. complementarity with existing GEF, CBD, UNCCD, UNFCCC approaches<br>ii. complementarity with other agency tools and approaches (eg FAO, IFAD, World Bank, Conservation International)<br>iii. a clear description of the range of potential implementation pathways through the above. |
| 2. Indicators for key attributes or controlling variables used in RATA Procedure | There are a large number of indicators relevant to SR in particular, but perhaps also to GR and T that are already reported through GEF, UNCCD, UNFCCCC, CBD at various levels. .<br><br>This was done in a very broad way in this report, and the Sydney 2014 workshop recommended that a more detailed study be conducted. | A. Assess the potential utility of the many indicators already reported in the three Conventions and the GEF, to recommend a subset of indicators which may be relevant and appropriate to different regions. Identify indicators of general resilience, that might be relevant to many applications.<br><br>B. Provide guidance on which indicators are relevant and which require modification – for example including trend, directionality, rate of change, thresholds may be required in order for them to be useful in the RATA Procedure, and how the resilience framework can be used to organize them into a set of indicators for the monitoring purposes of multi-focal area/multi-trust fund projects, to meet the GEF's needs.<br><br>This can be conducted in part as a desktop study, but there is also a need to refine and capture the learning through implementation of the framework. |
| 3. Summary Action Indicators | The Summary Action indicators were proposed in this report, but it was not possible to specify them in detail in a desktop study without full opportunity for testing Elements A, B, C and D of the RATA Procedure , in an applied setting. Developing a more clear specification which maximises utility to potential users of the RATA Framework will require a closer association, in an applied setting, with the users of the RATA Framework so that we can clarify the actual decisions which will be supported by such indicators, and tailor the specification accordingly. Therefore, although we are confident the approach is sound, the Summary Action indicators presented here are not mature. The level of conceptual challenge in designing these is high, and they should be taken as illustrative only at this point. | It is difficult to recommend finalising the specification of the Summary Action Indicators as an interim step. This is best done in piloting (See 9. In this Table) in collaboration with local stakeholders and GEF (and other relevant Conventions and organizations) during early implementation of RATA Framework to more fully specify and test these indicators. However, interim steps could include further consultation with GEF and other Rio Convention staff to<br><br>i) clarify the actual decisions which may be informed by such indicators<br><br>ii) build in the potential summary outcomes from the inclusion of Element C adaptive pathways planning (Task 1)<br><br>iii) link to Task 2 above and better interface with GEF existing M&E framework to improve the current (very loose) specification of these indicators, as an interim step. |

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| 4. Coverage indicators | The Coverage indicator – number of regions or area covered are proposed by the current study and are conceptually simple, and need no further work. However, work is required to scale up the Summary Action Indicators to provide a meaningful measure of the status of multiple agroecosystems. | Develop a new Coverage indicator that reflects the aggregate results of the Summary Action Indicators, so that this element can be scaled up for national reporting. |
| 5. Quality indicators | These meta-indicators relate to the quality of framework implementation There is a lot of existing theory and practice in the area of multi-stakeholder engagement processes, at multiple scales and within multiple domains of practise. This knowledge is however, held in many different disciplines. This could form a critical part of any evaluation framework used to 'gauge' RATA success/ failure.<br><br>These indicators were suggested at the Sydney November 2014 workshop, and are therefore yet to be developed. | A. Develop Quality indicators which are appropriate at focal scale and can be scaled up to national reporting in a manner consistent with the other meta-indicators. These indicators should clarify the legitimacy, salience and transparency to all stakeholders involved in implementation.<br><br>B. Some work can be done as a desktop study, but they will also require field testing during the early stages of implementation of the RATA Framework. |
| 6. Developing and testing the science | The material presented in this report, as well as any work conducted under 1 – 5 above, requires clear development and testing of theory, and the application thereof, and communication of this to a scientific audience for debate, peer review and generation of new scientific knowledge. | A. Journal paper should be produced presenting this report, and preferably including 1-5 above |
| 7. Developing understanding, support and capacity | This technical report, and any scientific papers that flow from it are a critical part of developing indicators and analytical approaches which can be expressed and applied as guidelines or policies. However, scientific papers are generally not user friendly to policy and stakeholder audiences. Therefore, there is a necessity for a range of materials to improve understanding, engagement, capacity and ultimately the utility of the RATA Framework. The range of users requires different forms and types of communication and this needs to be further explored WITH the users, and tailored accordingly. | This could have many components including:<br><br>A. Production of policy briefs for range of policy audiences, starting with GEF, UNCCD, UNFCCC, CBD and beyond<br><br>B. Production of guidelines on applying the framework that can be used by a range of users, starting with GEF project developers and UNCCD country representatives.<br><br>C. Production of guidelines and a range of user materials for those who will be conducting assessments, including presentation material. This is best prepared with a range of test users, the scientists who are developing the concepts, and specialists who understand areas of psychology, science communication including graphics and design, especially for simplified representations of complex concepts.<br><br>D. Building capacity for implementation<br><br>• Workshop process and materials<br>• Case study examples<br>• 'Train the trainer' workshops or courses |
| 8. Implementation of the RATA Framework – early stages | The RATA Framework was developed as part of a small consultancy project and has put forward an approach which is conceptually sound and may have high utility beyond the GEF.<br><br>The RATA Framework roll out should, however, proceed cautiously in a 'piloting' or 'early implementation' applied setting where co-development of the ideas by the scientists, with a range of users, can feed back into the knowledge development and make the RATA Framework robust and provide clarity about how best to apply it. | – The RATA Framework requires further development, and this is best conducted with researchers and a range of stakeholders during early stages of implementation:<br><br>– A. Testing and refining the whole RATA Framework (including Element C), R&D team co-developing with users, testing, and learning from the early implementation projects.<br><br>– B. Improvement of knowledge and application, feeding back into tasks 1-7 as appropriate as the approach matures |

## 6.4 Conclusions

The concepts of resilience, adaptation and transformation are gaining increasing support as an appropriate basis for sustainable development in agroecosystems worldwide and especially in the developing world. At this stage it is more of a clearly articulated aspiration than a demonstrably useful approach. Despite the valuable body of research which has been conducted on resilience and adaptation , there are still challenges to reconciling and operationalizing this knowledge and experience within an international or national policy arena.

This report has covered areas of literature including indicator development and use (Chapter 2) with a brief insight into some of the core desertification and degradation literature (section 2.1.1); and resilience theory and practice, adaptive management, adaptation pathways (Chapter 3). We have focussed on presenting glimpses into limited, specific areas of literature, drawing on that which is required to directly support the approach presented in Chapter 4. In doing so, we hope to have drawn together the appropriate threads to build a solid scientific foundation for the Resilience, Adaptation and Transformation Assessment Framework.

We have tested the approach with a rapid desktop assessment in two case studies (Chapter 5), and presented our approach to a workshop of 50 participants for some 'road-testing' and critique (Chapter 6). This technical report puts forward the underpinning science, a proposed approach, and some preliminary evaluation of this approach. The next steps will require this approach to be 'field-tested', and many supporting products may be developed including adapting the material presented here for various audiences including scientific peers (through journal papers), policy briefs, and simple user guidelines. These products will help to bridge the gap between science and policy in applying these complex and dynamic concepts in a consistent manner, potentially meeting the needs of multiple stakeholders at local, country and international levels.

There was enthusiasm and endorsement of the approach in the Sydney November 2014 workshop, and the next steps are ready to be taken. The RATA Framework has been presented in the context of this report in a way which highlights the relevance to the core task of developing an approach which may be applicable across the three Rio Conventions, with respect to assessing and enhancing agroecosystems. The approach is more broadly applicable and relevant, however, to a wide range of linked social-ecological systems, users and stakeholders (including national governments and international organizations), in navigating the future

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# Appendix 1

## Terms of Reference

The project will consist of the recruitment of a consultant (CSIRO) who will carry out the tasks as outlined below:

i. Synthesize the scientific understanding of resilience in interacting social and ecological systems, with a particular focus on agroecosystems. This includes the following tasks: i) analysing the current knowledge of assessment methods and potential resilience indicators relevant to agroecosystems. This effort will describe if, what, and how, indicators have been applied to measure resilience of agroecosystems, or farming systems (drawing from experiences from the developing and developed world); ii) identifying knowledge gaps; iii) assessing the challenges of developing and applying resilience metrics at appropriate temporal and spatial scales, given resource and knowledge constraints.

ii. Develop an approach for selecting and defining indicators to assess social-ecological resilience of farming systems. This will include: a) an internally consistent conceptual framework for applying resilience thinking; and, b) defining an approach to selecting and defining indicators that are applicable at different spatial scales – from the farm (or landscape) to regional and global level. Identifying indicators that can be applied across spatial scales will be important to the UNCCD and the GEF, given their work applies at all three levels.

iii. Provide the STAP, GEF, and UNCCD with a draft outline of the report's expanded table of contents for comment, and reflect the changes requested in the final structure of the report.

iv. Consult the STAP, GEF and the UNCCD Secretariat as needed for relevant input during the report preparation – for example, are the scales covered appropriately in the framework with regards to the Convention's and the GEF's needs? Skype or teleconferences will be held at regular intervals to discuss progress, major findings and any difficulties. Modifications to the details of the report may be discussed and agreed during these communications. Drafts of the report will be reviewed by STAP, GEF and the UNCCD. The consultant should keep closely work with Guadalupe Durón and Annette Cowie.

v. Write the report targeting the scientific and policymaking communities. This includes individuals with a good understanding of the scientific basis of ecosystem science – as well as an audience seeking to understand further this topic. The report will target the scientific community, and the UNCCD's and the GEF's policymakers.

vi. Provide a draft report by 15 October 2014. The report will be up to 30 pages, and include a bibliography of recent literature on the scientific understanding of resilience in agroecosystems and indicators of resilience. The authors will have the opportunity to translate the report into a journal paper, if appropriate content is developed.

vii. Participate in a workshop in Sydney, Australia on [in November 2014 – week of 10 or 17 November] where conceptual framework and proposed approach to defining indicators is presented as a keynote address. In addition, a review of NDVI[3] will be discussed.

viii. Include in the report a summary of the workshop discussion and conclusions on the conceptual framework and the proposed approach to defining indicators.

ix. Submit the final document to the STAP Secretariat by 15 December 2014.

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3 A review of the use of NDVI for national-level assessment of land degradation will be undertaken in parallel to the work on agroecosystem resilience. The review will allow experts and the GEF to consider the applicability of using NDVI in a revised GEF methodology for allocating resources to countries addressing land degradation. The review also will consider the appropriateness of using NDVI for monitoring ecosystem dynamics to assess its complementarities with an indicator of agroecosystem resilience.

# Appendix 2

## Participants of Sydney November 2014 workshop

| | | |
|---|---|---|
| Nick | Abel | Commonwealth Scientific and Industrial Research Organization, Australia |
| Ruy | Anaya de la Rosa | University of New England, Australia |
| Sandy | Andelman | Conservation International, United States |
| Mohamed | Bakarr | Global Environment Facility, United States |
| Martial | Bernoux | French Research Institute for Development, France |
| Charles | Besancon | Convention on Biological Diversity, Canada |
| Miguel | Brandão | International Energy Agency Bioenergy Task 38, Australia |
| Victor | Castillo | United Nations Convention on Desertification, Germany |
| Brian | Child | Scientific and Technical Advisory Panel, Zimbabwe |
| Annette | Cowie | STAP, NSW Department of Primary Industries, University of New England, Australia |
| Saul | Cunningham | Commonwealth Scientific and Industrial Research Organization, Australia |
| David | Dent | Independent Scientist, Honorary Fellow of LUCSUS, Lund University, Sweden |
| Marco | D'Errico | Food and Agriculture Organization of the United Nations, Italy |
| Guadalupe | Duron | Secretariat, Scientific and Technical Advisory Panel, United States |
| Pablo | Eyzaguirre | Bioversity International, Italy |
| Rasmus | Fensholt | University of Copenhagen, Denmark |
| Cameron | Fletcher | Commonwealth Scientific and Industrial Research Organization, Australia |
| Virginia | Gorsevski | Secretariat, Scientific and Technical Advisory Panel, United States |
| Nicky | Grigg | Commonwealth Scientific and Industrial Research Organization, Australia |
| Jeroen | Groot | Wageningen University, Netherlands |
| Tom | Hammond | Secretariat, Scientific and Technical Advisory Panel, United States |
| Steve | Hatfield – Dodds | Commonwealth Scientific and Industrial Research Organization, Australia |
| Ariella | Helfgott | University of Oxford, United Kingdom |
| Jeff | Herrick | United States Department of Agriculture, United States |
| Stefanie | Herrmann | University of Arizona, United States |
| Pierre | Hiernaux | National Center for Scientific Research, France |
| Zvi | Hochman | Commonwealth Scientific and Industrial Research Organization, Australia |
| Alfredo | Huete | University of Technology, Australia |
| Fareeha | Iqbal | Global Environment Facility, United States |
| Graciela | Metternicht | University of New South Wales, Australia |
| John | Morton | University of Greenwich, United Kingdom |
| Stephen | Murphy | University of Waterloo, Canada |
| Chris | Norman | Goulburn Broken Catchment Management Authority, Australia |
| Deborah | O'Connell | Commonwealth Scientific and Industrial Research Organization, Australia |

| | | |
|---|---|---|
| Lennart | Olsson | Lund University Centre for Sustainability Studies, Sweden |
| Maria Luisa | Paracchini | Joint Research Centre, Italy |
| Leonie | Pearson | University of Canberra, Australia |
| Paul | Ryan | Australian Resilience Centre, Australia |
| Lindsay | Stringer | University of Leeds, United Kingdom |
| Genesis Yengoh | Tambang | Lund University Centre for Sustainability Studies, Sweden |
| Anna | Tengberg | University of Gothenburg, Sweden |
| Van | Touch | University of New England, Australia |
| Compton | Tucker | National Aeronautics and Space Administration / Goddard Space Flight Center, United States |
| Alexander | van Oudenhoven | Wageningen University, Netherlands |
| Korinna | von Teichman | United Nations Framework Convention on Climate Change, Germany |
| Brian | Walker | Commonwealth Scientific and Industrial Research Organization, Australia |
| Cathleen | Waters | New South Wales Government, Department of Primary Industries, Australia |
| Stuart | Whitten | Commonwealth Scientific and Industrial Research Organization, Australia |
| Russ | Wise | Commonwealth Scientific and Industrial Research Organization, Australia |
| Aaron | Zazueta | Independent Evaluation Office of the Global Environment Facility, United States |

# Appendix 3

## Indicators used in the Rio Conventions

### UNCCD indicators

**TABLE 9 UNCCD PROGRESS INDICATORS ADOPTED AT ELEVENTH SESSION OF THE COP (DECISION 22/COP.11)**

| INDICATOR CODE | INDICATOR | METRICS/PROXIES | POTENTIAL DATA SOURCES |
|---|---|---|---|
| Strategic objective 1: To improve the living conditions of affected populations | | | |
| SO1-1 | Trends in population living below the relative poverty line and/or income inequality in affected areas | Poverty severity (or squared poverty gap)<br>or<br>Income inequality | The World Bank database<br>http://databank.worldbank.org/data/views/reports/tableview.aspx |
| SO1-2 | Trends in access to safe drinking water in affected areas | Proportion of population using an improved drinking water source | Database of WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation Methodology<br>http://www.wssinfo.org/data-estimates/table/ |
| Strategic objective 2: To improve the condition of affected ecosystems | | | |
| SO2-1 | Trends in population living below the relative poverty line and/or income inequality in affected areas | Poverty severity (or squared poverty gap)<br>or<br>Income inequality | The World Bank database<br>http://databank.worldbank.org/data/views/reports/tableview.aspx |
| SO2-2 | Trends in land productivity or functioning of the land | Land productivity dynamics | The New World Atlas of Desertification of the JRC<br>http://wad.jrc.ec.europa.eu/ |
| Strategic objective 3: To generate global benefits through effective implementation of the UNCCD | | | |
| SO3-1 | Trends in carbon stocks above and below ground | Soil organic carbon stock<br>*to be replaced by*<br>Total terrestrial system carbon stock<br>*once operational* | Harmonized World Soil Database (HWSD) of FAO/IIASA/ISRIC/ISSCAS/JRC<br>http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/ |
| SO3-2 | Trends in abundance and distribution of selected species<br>*(potentially to be replaced by an indicator measuring trends in ecosystem functional diversity once system understanding and data production allows)* | Global Wild Bird Index | No global data sets available |

## CBD indicators

| AICHI BIODIVERSITY TARGET | HEADLINE INDICATORS (IN BOLD) AND MOST RELEVANT OPERATIONAL INDICATORS |
|---|---|
| Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society | |
| **Target 3** – By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socioeconomic conditions. | **Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• Trends in the number and value of incentives, including subsidies, harmful to biodiversity, removed, reformed or phased out (B)<br>• *Trends in identification, assessment and establishment and strengthening of incentives that reward positive contribution to biodiversity and ecosystem services and penalize adverse impacts (C)* |
| **Target 4** – By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits. | **Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture**<br>• Trends in population and extinction risk of utilized species, including species in trade (A) (also used by CITES)<br>• Trends in ecological footprint and/or related concepts (C) (decision VIII/15)<br>• *Ecological limits assessed in terms of sustainable production and consumption (C)*<br><br>**Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers**<br>• *Trends in biodiversity of cities (C) (decision X/22)*<br>**Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• Trends in extent to which biodiversity and ecosystem service values are incorporated into organizational accounting and reporting (B) |
| Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use | |
| **Target 5** – By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced. | **Trends in extent, condition and vulnerability of ecosystems, biomes and habitats**<br>• Extinction risk trends of habitat dependent species in each major habitat type (A)<br>• Trends in extent of selected biomes, ecosystems and habitats (A) (decision VII/30 and VIII/15)<br>• Trends in proportion of degraded/threatened habitats (B)<br>• Trends in fragmentation of natural habitats (B) (decision VII/30 and VIII/15)<br>• *Trends in condition and vulnerability of ecosystems (C)*<br>• *Trends in the proportion of natural habitats converted (C)*<br>**Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture**<br>• *Trends in primary productivity (C)*<br>• *Trends in proportion of land affected by desertification (C) (also used by UNCCD)*<br>**Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers**<br>• Population trends of habitat dependent species in each major habitat type (A)<br>**Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• *Trends in proportion of depleted target and by-catch species with recovery plans (B)* |

| AICHI BIODIVERSITY TARGET | HEADLINE INDICATORS (IN BOLD) AND MOST RELEVANT OPERATIONAL INDICATORS |
|---|---|
| **Target 7** – By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity. | **Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture**<br>• Trends in population of forest and agriculture dependent species in production systems (B)<br>• Trends in production per input (B)<br>• *Trends in proportion of products derived from sustainable sources (C) (decision VII/30 and VIII/15*<br>**Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• Trends in area of forest, agricultural and aquaculture ecosystems under sustainable management (B) (decision VII/30 and VIII/15) |
| **Target 8** – By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity. | **Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers**<br>• Trends in incidence of hypoxic zones and algal blooms (A)<br>• Trends in water quality in aquatic ecosystems (A) (decision VII/30 and VIII/15)<br>• Impact of pollution on extinction risk trends (B)<br>• Trends in pollution deposition rate (B) (decision VII/30 and VIII/15)<br>• Trends in sediment transfer rates (B)<br>• *Trend in emission to the environment of pollutants relevant for biodiversity (C)*<br>• *Trend in levels of contaminants in wildlife (C)*<br>• *Trends in nitrogen footprint of consumption activities (C)*<br>• *Trends in ozone levels in natural ecosystems (C)*<br>• *Trends in proportion of wastewater discharged after treatment (C)*<br>• *Trends in UV-radiation levels (C)* |
| **Target 9** – By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment. | **Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers**<br>• Trends in the impact of invasive alien species on extinction risk trends (A)<br>• Trends in the economic impacts of selected invasive alien species (B)<br>• Trends in number of invasive alien species (B) (decision VII/30 and VIII/15)<br>• *Trends in incidence of wildlife diseases caused by invasive alien species (C)*<br>**Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• Trends in policy responses, legislation and management plans to control and prevent spread of invasive alien species (B)<br>• *Trends in invasive alien species pathways management (C)* |

| AICHI BIODIVERSITY TARGET | HEADLINE INDICATORS (IN BOLD) AND MOST RELEVANT OPERATIONAL INDICATORS |
|---|---|
| **Target 10** – By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning. | **Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers**<br>• Extinction risk trends of coral and reef fish (A)<br>• Trends in climate change impacts on extinction risk (B)<br>• Trends in coral reef condition (B)<br>• Trends in extent, and rate of shifts of boundaries, of vulnerable ecosystems (B)<br>• *Trends in climatic impacts on community composition (C)*<br>• *Trends in climatic impacts on population trends (C)* |
| Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity | |
| **Target 11** – By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes. | **Trends in coverage, condition, representativeness and effectiveness of protected areas and other area-based approaches**<br>• Trends in coverage of protected areas (A) (decision VII/30 and VIII/15)<br>• Trends in extent of marine protected areas, coverage of key biodiversity areas and management effectiveness (A)<br>• Trends in protected area condition and/or management effectiveness including more equitable management (A) (decision X/31)<br>• Trends in representative coverage of protected areas and other area-based approaches, including sites of particular importance for biodiversity, and of terrestrial, marine and inland water systems (A)<br>• Trends in the connectivity of protected areas and other area-based approaches integrated into landscapes and seascapes (B) (decision VII/30 and VIII/15)<br>• *Trends in the delivery of ecosystem services and equitable benefits from protected areas (C)* |
| **Target 12** – By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained. | **Trends in abundance, distribution and extinction risk of species**<br>• Trends in abundance of selected species (A) (decision VII/30 and VIII/15) (UNCCD indicator)<br>• Trends in extinction risk of species (A) (decision VII/30 and VIII/15) (MDG indicator 7.7) (also used by CMS)<br>• Trends in distribution of selected species (B) (decision VII/30 and VIII/15) (also used by UNCCD |

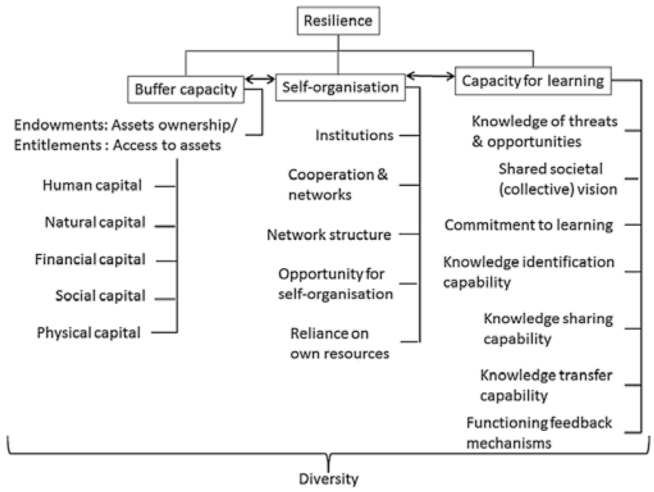
| AICHI BIODIVERSITY TARGET | HEADLINE INDICATORS (IN BOLD) AND MOST RELEVANT OPERATIONAL INDICATORS |
|---|---|
| **Target 13** – By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity. | **Trends in genetic diversity of species**<br>• Trends in genetic diversity of cultivated plants, and farmed and domesticated animals and their wild relatives (B) (decision VII/30 and VIII/15)<br>• Trends in genetic diversity of selected species (C)<br>**Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives**<br>• Trends in number of effective policy mechanisms implemented to reduce genetic erosion and safeguard genetic diversity related to plant and animal genetic resources (B) |
| Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services | |
| **Target 14** – By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable. | **Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being**<br>• Trends in proportion of total freshwater resources used (A) (MDG indicator 7.5)<br>• Trends in proportion of the population using improved water services (A) (MDG indicator 7.8 and 7.9)<br>• Trends in benefits that humans derive from selected ecosystem services (A)<br>• Population trends and extinction risk trends of species that provide ecosystem services (A)<br>• Trends in delivery of multiple ecosystem services (B)<br>• Trends in economic and non-economic values of selected ecosystem services (B)<br>• Trends in health and well-being of communities who depend directly on local ecosystem goods and services (B) (decision VII/30 and VIII/15)<br>• Trends in human and economic losses due to water or natural resource related disasters (B)<br>• Trends in nutritional contribution of biodiversity: Food composition (B) (decision VII/30 and VIII/15)<br>• *Trends in incidence of emerging zoonotic diseases (C)*<br>• *Trends in inclusive wealth (C)*<br>• *Trends in nutritional contribution of biodiversity: Food consumption (C) (decision VII/30 and VIII/15)*<br>• *Trends in prevalence of underweight children under-five years of age (C) (MDG indicator 1.8)*<br>• *Trends in natural resource conflicts (C)*<br>• *Trends in the condition of selected ecosystem services (C)*<br>• *Trends in biocapacity (C)*<br>**Trends in coverage, condition, representativeness and effectiveness of protected areas and other area-based approaches**<br>• Trends in area of degraded ecosystems restored or being restored (B) |
| **Target 15** – By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification. | **Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being**<br>• Status and trends in extent and condition of habitats that provide carbon storage (A)<br>**Trends in coverage, condition, representativeness and effectiveness of protected areas and other area-based approaches**<br>• Population trends of forest-dependent species in forests under restoration (C) |

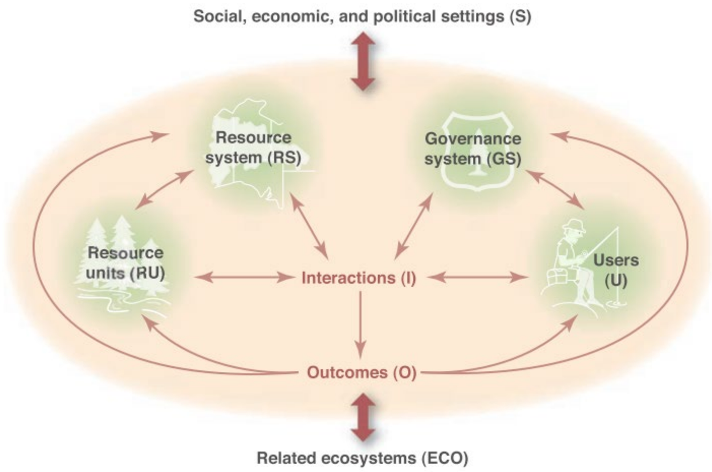
| Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building | |
|---|---|
| **Target 17** – By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan. | **Trends in integration of biodiversity, ecosystem services and benefit sharing into planning, policy formulation and implementation and incentives**<br>• Trends in implementation of national biodiversity strategies and action plans, including development, comprehensiveness, adoption and implementation (B) |
| **Target 18** – By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels. | **Trends in integration of biodiversity, ecosystem services and benefit sharing into planning, policy formulation and implementation and incentives**<br>• Trends in land-use change and land tenure in the traditional territories of indigenous and local communities (B) (decision X/43)<br>• Trends in the practice of traditional occupations (B) (decision X/43)<br>**Trends in accessibility of scientific/technical/ traditional knowledge and its application**<br>• Trends in which traditional knowledge and practices are respected through their full integration, safeguards and the full and effective participation of indigenous and local communities in the national implementation of the Strategic Plan (B)<br>**Trends in accessibility of scientific/technical/ traditional knowledge and its application**<br>• Trends of linguistic diversity and numbers of speakers of indigenous languages (B) (decision VII/30 and VIII/15) |
| | |

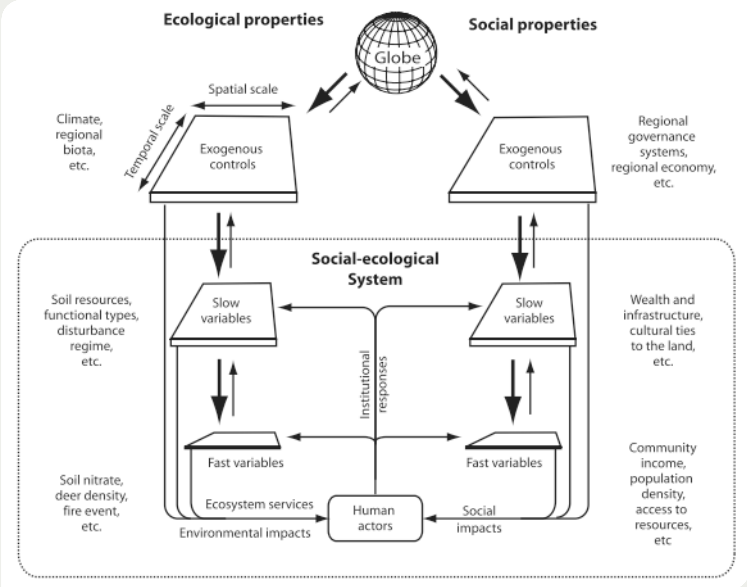
# Appendix 4

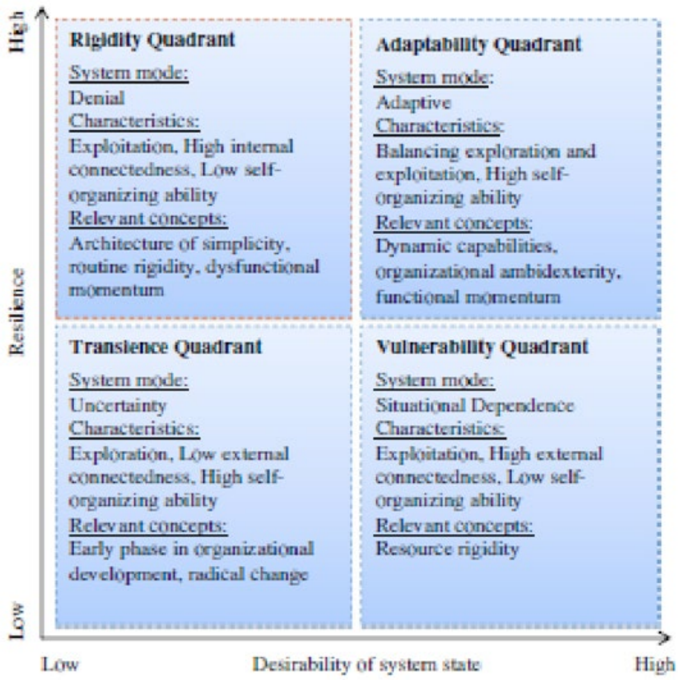
## Review of Resilience Indicators

| PROPOSED INDICATORS OR INDICATOR FRAMEWORKS | BRIEF NOTES AND REFERENCE |
|---|---|
| The Resilience Alliance hosts an online database on Thresholds and Regime Shifts in Ecological and Social-Ecological systems | http://www.resalliance.org/index.php/thresholds_database (Walker and Meyers, 2004) and an online Regime Shifts Database is an active initiative of the Stockholm Resilience Centre (http://www.regimeshifts.org/). While this is an extensive and growing resource, it is specific to particular studies and does not provide high-level or universally applicable indicators. |
| 'Resilience surrogates' derived from system dynamics archetypes (e.g. Limits to Growth with threshold, Tipping Point, Shifting Tipping Point). Examples of surrogates: state of the system relative to threshold, rate of system approach to thresholds, threshold location, rate of change of threshold location | *Ecosystems* special feature (Bennett et al., 2005)<br>Recommends using 'resilience surrogates', defined as 'quantifiable proxies derived from theory for use in assessing the resilience of social-ecological system'.<br>Steps for deriving resilience surrogates:<br>• Problem definition: what aspects of the system should be resilient and what kinds of change would we like the system to be resilient to?<br>• Identify feedback processes<br>• Design a systems model<br>• Use the syste*ms model to identify resilience surrogates*<br>System archetypes are a useful bridge between informal and formal descriptions of system function. |
| Quantifiable measures of system identity, (where particular measures are subjective and case-specific) and thresholds for these measures | *Ecosystems* special feature (Cumming et al., 2005)<br>Identify quantifiable measures of the following aspects of system identity:<br>• Components (e.g. focal habitat, cultural groups)<br>• Relationships (e.g. food webs, land tenure)<br>• Innovation (e.g. biodiversity, cultural & livelihood diversity)<br>• Continuity (e.g. seed banks, institutional memory, oral history)<br>'Definitions of identity will necessarily be based on human decisions and values. Given the impossibility of studying all aspects of any real-world system, some level of subjectivity in determining which system properties to study seems inevitable in any applied study of resilience.'<br>Define possible future systems (with the same and different identities), clarify change trajectories and likelihoods of alternate futures, and identify mechanisms and levers for change. |
| Example 'rules of thumb': 'big picture' view of threats and opportunities, far-reaching and accurate information networks, trust-building with stakeholders, include choices beyond current experience of farmers and agricultural professionals, use all forms of knowledge, flexible planning structures and processes, strong learning and support infrastructure, foster sense of purpose and belonging, confidence and optimism, confront change, strong leadership, live with uncertainty and admit mistakes, equitable and rapid access to resources | (Darnhofer et al., 2010)<br>Requires 'a participatory approach to establishing and assessing resilience surrogates (Ingrand et al., 2007), making a transdisciplinary approach a prerequisite. It follows that resilience needs to be understood as an emergent property of the system, which is strengthened or weakened through the interaction between farmer and farm, and between the farm and its context.'<br>Recommends surrogates of resilience, where specific expression depends on context. Provides examples of rules of thumb inferred from transdisciplinary work. |

| PROPOSED INDICATORS OR INDICATOR FRAMEWORKS | BRIEF NOTES AND REFERENCE |
|---|---|
| Behaviour-based indicators: Socially self-organized, Ecologically self-regulated, Appropriately connected, Functional and response diversity, Optimally redundant, Spatial and temporal heterogeneity, Exposed to disturbance, Coupled with local natural capital, Reflective and shared learning, Globally autonomous and locally interdependent, Honours legacy while investing in the future, Builds human capital, Reasonably profitable | (Cabell and Oelofse, 2012)<br><br>Presents 'an index of behaviour-based indicators that, when identified in an agroecosystem, suggest that it is resilient and endowed with a capacity for adaptation and transformation … their absence or disappearance suggests vulnerability and movement aware from a state of resilience'. The 13 behaviour-based indicators come from reviews of the resilience literature, and each refers explicitly to different phases in the adaptive cycle. |
| Diversity, Vulnerability of connections and networks (modularity, Tightness of feedbacks, Openness, Reserves (natural, social, economic), Leadership and social capital | (Cork, 2011)<br>http://www.environment.gov.au/system/files/pages/ba3942af-f815-43d9-a0f3-dd26c19d83cd/files/soe2011-supplementary-framework-assessing-resilience-soe-2011-reporting.pdf<br><br>Recommends assessment against resilience components drawn from the resilience literature, structured to inform and support the DPSIR reporting framework (Driving forces, pressures, state, impacts, responses). |
| **Buffer capacity**<br>Endowments/entitlements, Human capital – literacy level, Knowledge (experience), Skills, Health condition, Financial capital – income/yields, Savings<br>Labour income, Expenditure, Dependency ratio (DR), Social capital, Physical capital, Natural capital<br>**Self-organization**<br>Institutions, Cooperation and networks, Participation, Trust<br>Reciprocity, Network structure, Reliance on own resources,<br>**Capacity for learning**<br>Knowledge of threats and opportunities, Shared vision, Commitment to learning, Knowledge identification, capability-monitoring, Planning, Participation to access information, Experimentation, Openness, Knowledge-sharing capability, Knowledge transfer capability, Functioning feedback mechanisms<br>Diversity (a cross-cutting dimension) | (Ifejika Speranza et al., 2014)<br>Provides a framework for a 'comprehensive empirical analysis of livelihood resilience' based on theoretical and empirical resilience literature. The framework identifies three dimensions of resilience: buffer capacity, self-organization, capacity for learning. 'Resilience is maintained when buffer capacity exists and is not declining, self-organization exists and is promoted, and learning occurs.'<br>'A livelihood approach focuses on the following components and their interactions: the livelihood context, the livelihood capitals (assets), the institutions and processes mediating/influencing livelihood strategies … and the livelihood outcomes and trade-offs.'<br><br>Critical points for any empirical analysis:<br>• Understand the SES within which livelihoods occur<br>• Understand the positions of the farmers within an SES (e.g. does the SES make the resources needed available or accessible, what capacities to actors have to influence their SES?)<br>• Analysis of individual actor/farm-level capacities and processes that shape resilience. |

| PROPOSED INDICATORS OR INDICATOR FRAMEWORKS | BRIEF NOTES AND REFERENCE |
| --- | --- |
| Natural capital (air, water, land, habitats)<br><br>System variables and speeds for different system types<br><br>Ecological parameters (components, relationships and functions, diversity, memory and continuity) and associated fast and slow variables.<br><br>Livelihood parameters (well-being, poverty, income, vulnerability, food security, sustainable resource use)<br><br>Cooperative natural resource management framework (context, conditions, representation, power, process)<br><br>Adaptive co-management characteristics for social learning and collaboration (pluralism, communication and negotiation, transactive decision-making).<br><br>Tangible (e.g. agreed upon sanctions) and intangible (e.g. creative ideas for solving problems) outcomes | (Plummer and Armitage, 2007)<br><br>The framework is for the evaluation of three broad components of adaptive co-management: ecosystem conditions, livelihood outcomes, process and institutional conditions.<br><br>Acknowledges a fundamental problem: 'because an evaluative mechanism is ill-positioned to deal with emerging views of reality, such as complex systems theory … "many evaluations of collaborative policymaking miss the mark because they come from the perspective of an older, modernist paradigm of policymaking predicated on the assumption that policies can be designed to produce predictable outcomes, even in very complex settings" '.<br><br>The authors 'consider the tenets for a 'new mindset' for evaluation that corresponds to a complex adaptive systems view'. Systems are self-organizing with properties emerging from nested levels via multiple interactions and feedback mechanisms. Their proposed evaluation framework is based on complexity thinking. |
| Four core subsystems:<br>1. Resource systems<br>2. Resource units<br>3. Governance systems<br>4. Users<br><br>Multiple second-level variables for each of these subsystems, as well as for: interactions; outcomes; related ecosystems; and social, economic and political settings.<br><br>A subset of 10 of these second-level variables have been identified as affecting the likelihood of self-organization in efforts to achieve a sustainable SES. | (Ostrom, 2009) and (Ostrom et al., 2007)<br><br>'We need to recognize and understand the complexity to develop diagnostic methods to identify combinations of variables that affect the incentives and actions of actors under diverse governance systems. To do this we need to examine the nested attributes of a resource system and the resource units generated by that system that jointly affect the incentives of users within a set of rules crafted by local, distal or nested governance systems to affect interactions and outcomes over time.'<br><br><br><br><br>The framework aims to provide empirically supported answers to these questions:<br>1. 'What patterns of interactions and outcomes, such as overuse, conflict, collapse, stability and increasing returns are likely to result from using a particular set of rules for the governance, ownership and use of a resource system and specific resource units in a specific technological, socioeconomic and political environment?'<br>2. 'What is the likely endogenous development of different governance arrangements, use patterns and outcomes with or without external financial inducements or imposed rules?'<br><br>**'How robust and sustainable is a particular configuration of users, resource system, resource units and governance system to external and internal disturbances?'** |

| PROPOSED INDICATORS OR INDICATOR FRAMEWORKS | BRIEF NOTES AND REFERENCE |
|---|---|
| Exogenous controls, slow variables, fast variables, actors and their interactions and feedbacks | (Chapin et al., 2009)<br> |
| System-specific controlling variables and thresholds<br><br>Attributes of a resilient world:<br><br>Diversity (biological, landscape, social, economic), policies and processes that emphasize diversity and not just efficiency; Ecological variability; Modularity; Acknowledging slow variables; Tight feedbacks; Social capital; Innovation, learning and experimentation; Overlap in governance; Ecosystem services included in development proposals and assessments; Fairness/equity; Humility | (Walker and Salt, 2012)<br><br>A practical guide to applying resilience thinking to real-world social-ecological systems. Key components are:<br>1. Describing the system – identifying system drivers, controlling variables, feedbacks and thresholds.<br>2. Assessing resilience:<br>a. specified resilience, alternative regimes, thresholds and cross-scale interactions<br>b. general resilience<br>c. transformability<br>3. Managing resilience – adaptive cycles informing when and where to intervene, adaptive management and governance.<br><br>Case studies show how assessment framework is used to elicit the key variables and system attributes to measure, monitor and manage. |
| Attributes or indicators of general resilience<br><br>Diversity, Connectivity, Modularity, Reserves, Governance, Shared mental model, Social capital, Social cohesion, Agency, Self awareness, Economic capacity/farm viability, Time since and nature of shocks | (Walker et al., 2014)<br><br>Identified twelve components of general resilience relevant to natural resource management in Australian catchment social-ecological systems. Components were also given one of two levels of confidence. The author cautioned that 'In assessing general resilience it is not a handbook that is needed but a way of thinking, and the process has to be adaptive'. Conceptual rigour identified as important for codification. Recognition that social components are least understood or recognized.<br><br>Identified nine forms of influential interventions. |
| Indicators of intentional transformability or transition to a new regime – value change, integrating knowledge and learning, distributed governance, effective social networks, effective agency, 'safe arenas' in which to develop and test new ideas, rule changes, new investment patterns, and monitoring and adjusting the transition path. The transition would necessarily cross scales from urban centres and farms to sub-national and national governments | (Abel) et al. (in prep.)<br><br>Proposes these indicators of transformability, which operate across scales, rather than focusing on just one scale rather than focal scale. |

| PROPOSED INDICATORS OR INDICATOR FRAMEWORKS | BRIEF NOTES AND REFERENCE |
|---|---|
| This paper works from this premise: 'existing approaches of resilience… fail to recognize the dual manifestation of persistence as either capacity for adaptive learning, or resistance to change. The major consequence of this conceptualization is that resilience is not always desirable system characteristic and thus cannot be a target in itself'. Proposes Resilience Architecture Framework, which may have application in the current task for this report, but has not yet been explored in detail (last minute inclusion) | <br><br>Limnios et al., 2014 |
| FAO's Resilience Index Measurement and Analysis (RIMA) | FAO has developed a resilience framework over some years, based on developing a Resilience Index for households. It is made up of six dimensions, four of them direct measures of income and food, services, assistance and assets, and two, more complex, estimates of adaptive capacity and stability. It has been incorporated into an econometric approach, the Resilience Index Measurement and Analysis (RIMA) model, which is used to compare household livelihood groups. It is useful tool for their purposes but for the approach being developed in this report the single (household) scale is too limiting. |
| The Toolkit for the Indicators of Resilience in Socio-Ecological Production Landscapes and Seascapes (SEPLS) | UNU–IAS, Bioversity International, IGES and UNDP (2014) produced a simple guide to the indicators for resilience and how to use them. The indicators are grouped into those for landscape/seascape diversity and ecosystem protection, biodiversity, knowledge and innovation, governance and social equity, livelihoods and well-being. The guide also covers practical steps to using these indicators in a resilience assessment, providing useful advice for the preparation, running and follow-up of workshops. |

# Appendix 5
## Evaluation of utility of indicators against documented purposes

**TABLE 10 ASSESSING THE UTILITY OF PROPOSED APPROACH AGAINST DOCUMENTED PURPOSES – DETAILED ANALYSIS**

| PURPOSE | DETAIL |
|---|---|
| It is a valuable way to develop and articulate a narrative, or storyline (paragraphs 12, 13) | *'12. Ideally, "storylines" developed at local scale, that is, the documented history of successes and failures experienced at a particular site threatened by desertification and related processes, should provide the information and knowledge required to understand the dynamics of DLDD [Desertification, Land Degradation, Drought] processes. The production of storylines should be supported by a coordination system across spatial and governance levels, backed up by sufficient resources to deliver the quality that is required to feed the local understanding of the land degradation and desertification systems, to plan local mitigation and adaptation policies, and inject fresh ideas and concepts to enable the adaptive evolution of the M&E approach, including the necessity of new indicators.*<br><br>*13. Building and continuously updating storylines at representative hot and cold spots (see section II.A below) in each country emerges as the main source of local information (documentation and ground survey), which can be shared between Parties and framed in global assessments.'* COP(11)/CST/2 |
| It is amenable to selecting the most relevant indicators from existing databases/reporting requirements, and guiding the importance or utility of gathering other more locally specific indicators in accordance with the analysis and narrative (Recommendation 4) | *'3. Recommendation 4 It is recommended that the set of common, global progress indicators be complemented with formal and narrative indicators at national/local scale that could be sourced from (predominantly) local storylines and could provide more detailed information on the level and characterization of land degradation that is specific to each context.'* COP(11)/CST/2 |
| It could complement the call for a for a new indicator integration framework (recommendation 5, UNCCD 2013a) to track progress and report at multiple scales, explicitly including human-environment interactions | *'C. Conceptual indicator integration framework*<br><br>*Recommendation 5 It is recommended that a new indicator integration framework be implemented as part of the M&E approach to track progress and report at multiple scales on meeting policy objectives addressing DLDD. The new integration framework, DPSheIR, allows impacts on human well-being to be recorded along with impacts on ecosystem services'* COP(11)/CST/2 |
| It is proposed in UNCCD 2013a that a modified Driver-Pressure-State-Impact-Response – Millennium Assessment (DPSIR – MA) conceptual framework, called Driver-Pressure-State(human x environment)-Impact-response (DPSheIR) (paragraphs 36 – 45), be combined with an systems dynamic-based understanding of desertification processes (SDUDP) (paragraph 46) to describe the listed interactions | *'46 (a) Enabling the upscaling/downscaling feedback loop that allows synergy between the local and global levels (see section E below);*<br><br>*(b) Drawing storylines able to integrate the work of national action programmes (NAPs) and to help Parties to solve their own problems and, in particular, characterize the hot/cold spots identified in the advanced delineation of affected areas (see paragraph 12 above);*<br><br>*(c) Providing Parties with conceptual and functional support to their chosen indicators sets, which improves their capacity to interpret them (see Recommendation 8);*<br><br>*(d) Ensuring comparability between countries through the syndrome approach (see paragraph 22 above);*<br><br>*(e)Helping the formulation of research and action project (see paragraph 50 below); below);*<br><br>*(f) Delivering DLDD information at global scale in line with a GDOS (see paragraph 25 above) and framing synergies with global initiatives (SLM) (see paragraph 34 above)'* COP(11)/CST/2 |

| PURPOSE | DETAIL |
|---|---|
| If implemented in a participatory fashion at a more localized local scale, or across nested scales from local through to national, could meet the need for engaging local stakeholders, and harmonizing the approach across reporting scales (paragraphs 48, 49) and potentially help to realize or synergistic links between environmental interventions and development efforts (paragraphs 50 – 52) | *'(b) Implementation guideline*<br><br>*(i) Engaging local stakeholders*<br><br>*48. NAPs comprise local activities on the one hand, and contribute to global M&E needs on the other. In aligned NAPs, objectives, targets and benchmarks should be set based on socioeconomic and biophysical baseline information and in harmony with the required reporting process. This is possible through engagement with a wide range of relevant local stakeholders from the start of the NAP alignment process when developing appropriate M&E procedures.*<br><br>*49. It is therefore essential that the NAP alignment process include a harmonized approach for soliciting local input from local stakeholders, so that this can inform national to global reporting. Furthermore, the importance of area-based or territorial development approaches is increasingly recognized in addressing complex development problems in specific geographical areas. Key characteristics of such approaches are: bottom-up and participatory (highlighting the involvement of stakeholders), inclusive (across different societal groups), integrative (across economic sectors) and flexible (i.e. responsive to changes) (Harfst, 2006; Vrbensky, 2008).*<br><br>*(ii) Integrating monitoring and evaluation efforts in community development activities*<br><br>*50. M&E of DLDD should not be done simply as a mandatory reporting exercise to the COP, but rather should be incentivized through the benefits that it can bring to local/national development. Reporting on indicators should therefore involve the local assessment of the outcome of the M&E process, and should be driven by the local/national need for the data, rather than the global reporting obligation. Land degradation and human well-being are intrinsically linked; however, environmental interventions and development efforts are not always carried out synergistically.*<br><br>*51. Integration of DLDD and SLM M&E into community development required to highlight the benefits of M&E and reporting to broader development efforts at the local level. From a policy perspective, this link can be promoted through a more formal tie between NAPs and CDPs.*<br><br>*52. The value of participation in progress indicator selection and reporting at the local level is the capacity for resultant M&E data to inform decision-making intended to improve livelihoods and overall well-being. It is therefore essential that efforts to combat desertification include an M&E component that is tied to (and can strengthen) community development activities'* COP(11)/CST/2 |

| | |
|---|---|
| The proposed approach could directly meets call for an explicit incorporation of positive feedback loops between local and global scales, as discussed in recommendation seven, and paragraphs 56–62 | *'E. Linking across scales*<br><br>***Recommendation 7 It is recommended that a positive feedback loop (both ways) be built between local and global scales supported by a coordination system across spatial and governance levels. The national level should be responsible for identifying sites and systematically gathering the storylines coming from local M&E that are required to understand the dynamics of DLDD. The global level should be responsible for generalizing this information over the national, sub-regional, regional and global levels.***<br><br>***(a) Rationale***<br><br>*56. In the present situation there is a lack of information flow. Parties deliver their evaluations of strategic objectives through global indicators in their territories without any feedback, while their local indicators are developed and applied locally. The whole system is therefore unable to react in an integrated way and deal appropriately with DLDD. The creation of a coordination system across spatial and governance levels would enable an information flow across UNCCD institutions so as to provide support to policies and specific actions in the field of desertification and land degradation.*<br><br>***(b) Implementing guideline***<br><br>*Scale dependency of indicators*<br><br>*57. Indicators of land degradation and desertification are scale-dependent; that is, the resulting measurement depends on the area being considered and the process of land degradation being assessed. Thus, technical, logistical and scientific issues make the aggregation of indicator data from local to global scale challenging. At the same time, for some indicators it is easier and more accurate to recapture the data at different scales, rather than attempting to consolidate and aggregate data. Nevertheless, the storylines coming from local M&E can be upscaled for global reporting, enhancing the potential to generate information and knowledge from the minimum set of global progress indicators used by all Parties. In this sense, using the correct indicator for a situation-specific purpose may be more important than the need to upscale/downscale these specific data. The combined and parallel use of global progress and national/local formal and narrative indicators can thus strengthen the reporting on combating DLDD. In addition, facilitating the upscaling of local to national storylines into global reporting allows the number of common progress indicators to be limited, focusing on the strategic objectives only.*<br><br>*58. In the case of intrinsic scale dependency of indicators/variables (i.e. if their values change with their resolution), special care should be taken when considering the integration, and in particular the aggregation, of such data. Note that integrating (upscaling or downscaling) indicators is distinct from aggregating indicators (e.g. by calculating a weighted index) across scales. Indicator metrics/proxies (including their units) need to be carefully specified in the UNCCD reporting manual for strategic indicators and performance indicators,5 and precautions need to be taken if metrics/proxies are integrated or aggregated to document DLDD at a lower spatial resolution/less-detailed spatial scale.*<br><br>*59. In the case of contextual scale dependency of indicators/variables (i.e. they change across scales embedded in more generic variables), upscaling and downscaling will be possible only if they are supported by the same function across scales. This suggests the need for a common integration protocol, with the national level responsible for identifying sites, systematically gathering the storylines coming from local M&E that are required to understand the dynamics of DLDD, and generalizing this information over the national, sub-regional, regional and global levels.*<br><br>*60. Integration of formal and narrative indicators (potentially at all scales) could be harmonized and normalized through the use of easy-to-understand ordinal scales tailored to each indicator, such as the scorecard approach that the United Nations Development Programme, the United Nations Environment Programme and the Global Environment Facility (GEF) have implemented on capacity development in GEF projects.*<br><br>*61. Thus, the combined use of global progress and national/local formal and narrative indicators allows both reporting globally, while maintaining relevant and context-specific local/national information (Abraham et al., 2006; Abraham, 2009), and dealing locally with global constraints (Kiparsky et al., 2012).'* COP(11)/CST/2 |

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