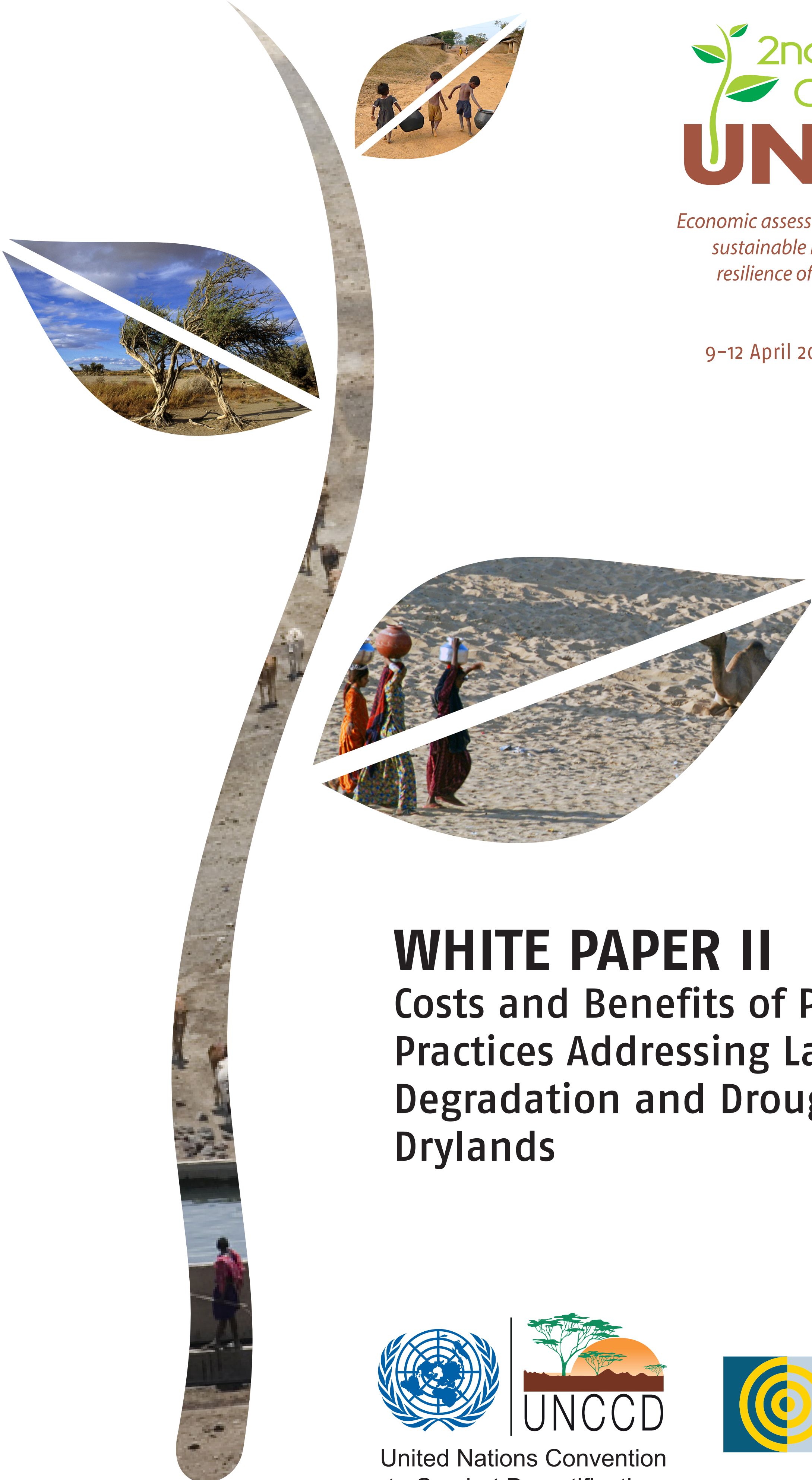

2nd Scientific Conference
UNCCD

*Economic assessment of desertification, sustainable land management and resilience of arid, semi-arid and dry sub-humid areas*

9–12 April 2013 – Bonn, Germany

# WHITE PAPER II
## Costs and Benefits of Policies and Practices Addressing Land Degradation and Drought in the Drylands

UNCCD
United Nations Convention to Combat Desertification

GLOBAL RISK FORUM
GRF DAVOS
GRF

We would like to extend our sincere appreciation to, in particular, the Governments of Germany, Finland, the Republic of Korea, Spain, Sweden and Switzerland for their contributions and generous support. Voluntary financial contributions have helped in the preparation and organization of the United Nations Convention to Combat Desertification (UNCCD) 2nd Scientific Conference and are strengthening our scientific understanding of the social and economic drivers and consequences of desertification, land degradation and drought. By investing in science and ensuring the participation of scientists in the decision-making processes, these voluntary contributions have significantly advanced the implementation of the Convention.

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# ABBREVIATIONS

| | |
|---|---|
| CST | Committee on Science and Technology (of the UNCCD) |
| ELD | Economics of Land Degradation (initiative) |
| FAO | Food and Agriculture Organisation |
| GDP | Gross Domestic Product |
| OECD | Organization of Economic Cooperation and Development |
| SEEA | System of Environmental-Economic Accounts |
| SNA | System of National Accounts |
| TEEB | The Economics of Ecosystems and Biodiversity (study) |
| UN | United Nations |
| UNCCD | United Nations Convention to Combat Desertification (in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa) |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environmental Programme |

# ABSTRACT

- Drylands are complex social-ecological systems, characterized by non-linearity of causation, complex feedback loops within and between the many different social, ecological, and economic entities, and potential of regime shifts to alternative stable states as a result of thresholds. As such, dryland management faces a high level of uncertainty and unpredictability.
- To strengthen the scientific foundation for sustainable dryland and drought risk management, there is a need for a system approach based on transdisciplinarity with emphasis on participatory research and involvement of practitioners as well as scholars from different scientific disciplines to address problems in an integrated manner.
- A critical means to achieve sustainable dryland and drought risk management is to strengthen resilience through capacity development of individuals, communities, and systems to survive, adapt, and follow a positive trajectory in the face of external and/or internal changes, even catastrophic incidents, and rebound strengthened and more resourceful while retaining essentially the same functions.
- Another critical means is the application of an ecosystem services approach to ensure proper attention to the dynamic and interlinked provisioning, regulating, supporting, and cultural dryland ecosystem services. The ecosystem services approach has proven particularly useful and challenging for economic valuation of sustainable dryland and drought risk management as a basic tool for direct management purposes as well as policy decision-making.
- Based on a comprehensive literature review of recent peer-reviewed scientific journals complemented with grey literature, this White Paper provides an introduction to current thinking about economic valuation techniques related to different aspects of dryland management and policy-making. The paper highlights the challenges that exist, the different opinions about the best way to address environmental economic valuations, and the many assumptions that need to be clearly identified for each exercise in order to communicate the results efficiently to decision-makers at all levels.

# PREAMBLE

The term 'drylands' invokes different associations for different people: beautiful deserts, poor people desperately trying to make a living in a hostile environment, cowboys roaming on the prairies, proud Maasai people claiming their rights to continue their 1,000-year old pastoralist way of living, irrigated tomato fields, oases in the middle of endless miles of scorched soils, to name a few. That there are many different aspects associated with the dryland concept is not surprising, considering that drylands cover more than 40% of the Earth's land mass and are distributed on all continents. Drylands therefore cover an endless number of cultures, traditions, and livelihoods as well as a great variety of dryland ecosystems. What unites those different areas is of course the dryness or the aridity and with that the constant need to adapt to actual and potential water scarcity whether it is a natural ecosystem or a social-ecological system. With the aridity comes the management of scarce resources and hence the importance of sound economic management to ensure sustainable use of the drylands.

Unfortunately, what also unites many drylands is the ongoing degradation and challenges in maintaining the important outputs that the drylands provide humanity, such as agricultural productivity, carbon sequestration, global biodiversity, and spiritual and recreational services. Over the last decades, the international community has therefore given increasing attention to ensuring sustainable land use management with emphasis on integrating social, economic, and environmental aspects. The need for a holistic approach to ensure sustainability in the drylands was highlighted at the Rio Earth Summit in 1992 and it is a key principle in the UN Convention to Combat Desertification and Mitigate the Impact from Droughts (UNCCD) from 1994.

The recognition that the Earth is one system with strong interrelationships and dependency among the economic, social, and ecological subsystems is also the basis for the broader concept of 'green economy'. Over the last years, the importance of 'green economy' has gained increasing recognition and it was highlighted in the 2012 outcome document of the Rio+20 Summit: "The Future We Want."[1] The document, furthermore, underlines that the green economy should be based on holistic approaches integrating sustained economic growth, improved human welfare, employment opportunities, social inclusion, and poverty eradication, while sustaining ecosystem services.

To foster sustainable dryland and drought risk management we need true interdisciplinary and multi-stakeholder involvement, i.e. a transdisciplinary approach in the development of a green dryland economy. Each discipline and each stakeholder group will have their own traditions for research, development, and communication and there will be many different approaches to address the dryland development issues. The challenge will be to ensure that the different stakeholders work together and that their input will be complementary and end up in a green dryland economy that makes sense for everybody and that will secure and improve dryland-based livelihoods throughout the world.

[1] United Nations (2012) "The Future We Want" United Nations, New York uncsd2012.org/content/documents/727The%20Future%20We%20Want%2019%20June%201230pm.pdf

In March 2012, the organizers of the 2nd UNCCD Scientific Conference convened a working group for the preparation of two White Papers on Economic Assessment of Desertification, Sustainable Land Management, and Resilience of Drylands. In line with the principles of the new green economy, the working group consisted of scientists different biological, physical, and socio-economic disciplines as well as dryland development practitioners from around the world. Together they agreed on a set of critical issues that should be addressed in White Papers on the economics of sustainable dryland development. As a result, we now have two White Papers presenting the current thinking of how to assess the economics of land degradation and sustainable dryland and drought risk management. This White Paper specifically addresses the costs and benefits of policies and practices for sustainable land and drought risk management, including resilience management based on an integrated system approach to social-ecological systems.

The subject is vast and there will be a number of omissions and probably also wrong interpretations of the discipline specific findings that form the basis of this White Paper. Your inputs and comments are therefore needed and very welcome.

Many Thanks,

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# PART 1: TECHNICAL DISCUSSION

# 1. BACKGROUND

1. The 1994 UN Convention to Combat Desertification (UNCCD)[2] is a remarkable international agreement. Through the UNCCD, more than 190 ratifying countries as well as the European Union have committed to effectively address land degradation in the drylands[3], i.e. desertification, and reduce the risks of severe drought impacts. The UNCCD has definitely increased international attention to dryland degradation and related socio-economic predicaments such as marginalization, poverty, and food insecurity. Still, sustainable dryland and drought risk management remains a far-fetched goal. A critical challenge is the limited knowledge and understanding of the complex processes in dryland ecosystems. For instance, in a 2011 review[4] of the implementation of the follow-up to the 1992 Rio Earth Summit[i5], UNEP explains that the review did not cover land degradation because of lack of information that met the data criteria for the review[6]. Likewise, the UNDP Disaster Risk Index[7] from 2004 did not include country specific information on drought risk because of methodological challenges.

2. The 2011 UN Global Assessment Report on Disaster Risk Reduction[8] asserts that the fact that there is still no credible drought risk model is partly a result of the complexity of drought risks with many different social, biological, and climatic drivers. Moreover, droughts are slow-onset events that typically require a minimum of two to three months to become established. While droughts can continue for years socio-economic impacts are normally deferred over time[9] making assessments more complicated and controversial. Consequently, drought is often left out of disaster risk management assessments and impact models. So in spite of improved methods to assess the biophysical aspects of land degradation and drought risks, there are still limited reliable socio-economic data on the costs and benefits of sustainable dryland and drought risk management. The methodological challenges are enormous. E.g., how to deal with indirect impacts, how to value environmental processes and stocks where market values do not exist, and what should be the space and time limits for the assessments? These challenges are even more pronounced when dealing with countries and regions with weak statistical systems, which is the

[2] The full name of the UNCCD is "United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa." The objective of the UNCCD is to "…combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification..." As such, the UNCCD addresses both desertification and drought. unccd.int/Lists/SiteDocumentLibrary/conventionText/conv-eng.pdf

[3] We use the term 'drylands' for arid, semi-arid, and dry sub-humid areas, i.e. areas classified according to their aridity and where the potential amount of water that is transferred from the land to the atmosphere is at least 1.5 times greater than the precipitation according to the definitions of the UNCCD. The UNCCD does not use the term 'drylands' but it is common practice to refer to 'drylands' in the context of desertification discussions. It should be noted, that in some contexts 'drylands' also include hyper-arids; i.e. deserts, which account for around 8% of the total land mass of the Earth, while arid, semi-arid, and dry sub-humids cover around 40%. The UNCCD does not include hyper-arids in the desertification definition.

[4] UNEP (2011) "Keeping Track of Our Changing Environment – From Rio to Rio+20 (1992 – 2012)" United Nations Environmental Programme, Nairobi unep.org/GEO/pdfs/Keeping_track.pdf

[5] In 1992, the first UN Conference on Sustainable Development, known as the Rio Earth Summit, was convened in Rio de Janeiro, Brazil to address the state of the environment and sustainable development. The Earth Summit developed the framework for a new generation of global environmental treaties, including the UNCCD.

[6] The three data criteria were: 20-year temporal data, coverage of most countries, and reliable sources.

[7] UNDP (2004) "Reducing Disaster Risk – A Challenge for Development" United Nations Development Programme, Bureau for Crisis Prevention and Recovery, Geneva.

[8] UNISDR (2011) "Global Assessment Report on Disaster Risk Reduction" United Nations International Strategy for Disaster Reduction, Geneva preventionweb.net/english/hyogo/gar/2011/en/home/download.html

[9] Cardona, O.D. (2007) "Indicators of Disaster Risk and Risk Management" National University of Columbia – Manizales & Inter-American Development Bank, Washington D.C.

case in many dryland countries, particularly in Africa and the Middle East[10]. As a result, a great deal of recent work on disaster risk indexes, which includes droughts, focuses only on direct losses of human lives[11]. Likewise, the Disaster Risk Index presented in the 2011 World Disaster Report[12] does not include critical factors such as disaster preparedness and early warning capacity because of lack of data; components that are critical for resilience of complex systems as will discuss in chapter 2.

3. In spite of the growth in scientific research and studies on ecosystem valuations, research shows a misconception in the public about the benefits provided by dryland ecosystems. According to a recent Spanish study[13], for instance, 20% of local inhabitants, visitors, environmental experts, and other stakeholders considered that drylands did not provide benefits. This was in contrast to other ecosystems such as forests and mountains. While we are unaware of a proper assessment of the distribution of environmental economic research[14] between dryland and non-dryland ecosystems, the general research that has gone into the preparation of this White Paper indicates a limited focus on drylands. It can therefore be argued that the limited scientific knowledge about the potential values of the drylands has led to underinvestment in these areas compared to more humid areas that are generally perceived as more productive, less vulnerable, and more resilient.

4. In an effort to upgrade the scientific base for the implementation of the UNCCD, parties to the Convention decided in 2007 to reshape the UNCCD Committee on Science and Technology (CST) in line with the 10-Year Strategic Plan and Framework for the Implementation of the Convention (2008–2018)[15]. One of the initiatives to strengthen the CST is the organization of scientific conferences to enhance the knowledge base about desertification and drought processes. The first UNCCD Scientific Conference was organized in 2009[16] under the theme "Understanding Desertification and Land Degradation Trends." The second Conference will take place in April 2013 and will focus on "Economic Assessment of Desertification, Sustainable Land Management, and Resilience of Arid, Semi-Arid and Dry Sub-Humid Areas."

5. The 2nd Scientific Conference will build on recent global initiatives addressing the shortage of economic data to promote and guide restoration of degraded land, zero net land degradation, and minimizing the impacts from droughts. Among the recent initiatives should be mentioned, the Economics of

[10] See for instance the Bulletin Board on Statistical Capacity, World Bank, worldbank.org

[11] This, for instance, is the case in the follow-up work to UNDP's 2004 Disaster Risk Index: Peduzzi, P. et al. (2009) "Assessing Global Exposure and Vulnerability towards Natural Hazards: the Disaster Risk Index" Natural Hazards and Earth System Sciences, 9 pp. 1149-1159.

[12] UNU (2011) "World Disaster Report – 2011" United Nations University ehs.unu.edu/file/get/9018

[13] Martín-López, B. et al. (2012) "Uncovering Ecosystem Service Bundles through Social Preferences" PLoS ONE 7(6) plosone.org/article/info:doi/10.1371/journal.pone.0038970

[14] We use the term 'environmental economics' here as a broad concept for all economics concerned with environmental and natural resource issues. We recognize the many schools of economics related to environmental and natural resource issues, including ecological economics, as we will discuss later in this White Papaer.

[15] UN (2007) "Report of the Conference of the Parties on its Eighth Session, held in Madrid from 3 to 14 September 2007 – Addendum - Part two: Action taken by the Conference of the Parties at its Eighth session" UNCCD Secretariat unccd.int/Lists/OfficialDocuments/cop8/16add1eng.pdf

[16] dsd-consortium.jrc.ec.europa.eu/php/index.php?action=view&id=150

Land Degradation (ELD)[17] which was launched in 2011 by the German Ministry for Economic Cooperation and Development (BMZ), the European Union, the Secretariat of the UNCCD, and the Korean Forest Service. In preparation of the ELD initiative, a preliminary study[18] was prepared in 2011 focusing primarily on the impact of desertification on specific ecosystem services. The study underlines that comprehensive valuation of the cost of desertification is a highly complex task. Substantial work is therefore still required to reach acceptable assessment models with commonly agreeable boundaries regarding issues such as what indirect costs to be integrated and the timeframe for the valuations. The 2nd Scientific Conference therefore comes when a lot of interesting method development and testing is taken place to enhance our knowledge of the economic and social values of sustainable dryland and drought risk management. This ongoing work of leading international research and development institutions will form a critical contribution to the Conference and be further tested and complemented by research and development results from other partners.

6. In preparation of the Conference, two complementary White Papers on the valuation of dryland economics, including drought risk management, have been prepared to present the current scientific understanding and knowledge. The present White Paper addresses methodologies and approaches for assessing costs and benefits of sustainable dryland management policies and practices with a special focus on ecosystem services and resilience.

7. The Scientific Conference will offer a platform for exchange of information between researchers, but it will still bear the hallmark of the UNCCD principle of multi-stakeholder participation and partnerships. In this way, it will bring together not only scientists from many different fields but also dryland and drought risk management practitioners and policy makers. As such, the Conference will provide a platform where science, policy, and society interact. The combination of many different stakeholder groups and disciplines offers the possibilities for a rich discussion and development of realistic solutions. However, it also presents special communication challenges and a need for a common language that is void of scientific and discipline specific slang. The White Paper therefore attempts to offer an easy introduction to identify the current key issues, methodologies, and application of methods for assessing sustainable dryland management, dryland resilience, and ecosystem services. The two White Papers will be presented at the Conference and comments and inputs will be integrated into their finalization. The principal goal is then to present relevant policy decision makers with available options and possible scenarios for assessments of social and economic values of sustainable dryland and drought risk management.

[17] ELD's scientific partners include the International Food Policy Research Institute (IFPRI), the Stockholm Environment Institute (SEI), the Global Mechanism (GM-UNCCD), the United Nations University (UNU), and the German Center for Development Research (ZEF). eld-initiative.org/.

[18] Nkonya, E. et al. (2011) "The Economics of Desertification, Land Degradation, and Drought Toward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150, ifpri.org/sites/default/files/publications/ifpridp01086.pdf

# 2. INTRODUCTION: DRYLAND ECOSYSTEMS, SUSTAINABLE MANAGEMENT, RESILIENCE, AND ECOSYSTEM SERVICES

## 2.1 UNDERSTANDING OF THE BASICS

8. The title of this White Paper as identified by the Bureau of the Committee on Science and Technology (CST) focuses on the costs and benefits of unsustainable dryland and drought risk management, namely desertification and drought affected areas and communities. But the Bureau also requested that the focus should be on the costs and benefits of measures to prevent desertification and negative impacts from droughts in form of policies and practices for sustainable management as well as measures to promote sustainable land use, particularly resilience and ecosystem services. This difference in focus is important and reflects a general tendency over the last years to move away from a reactive to a pro-active approach often epitomized as “prevention is better/cheaper than cure.”

9. In the following, we will present an introduction to key aspects related to sustainable dryland and drought risk management with a focus on a system approach and application of an ecosystem services valuations and social-ecological resilience. The terms of reference for the White Paper requested special focus on resilience, which is fully justifiable considering the rapidly increasing use of the concept. However, as we will show it is also a concept that is used in many different ways. In this introduction, we will present a more detailed analysis of the resilience concept and its usefulness to promote sustainable dryland and drought risk management with special attention to valuations and assessments in general. Similarly, we will review the usefulness of the ecosystem service approach. The concepts of resilience and ecosystem services are defined by complex system theory. We will therefore start the introduction with a short presentation of complex systems and drylands and the approach of environmental and ecological economics to valuate complex social-ecological systems before introducing the ecosystem services approach and resilience in relation to sustainable dryland and drought risk management. Recognizing that many concepts and terms require context specific definitions we also believe that it is critical to have clearly stated working definitions when using complex concepts. We have therefore compiled working definitions used in this White Paper in annex 1 for easy reference. Throughout the text, we have indicated when we have doubts about the underlying definitions used in the analyzed literature.

### *2.1.1 COMPLEX SYSTEMS*

10. When people refer to drylands in the sense of the UNCCD, there is an implicit reference to systems, including ecosystems, economic production systems, and social systems. Moreover, drylands are often referred to as complex systems. A common understanding of a complex system approach is therefore critical for sustainable dryland and drought risk management.

11. Renowned scholar Bertanlaffy presented the General System Theory[19] in the 1930s. The theory is based on the Aristotelian notion that the whole is more than the parts and explains the coordination

[19] Bertalanffy, L.V. (1968) “General System Theory – Foundations, Development, Application” George Braziller, New York

and processes within organisms and their functioning as a whole. As such, the general system theory addresses shortcomings of mechanics concepts in explaining phenomena such as self-regulation, metabolism in biological systems, and behavior in social systems. The 'general' refers to the common set of models, principles, and laws that is applicable to systems irrespective of field or discipline. The General System Theory is therefore par excellence relevant for interdisciplinary research[20]. Critical characteristics of systems are that 1/the whole has one or more defining functions, 2/systems are composed of interconnected and interdependent parts and each part can affect the property and behavior of the whole, and 3/the structure, i.e. how the parts are connected, is essential for system behavior.

12. Complexity refers to interconnected and interdependent parts and the term 'complex systems' refers to systems with a high degree of parts, connections, inhomogeneity, number of scales, number of subsystems, and dynamism. The complexity science has proposed various frameworks for complexity measurement and definitions of what makes a system complex[21]. In general, though, the term 'complex systems' is used in a generic way for systems characterized by:

- many different entities that are interconnected and interdependent in different ways,
- the systems are dynamic, adaptive and show emergence where system behavior cannot be predicted from knowledge of the system parts alone,
- alternative stable states exhibiting the long-term dynamics of the system,
- regime shifts to alternative stable states can be sudden as a result of thresholds,
- non-linearity of causation,
- multi-scale, and
- negative[22] (damping effects) and positive (amplifying) feedbacks.

13. The term 'complex systems' is sometimes used to refer to complicated systems. However, as highlighted by Crawford et al. (2005)[23] the difference is fundamental. What sets a complex system apart from a complicated one is the emergence and self-organization properties[24].

14. These features are defining for the notion of system resilience and hence defining for sustainability. As a result, management for sustainability in the drylands, including valuation, is essentially management of complexity, an inherent level of uncertainty[25] and unpredictability, difficulties in defining

[20] García, R. (2006)"Sistemas Complejos" , GEDISA, México City

[21] See for instance Kinsner, W. (2010) "System Complexity and Its Measures: How Complex Is Complex" Studies in Computational Intelligence 323 pp. 265-295

[22] Negative and positive feedbacks does not refer to the desired quality of the systems as such; e.g., a positive feedback can enhance an undesired quality.

[23] Crawford, T. et al. (2005) "Complexity Science, Complex Systems, and Land-Use Research" Environment and Planning B-Planning & Design 32(6) pp. 792-798

[24] CSIRO (2012) "Complex or Just Complicated: What Is a Complex System?" CSIRO Complex Systems Science au/en/Organisation-Structure/Divisions/Marine--Atmospheric-Research/Complex-systems-science-2/About-Complex-Systems.aspx

[25] As shown in climate change science, 'uncertainty' is not because of lack of research or incomplete knowledge but because of the inherent characteristics of complex systems. There are many definitions of "uncertaintly". Sigel et al. (2008) suggest that a "person is uncertain if he[/she] lacks confidence about his[/her] knowledge relating to a specific question" (Sigel, K. et al. (2008) "Conceptualising Uncertainty in Environmental Decision-Making: The Example of the EU Water Framework Directive" UFZ-Diskussionspapiere, Helmholtz-Zentrum für Umweltforschung, Leipzig

boundaries, difficulties in identifying thresholds, difficulties in recognizing slowly regime shifts that are the result of slow changes, and constantly changing patterns.

### *2.1.2 Drylands: Social-Ecological Systems*

15. Similar to ecosystems in general, the boundaries for dryland ecosystems can be delineated by many different environmental factors and a variety of classification systems exists[26]. According to the Millennium Ecosystem Assessment[27,28], ecosystems can be small units such as a small waterhole or a big river basin. The ecological boundaries of the ecosystems might be relatively easy to define in terms of land characteristics such as vegetation cover and type of soil. However, adding the social component might blur the boundaries as social actors and institutions will often reside outside the biophysical or ecological boundaries. This means that delineation of dryland social-ecological systems[29] includes boundary or scale challenges for management of critical issues such as sustainability, resilience, and socio-economic costs and benefits. The challenge of misguided management because of poor boundary definitions of social-ecological systems is exemplified in the 2005 Katrina hurricane disaster hitting New Orleans in southern USA. The severe impact from the hurricane was partly a result of limited city planning that did not account for changes in the wetland surroundings[30].

16. Another management challenge of social-ecological systems is their inherent characteristics of complexity, non-linearity, and functionality in multi-stable states[31,32]; i.e., predictability and controllability are limited. Moreover, with increasing complexity of the systems there will be increasing levels of uncertainties and ignorance about future events. With the recognition of social-ecological systems as complex and non-linear, adaptive management[33] has been introduced with a focus on processes rather than products. Adaptive management is based on learning by doing, building memory of past events, expecting the unexpected, and the notion that total risk avoidance is not in the interest of development and growth. Rather, disaster experience might strengthen the systems' resilience, as we shall develop further.

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[26] See for instance, Safriel, U. & Z. Adeel (2005) "Dryland Systems" in Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C. pp. 623-662

[27] The Millennium Ecosystem Assessment is a scientific appraisal of the state of the Earth's ecosystems and the consequences of ecosystem changes for human well-being. Based on an assessment of the sustainability of the main ecosystems, the Millennium Ecosystem Assessment identifies actions required to ensure ecosystem sustainability.

[28] Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C.

[29] Reynolds, J.F. et al. (2007) "Global Desertification: Building a Science for Dryland Development" Science 316 pp. 847-851

[30] Martin-Breen, P. & J.M. Anderies, (2011) "Resilience – A Literature Review" Rockefeller Foundation, New York, rockefeller-foundation.org/news/publications/resilience-literature-review

[31] Berkes, F. (2007) "Understanding Uncertainty and Reducing Vulnerability: Lessons from Resilience Thinking" Natural Hazards (41) pp. 283-295

[32] Turner II, B.L. et al. (2003) "A Framework for Vulnerability Analysis in Sustainability Science" Proceedings of the National Academy of Science, Washington D.C. 100(14) pp. 8074–8079

[33] Adaptive management is not synonymous with climate adaptation. Please refer to Annex 1 for definition of Adaptive Management.

### 2.1.3 MANAGEMENT FOR SUSTAINABILITY OF SOCIAL-ECOLOGICAL SYSTEMS

17. Management is about using available resources efficiently to reach operational and strategic objectives. In theory, management for sustainability is therefore about how resources are considered and prioritized in a sustainability framework and decisions about how much to consume now and how much to invest to increase consumption later. When the inputs consist of both natural and human-made capital, the management decisions also become an issue about the substitutability of natural by human-made capital[34]. Among natural resource economists there are different positions regarding the possible substitutability, presented in a discourse about 'weak' versus 'strong' sustainability. Proponents of 'weak sustainability' focus on utility or wellbeing and claim that natural and human-made capital can be substituted within specific production processes. On the other hand, 'strong sustainability' proponents argue that natural capital, including ecosystem services, can only be substituted by human-made capital until a certain level, which is referred to as the critical natural capital level. For 'strong sustainability' proponents, human-made and natural capital are therefore viewed as complementary inputs. The critical natural capital performs important and irreplaceable environmental functions and represents the part of ecosystems that has to be maintained to ensure ecosystem functioning for future generations. As a result of critical natural capital possibilities for substitution become more limited and costly[35] with increasing degradation of natural resources. In practice, what is important for management for sustainability of social-ecological systems is the identification of the critical natural capital that cannot be substituted by human-made capital.

### 2.1.4 VALUATION OF SOCIAL-ECOLOGICAL SYSTEMS: ENVIRONMENTAL, ECOLOGICAL, AND GREEN ECONOMICS

18. The specific dynamic, non-linear, and multi-state characteristics of social-ecological systems mean that traditional neoclassical[36] or mainstream economic methods, which are based on linearity and predictability, cannot be directly applied. A major challenge for valuation of complex systems is thus how to merge linear with non-linear techniques. As suggested by Rose (2009)[37], for instance, the concept of changes in states, which is a characteristic of complex systems is normally not relevant to economic systems. E.g., only a severe hazard results in a total change of state of an economic system.

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[34] Dietz, S. & E. Neumayer (2007) "Weak and Strong Sustainability in the SEEA: Concepts and Measurement." Ecological Economics 61(4 ) pp.617-626

[35] Brand, F. (2009) "Critical Natural Capital Revisited: Ecological Resilience and Sustainable Development" Ecological Economics, 68, 2009 pp. 605-612

[36] Neoclassical economics is also referred to as mainstream economics. It is based on a microeconomic framework, i.e. how individuals, households, and firms make decisions to allocate limited resources and how these decisions affect supply and demand. The focus of neoclassical economics is the notion of a static equilibrium between supply and demand rather than a dynamic equilibrium. Other key characteristics of neoclassical economics are the notions of perceived value (utility) and marginalism. According to Gowdy (2004) "Mainstream economics is becoming so diverse that the term "neoclassical" is increasingly hard to define" (Gowdy, J.M. (2004) "The Revolution in Welfare Economics and Its Implications for Environmental Valuation and Policy" Land Economics 80(2) pp. 239-257). We share Gowdy's concern but will use the term "neoclassical economics" in the text referring to mainstream economics with the characteristics described here.

[37] Rose, A. (2009) "Economic Resilience to Disasters" CARRI Research Report 8, Community & Regional Resilience Institute, Oak Ridge

19. But there are many different schools of economics. Institutional economics was introduced early in the last century[38] and claims that institutions are the key elements of any economic system. Institutions such as social norms and governance practices are constantly evolving and determine the behavior of individuals. The notion of individual agents as utility maximizing entities is therefore not sufficient for institutional economic analysis. Instead, institutional economics is characterized as holistic, systemic, and evolutionary[39]. Moreover, for institutional economists there are no universal laws of economics. Rather some trends, tendencies, and patterns can be identified but the inherent instability of economic data and the non-equilibrium challenge predictions. In the 1970s, the New Institutional Economics was introduced with a focus on transaction costs[40] and externalities - elements that had not been addressed by traditional neoclassical economics. With the use of standard economic theory to analyze the functioning of institutions, the new institutional economics has become more mainstream and can be seen as a further development of both institutional and neoclassical economics.

20. For ecosystem valuations, environmental economics[41] emerged in the 1960s in response to the general concern about pollution and natural resource shortages. The concern was the focus popular publications such as Rachel Carson's "Silent Spring"[42] in 1962 and the Club of Rome's "Limits to Growth"[43] in 1972. To show the overall importance of environmental degradation, economic figures soon became necessary and environmental economics was developed based on traditional neoclassical economics. The environmental economics focused initially on the 'missing markets' for environmental goods and services and developed methods to assign economic values[44] for goods and services that were not linked to markets such as clean air. The introduction of externalities and opportunity costs allowed the environment to be valuated and compared with more traditional economic activities and application of environmental management tools such as taxation and tradable permits. Ultimately, environmental economics formed the basis for approaches for integrated valuation of sustainable development[45].

21. Various scholars soon started to criticize the environmental economic approaches and principles, including the use of optimization techniques, the high degree of abstraction, the idea of an independent and rational consumer, the aggregation of individuals' utility valuations instead of seeing individuals as moral agents assigning values from a social perspective for public goods[46], and the notion of

[38] Hodgson, G. (2000) "What is the Essence of Institutional Economics?" Journal of Economic Issues XXXIX (2) pp. 317-329)
[39] Wilber, C K. & R. S. Harrison (1978) "The Methodological Basis of Institutional Economics: Pattern Model, Storytelling, and Holism" Journal of Economic issues 12(1) pp. 61-89
[40] The cost of negotiating, securing, and completing transactions in a market economy. Transaction costs can also be seen as the factors that prevent markets from operating efficiently (Solomon, B.D. (1999) "New Directions in Emissions Trading: The Potential Contribution of New Institutional Economics" Ecological Economics 30 pp. 371-387)
[41] Historically, distinctions have been made between environmental economics and natural resource economics. While recognizing the theoretical differences, we use 'environmental economics' here for the combination of the two terms.
[42] Carson, R. (1962) "Silent Spring" Riverside Press, Cambridge
[43] Meadows, D.H. et al. (1972) "The Limits to Growth" Universe, New York.
[44] Economic values refer to the contribution to human welfare in terms of individuals' assessments.
[45] Dietz, S. & E. Neumayer (2009) "Economics and the Governance of Sustainable Development" in Adger, W.N. & A. Jordan "Governing Sustainability" Cambridge University Press, Cambridge pp. 259-282
[46] Duraiappah, A.K. (2006) "Markets for Ecosystem Services - A Potential Tool for Multilateral Environmental Agreements" International Institute for Sustainable Development, Manitoba
iisd.org/pdf/2007/economcs_markets_eco_services.pdf

equilibrium. The criticism was inspired by system thinking and the implications of constantly evolving systems and unpredictability[47]. As an alternative, ecological economics developed and was formalized as a research field in the late 1980s. Costanza et al. (1991)[48] describe ecological economics as a trans-disciplinary[49] field of study that goes beyond traditional research fields. According to the authors, the focus of ecological economics should be concrete problem solving rather than conceptualization about sustainable development. The key is the integration of many different disciplines and stakeholders and the application of relevant tools and techniques to specific systems. Some critics highlight that this pluralism of methodologies leads to lack of coherence[50] and challenge the usefulness of ecological economics for planning purposes[51]. In her review of ecological economics, Røpke (2005)[52] notes that the "field could be said to cover almost anything with a faint relation to the environment[53]." She identified some general focus areas, though, including valuation based on integrated economic-ecological-social and institutional approaches, multi-scale time and space frames, and the notions of dynamic and evolutionary systems. Because of the integrated system approach, many ecological economists will use new institutional economics methods. Within this approach, notions such as externalities are meaningless as those costs originate from the system itself[54]. Furthermore, Røpke notes that ecological economists have a wider audience than many other related academics and relate more often directly with policymakers at local and central level. This, furthermore, reflects the transdisciplinarity of ecological economics.

22. Over the last years, advocacy efforts based on ecological economic principles tend to be presented more and more as 'green economics', which in itself is still not a clearly defined scientific[55] discipline but more an "engaged study" according to Cato (2012)[56]. Like ecological economics, green economics is based on system thinking recognizing that all entities of complex social-ecological systems are connected. Moreover, like ecological economists, green economists are a heterogeneous group with a

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47 Røpke, I. (2004) "The Early History of Modern Ecological Economics" Ecological Economics 50 pp. 293-314

48 Constanza, R. et al. (1991) "Goals, Agenda and Policy Recommendations for Ecological Economics" in Constanza, R. (Ed.) (1991) "Ecological Economics: The Science and Management of Sustainability" Columbia University Press, New York pp. 1-21

49 Transdisciplinary research differs from interdisciplinary research in their approaches where transdisciplinary research deliberately puts emphasis on participatory research and involvement of practitioners as well as scholars from different scientific disciplines to address problems in an integrated manner while interdisciplinary research in general is only seen as the integrated approach of different scientific disciplines.

50 Spash, C.L. (2012) "New Foundations for Ecological Economics" Ecological Economics 77 pp. 36-47

51 Özkaynak, B. et al. (2012) "The Identity of Ecological Economics: Retrospects and Prospects" Cambridge Journal of Economics 36(5) pp. 1123-1142

52 Røpke, I. (2005) "Trends in the Development of Ecological Economics from the Late 1980s to the Early 2000s" Ecological Economics 55 pp. 262-290

53 Ecological economists focusing on the interrelationships between ecological and economic systems are mainly based in the United States while ecological economists questioning the use of traditional economic methods for environmental valuations are mainly based in Europe (Özkaynak, B. et al. (2012) "The Identity of Ecological Economics: Retrospects and Prospects" Cambridge Journal of Economics 36(5) pp. 1123-1142)

54 Özveren, E. & S. E. Nas (2012) "Economic Development and Environmental Policy in Turkey: An Institutionalist Critique" Cambridge Journal of Economics 36(5) pp. 1245-1266

55 For its Green Economy Initiative, UNEP defines 'green economy' as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive" unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx. Cato, on the other hand, states that green economics is inherently linked to social justice and to a large degree grounded in development economics. (Cato, M.S. (2009) "Green Economics – An Introduction to Theory, Policy, and Practice" Earthscan, London)

56 Cato, M.S. (2012) "Green Economics: Putting the Planet and Politics Back Into Economics" Cambridge Journal of Economics 36(5) pp. 1033-1049

variety of positions on critical issues such as economic valuations and possibilities of substitution between natural and manmade capital. In general, though, ecological / green economists are proponents of weak sustainability in contrast to environmental economists who suggest strong sustainability. However, both between and within the different schools there are many different levels with respect to weak vs. strong sustainability. On the other hand, green economists have been on the forefront in presenting new measures to advocate for sustainable policies, such as the ecological footprint[57].

23. In spite of the growing recognition of complex system approaches to environmental valuations, Douai et al. (2012)[58] argue that traditional neoclassical economics is still the predominant approach for economic analysis of ecosystems both within academic circles and as inputs to policy-making. Based on a literature review the authors observe that the use of the neoclassical approach to economic environmental valaution implies that the economic analyses are separated from social relations and the natural environment whether the analyses are presented as environmental or ecological economics.

### 2.1.5 *Ecosystem Services Approach*

24. A special approach to the valuation of social-ecological systems is through the analysis of ecosystems services. Ecosystem services describe the relationship between nature and human beings and refer broadly to the benefits people can obtain from ecosystems and thereby linking the social and the ecological systems. The notion of ecosystem services was initially used to promote biodiversity conservation[59] in the 1970s. Since then, the concept has gained general acceptance, particularly after the 2005 Millennium Ecosystem Assessment[60]. The Millennium Assessment presented a groundbreaking framework for sustainable development and related analyses by introducing and classifying ecosystem services[61] into:

- provisioning services: e.g., food, timber, and water,
- regulating services: e.g., erosion control and flooding protection from vegetative cover,
- supporting services: e.g., nutrients recycling and pollination, and
- cultural services: e.g., recreating and spiritual benefits.

25. While the Millennium Assessment's four-category classification of ecosystem services has been useful for harmonizing valuations of ecosystems, some challenges have emerged, including difficulties in differentiating between regulating and supporting services and the risk for double counting[62]. Alterna-

[57] Cato, M.S. (2009) "Green Economics – An Introduction to Theory, Policy, and Practice" Earthscan, London
[58] Doaui, A. et al. (2012) "Prospects for a Heterodox Economics of the Environment and Sustainability" Cambridge Journal of Economics 36(5) pp. 1019-1032
[59] Gómez-Baggethun, E. et al. (2010) "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes" Ecological Economics (69)6 pp. 1209-1218
[60] Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C.
[61] UNSD et al. (2011) "SEEA Experimental Ecosystem Accounts: A Proposed Outline, Road Map and List of Issues" Paper prepared by UNSD, EEA and the World Bank and presented at the 17th Meeting of the London Group on Environmental Accounting, 12-15 Sept., 2011, Stockholm unstats.un.org/unsd/envaccounting/londongroup/meeting17/LG17_9a.pdf
[62] Fu, B.J. et al. (2010) "Double Counting in Ecosystem Services Valuation: Causes and Countermeasures" Ecological Research 26(1) pp. 1-14

tive classifications have been suggested, mostly reflecting the logic of the studies for which they have been applied. The 2010 study "The Economics of Ecosystems and Biodiversity" (TEEB)[63], for instance, is based on the following categories: provisioning, regulating, habitat, and cultural services, whereas supporting services are not considered a service per se but seen as part of the ecosystem processes. In light of the TEEB study's objective, the study distinguishes between ecosystem services and actual benefits[64]. Others have suggested using the concept of 'final ecosystem services' as the last chain of ecosystem functioning to avoid double counting. However, as noted by Bateman et al. (2011)[65] this 'simplification' can come at the expense of the usefulness of the ecosystem service framework for sustainable ecosystem management.

26. The concept of ecosystem services has been critical to convey the general message that nature brings vital social values and that human wellbeing depends on the constant flow of ecosystem services. A recent survey[66] in Spain, for instance, showed that people in general has a good perception about the concept that ecosystems provide services; particularly regulating services[67] and more than 90%[68] of the people identified one or several ecosystem services. Another study[69] focusing specifically on the drylands showed that stakeholders generally recognize that dryland ecosystems provide clean air and water. The ecosystem services approach has also been instrumental to show that agriculture ecosystems provide more services to society than the directly marketed products, such as carbon sequestration, water purification, and cultural benefits. The notion of multifunctional agriculture has therefore been promoted by the European Union in the global trade negations to justify subsidies[70] for enhancement of environmental sustainability and rural development.

27. For sustainable land management, the ecosystem services approach can be important as it allows to take account of not only the provisioning services; i.e. the obvious benefits but also services required for maintaining the system functional in the future. To support management decisions, ecosystem services valuations have become increasingly popular[71] and there has been a shift from the initial use for advocacy purposes towards financial applications for sustainable development management[72]. In principle, ecosystem services valuations will allow a comparison of alternative use of ecosystems and can provide critical input for environmental impact evaluations of projects, programs, and policies[73].

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[63] The TEEB study is a major international assessment of the economic value of biodiversity. This groundbreaking study was launched in 2007 and the reports were publicized in 2010. teebtest.org/

[64] Kumar, P. (Ed.) (2010) "The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations" Earthscan, Routledge, New York

[65] Bateman, I.J. et al. (2011) "Economic Analysis for Ecosystem Service Assessments" Environmental Resource Economics 48 pp. 177-218

[66] Matín-López, B. et al. (2012) "Uncovering Ecosystem Service Bundles through Social Preferences" PLoS ONE 7(6)

[67] There was also a strong age impact. Older populations identified more provisioning services, for instance.

[68] There was a strong impact from sex, formal education, lifestyle, and rural-urban characteristics.

[69] Castro, A.J. et al. (2011) "Social Preferences Regarding the Delivery of Ecosystem Services in a Semiarid Mediterranean Region" Journal of Arid Environments 75(11) pp. 1201-1208

[70] Moon, W. (2012) "Conceptualizing Multifunctional Agriculture from a Global Perspective" Paper presented at the Southern Agricultural Economics Association in its series 2012 Annual Meeting, February 4-7, 2012, Birmingham, Alabama ageconsearch.umn.edu/bitstream/119751/2/Multifunctionality_GlobalPerspective_SAEA2012_Birmingham_WankiMoon.pdf

[71] Gómez-Baggethun, E. et al. (2010) "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes" Ecological Economics (69)6 pp. 1209-1218

[72] Chee, Y.E. (2004) "An Ecological Perspective on the Valuation of Ecosystem Services" Biological Conservation 120 pp. 549-565

[73] Liu, S. et al. (2010) "Valuing Ecosystem Services" Annals of the New York Academy of Sciences, 1185 pp. 54–78

However, so far, only few regulating, supporting, and cultural ecosystem services have been valued directly[74]. The problem is not only linked to the valuation per se for services where no market exists but also to the uncertainty about the exact relationship between land use change and shift in ecosystem functions and services in a quantitative manner[75]. Not all services are synergistic and many may display trade-offs; e.g., enhancing provisioning services can lead to a reduction in cultural services. In a study of 12 ecosystem services in rural Quebec, Canada, Raudsepp-Hearne et al. (2010)[76] show tradeoffs between provisioning and both regulating and cultural services, e.g., crop production and s oil phosphorus retention but also synergies among other services, e.g., all regulating services were positively correlated. Recent research on ecosystem services show promising models for analyzing ecosystem services bundles, i.e., sets of ecosystem services that repeatedly appear together across space or time, which should help identify tradeoffs and synergies and increase understanding of their dynamic and complex relationships.

28. One of the challenges for effective measurement and valuation of different ecosystem services is that the definition applied in the Millennium Assessment that ecosystem services are the benefits people obtain from ecosystems[77] is too general[78]. For neoclassical economists, 'benefits' are limited to those that people perceive[79] and are willing to pay for. Boyd and Banzhaf (2007),[80] therefore suggest that "Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being". By using the term 'final' the authors put focus on end products from the nature from a human use perspective, but they also stress that final ecosystem services do not equate to benefits; or the value people assign to the service. Rather the benefits depend typically on access and availability to complementary goods and services; e.g., harvest infrastructure for food or roadways to enjoy the recreation service. Likewise, according to Boyd and Banzhaf (2007)[81] by referring to components they underline that final ecosystem services are not ecosystem functions or processes, e.g., regulating services or intermediary services such as nutrient cycling. On the other hand, intermediary services are considered to be accounted for in the final product. However, as mentioned above this is a controversial argument when using economic valuation for sustainable management. E.g., many will argue that unsustainable management of natural resources is the result of undervalued regulatory and supportive ecosystem services.

29. The different positions regarding the possibilities for economic valuations of nature as expressed by environmental and ecological economists, is obviously also reflected in perceptions about

[74] Viglizzo, E.F. et al (2012) "Ecosystem Service Evaluation to Support Land-Use Policy" Agriculture, Ecosystems and Environment 154 pp. 78-84
[75] Ibid.
[76] C. Raudsepp-Hearne, C. et al. (2010) "Ecosystem service bundles for analyzing tradeoffs in diverse landscapes" Proceedings of the National Academy of Sciences 107(11) pp. 5242-5247
[77] Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C.
[78] Boyd, J. & S. Banzhaf (2007) "What are Ecosystem Services? The Need for Standardized Environmental Accounting Units" Ecological Economics 63 pp. 616-626
[79] Costanza, R. (2008) "Letter to the Editor: Ecosystem Services: Multiple Classification Systems are Needed" Biological Conversation141 pp. 350-352
[80] Boyd, J. & S. Banzhaf (2007) "What are Ecosystem Services? The Need for Standardized Environmental Accounting Units" Ecological Economics 63 pp. 616-626
[81] Ibid.

the usefulness of ecosystem services valuations. One of the founding fathers of ecological economics, R.B. Norgaard (2010)[82] questions the direct use of economic terms for environmental management. While recognizing the communication effect of the metaphor of valuing ecosystem services, Norgaard claims that it is now being used to maintain unsustainable traditional consumption patterns in developed countries. The ecosystem services framework should therefore only be combined with other ecological assessment frameworks.

30. Overall, ecosystem services valuations are used for a number of reasons including for advocacy purposes and should not necessarily be seen as aiming at a commodification of all ecosystem services per se[83]. Rather, the objective is to communicate the importance of sustainable ecosystem management in the dominant political and economic language. Therefore, several authors have posed the logic of valuations as a pragmatic short-term tool rather than as an end in itself. Still, the framing of ecological concerns in economic terms can have negative impacts as it sets the stage that all ecosystem functioning can be valued and marketed at exchange values.

31. So while there have been many efforts to develop and apply methodologies for valuation of ecosystem services as inputs for policymaking for sustainable and productive land management, success stories remain rare and most studies refer to the water sector[84].

## 2.2 Sustainable Dryland and Drought Risk Management

32. The notion of sustainable dryland management is often used with an intuitive definition that current management will not compromise future benefits. While this definition might be sufficient for general discussions, it is too general when it comes to monitoring and evaluation, including economic valuations[85]. In neoclassical economics, an economy is sustainable when the welfare changes are not negative; i.e., when the present value of future benefits remains positive from one time period to the next[86]. From an ecosystem perspective, "Sustainability is the capacity to create, test, and maintain adap-

[82] Norgaard, R. B. (2010) "Ecosystem Services: From Eye-Opening Metaphor to Complexity Blinder" Ecological Economics 68 (6) pp. 1219-1227

[83] Gómez-Baggethun, E. et al. (2010) "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes" Ecological Economics (69)6 pp. 1209-1218

[84] Viglizzo, E.F. et al (2012) "Ecosystem Service Evaluation to Support Land-Use Policy" Agriculture, Ecosystems and Environment 154 pp. 78-84

[85] 'Valuation' and 'Evaluation' are often used with no clear distinction. According to Desgupta (2009) "In common parlance we use the term "valuation" when comparing objects, and "evaluation" when comparing the relative merits of actions" (Desgupta, P. (2009) "Valuation and Evaluation: Measuring the Quality of Life and Evaluating Policy" Background paper for the World Development Report, 2000 worldbank.org). Likewise, Lamont (2012) describes valuation as assigning or defining the value (not necessarily monetary) of an entity while 'evaluation' focuses on how an entity attains a certain value. However, Lamont recognizes that the two concepts are intertwined in practical use. (Lamont, M. (2012) "Toward a Comparative Sociology of Valuation and Evaluation" Annual Review of Sociology 38 pp. 201-221). The environmental economist, J.A Dixon (2008), on the other hand, suggests that 'environmental valuation' is the "process of putting monetary values on environmental goods and services" (Dixon, J.A. (2008) "Environmental Valuation: Challenges and Practices" Paper presented at the Conference Economics and Conservation in the Tropics: A Strategic Dialogue, January 31 – February 1, 2008, San Fancisco, organized by the Conservation Strategy Fund, Resources for the Future, and the Gordon and Betty Moore Foundation rtf.org). In the present White Papaer, we use 'valuation' for the process of assigning or identifying the value of an entity or process, whether measured in monetary or other societal terms.

[86] Mäler, K.-G., et al. (2008) "Accounting for Ecosystem Services as a Way to Understand the Requirements for Sustainable Development" Proceedings of the National Academy of Science 105(28) pp. 9501-9506

tive capability" according to ecologist C.S. Holling[87]. This definition calls for 'adaptive management', i.e. the planning, organization, use, and monitoring of activities based on flexible decision-making that is informed by an iterative[88] learning process. Adaptive management is particularly relevant for complex social-ecological systems characterized by unpredictability[89] such as drylands.

33. In the absence of a common definition of sustainable dryland management[90], we therefore suggest the following working definition of Sustainable Dryland and Drought Risk Management as a basis for the following discussions, including the suggested definition of resilience (see section 2.4.1):

> *Planning, organization, and monitoring of activities linked to the use of all natural resources in dryland social-ecological systems based on iterative learning processes and adaptive management ensuring positive trends in the value of the dryland ecosystems, including the monetary net present value of longer-term future benefits.*

34. According to this definition, sustainable dryland management is based on social norms and values and assessments will be context specific. Global comparative studies will therefore be challenging. In Chapter 3, we will discuss the complexity of undertaking and presenting global valuations of desertification and sustainable land management. In fact, most assessments of sustainable land use management are based on local studies that will apply indicators for sustainable land use management identified locally. Abraham (2009)[91], for instance, concludes that a participatory approach allowing context specific indicators is necessary for assessment of desertification. The need for context specific definitions might also be the reason for the lack of a common definition for sustainable agriculture[92].

35. Drylands as complex social-ecological systems imply a complex of economic, social, and environmental values; all measured in different units, which makes land use management decisions difficult. Applying an ecosystem services framework allows first of all a system approach to management, including valuation. Moreover, the terminology of ecosystems facilitates the consideration of ecosystem processes, services, and benefits[93] for the valuation and a natural alignment of ecological and economic sciences. In order for this alignment to be effective, though, there is a need for a strong transdisciplinary

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[87] Holling, C.S. (2001) "Understanding the Complexity of Economic, Ecological, and Social Systems" Ecosystems 4(5) pp. 390-405

[88] The 'iterative' aspect is critical. Post-crisis studies show that people become very cautious immediately after a crisis but as time goes, they forget and become more complacent. Moreover, minor disturbances will typically only be analyzed when part of a systematic learning process.

[89] Williams, B. K. et al. (2009) "Adaptive Management – The U.S. Department of the Interior Technical Guide" Adaptive Management Working Group, U.S. Department of the Interior, Washington D.C. doi.gov/archive/initiatives/AdaptiveManagement/TechGuide.pdf

[90] The need to define sustainable land management was highlighted in the 2011 Scientific Review of the UNCCD Impact Indicators where one expert is cited for asking what sustainable land management is? "What is sustainable? The land? The management? Nevertheless, there is an acronym, and now no one will dare ask more disturbing questions" – Orr, B.J. (2011) "Scientific Review of the UNCCD Provisionally Accepted Set of Impact Indicators to Measure the Implementation of Strategic Objectives 1, 2 and 3" White Paper Version 1
unccd.int/en/programmes/Science/Monitoring-Assessment/Documents/White%20paper_Scientific%20review%20set%20of%20indicators_Ver1.pdf

[91] Abraham, E. (2009) "Enfoque y Evaluación Integrada de los Problemas de Desertificación" Zonas Áridas 13(1) pp. 9-24

[92] Walter, C. & H. Stützel (2009) "A new method for assessing the sustainability of land-use systems (I): Identifying the relevant issues" Ecological Economics 68(5) pp.1275-1287.

[93] Kumar, P. et al. (2010) "Guidance Manual for the Valuation of Regulating Services" United Nations Environmental Program, University of Liverpool and Indian Institute of Forest Management
hqweb.unep.org/pdf/Guidance_Manual_for_the_Regulating_Services.pdf

approach to understand the functioning and interactions of the social, economic, and ecological components[94].

36. However, the valuation of ecosystem services alone is not enough to provide valuation of the sustainability of the ecosystems. As such, it is necessary to look at both goods and services; i.e., the value of ecosystem assets as a function of ecosystem stocks and flows or processes and services. This is also the principle of the suggested ecosystem accounts to enhance the UN-adopted national System of Environmental-Economic Accounts (SEEA) that we will discuss in further details in Chapter 5. As mentioned by Atkinson et al. (2012)[95] in their review of recent advancements of ecosystem services valuations, it is only recently that valuations start to systematically integrate ecosystem assets or stocks. Still, there is a growing recognition about the importance of ecosystem stocks for overall resilience and some environmental economists will even assert that environmental assets can be seen as the resilience of the ecosystems[96]. Moreover, Atkinson et al. (2012)[97] highlight the importance of predictive valuations in order to provide support to land-use decision-making at all levels. Therefore, ecosystem services valuations should assess the likely impact on the ecosystem stocks from the complex interactions of internal and external factors[98].

## 2.3 Sustainable Development and Resilience

37. While the focus of sustainable development is defined in terms of outcomes, i.e. meeting the needs of today without compromising the ability of future generations to meet their own needs[99], recent research on resilience in complex systems highlights that resilience is a process. These differences actually explain the relationship between resilience and sustainability; that resilience is part of the process leading to sustainability[100].

38. Among what can be seen as 'disillusioned voices' or revisionists of the sustainability movement, there has been attempts to discredit the idea of sustainable development. Dennis Meadows, one of the authors of the landmar publication "Limits to Growth"[101,102], which introduced the concept of global sus-

[94] Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47
[95] Ibid.
[96] Ibid.
[97] Ibid.
[98] Ibid.
[99] World Commission on Environment and Development (1987) "Our Common Future": Oxford University Press, Oxford
[100] Mäler, K.-G. & L. Chuan-Zhong (2010) "Measuring Sustainability under Regime Shift Uncertainty: A Resilience Pricing Approach" Environment and Development Economics 15, pp. 707-719
[101] Meadows, D.H. et al. (1972) "The Limits to Growth" Universe, New York.
[102] 'Limits to Growth' used a computer simulation model, World3, to assess global sustainability through the impact of physical growth on five key parameters: population, food, industrial production, pollution, and non-renewable resources. World3 was the first model taking a system approach integrating the world economy with the environment. Based on 12 scenarios and the assumption that there are limits to growth on a finite planet the study showed that prevailing growth policies would exceed the capacity of the global resources sometime in the 21th century. Nevertheless, the authors also contended that the right technical, social, and cultural policy interventions could ensure sustainable development. The analysis showed t World3 was also used for updated versions of the publication: 'Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future' from 1992 and 'Limits to Growth: The 30-Year Update' from 2004. These updated versions have been criticized for not validating the original model based on actual knowledge gained since 1972.

tainable development, now claims that it is too late to achieve sustainable development[103] in the sense of equity and use of natural resources that will not exceed regeneration. Meadows recognizes, though, that sustainable development has been the subject of so many definitions that it tends to be meaningless. Recognizing that global sustainable development is no longer an option and that the global system is in an unpredictable or incontrollable decline, Meadows and others now advocate for increasing resilience at all levels of the global system. Eventually, when the system has settled at a new equilibrium this will then allow sustainable development from that basis. It is therefore not a discredit of the sustainable development as an objective but rather the need for resilience as a means to regain and redefine the path towards that objective.

39. Whereas the decade of the Rio Summit in 1992 was the decade of 'sustainability', the decade of Rio+20 seems to be the decade of 'resilience'. Over the last couple of years there has been an endless number of documents on resilient societies, resilient policies, resilient organizations, resilient communities, etc and the term 'resilience' is now used across most professions. It is mostly used as a versatile term referring to positive development responses to stress but without any clear definition. Moreover, when defined there are different perceptions both within and among professions about the meaning of resilience. The high-level document for the Rio+20 Conference "Resilient People – Resilient Planet"[104] is a good example of the general use of the concept. The document does not present a definition of 'resilience' but it seems to be used as a positive concept to refer to strengths to withstand disturbances through adaptation and flexibility. The special chapter in the document dedicated to building resilience applies the concept in relation to social protection and safety nets[105] showcasing for instance the Indian Mahatma Gandhi National Rural Employment Guarantee Act, which guarantees all citizens 100 days of employment each year.

## 2.4 The Resilience Concept

40. While resilience research has been intensifying over the last years, it still seems that the policy community is ahead of the research community in pushing resilience as an operational tool to further sustainable development[106]. Moreover, there seems to be a general perception that resilience is something that can be created and programs to 'build resilience' have grown exponentially over the last years. However, from a system perspective, resilience is an inherent characteristic of complex systems, such as social-ecological systems, cities, or organizations. Chapin et al. (2009)[107], for instance, note that

[103] See for instance, Dennis Meadow's presentation to the symposium "Perspectives on Limits to Growth – Challenge to Building a Sustainable Planet", Smithsonian Institute, Washington D.C. March 1, 2012. The Symposium was co-organized by the Club of Rome and the Smithsonian Institute. The presentation is available at youtube.com/watch?v=f2oyU0RusiA

[104] United Nations Secretary-General's High-Level Panel on Global Sustainability (2012) "Resilient People, Resilient Planet: A Future Worth Choosing" United Nations, New York

[105] Public interventions that help individuals, households, and communities to manage risk or that provide support to the critically poor.

[106] Cutter S.L. et al. (2010) "Disaster Resilience Indicators for Benchmarking Baseline Conditions" Journal of Homeland Security and Emergency Management, 7(1): 51, Berkeley Electronic Press bepress.com/jhsem/vol7/iss1/51

[107] Chapin III, S.F. et al. (2009) "Resilience-Based Stewardship: Strategies for Navigating Sustainable Pathways in a Changing World – Integration and Synthesis" in Chapin III, F.S. et al. (eds.) Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in A Changing World, pp. 319-339, Springer, New York

every system has sources of socio-economic, biological, and institutional diversity that provide building blocks for adaptation and hence resilience[108]. The resilience can be low or high, or weak or strong but it is part of all complex systems. Other characteristics of such systems are that they are constantly evolving through cycles of growth, accumulation, crisis, and renewal, and often self-organize into unexpected new structures, as we will describe in more details in the section 2.4.2.

41. One of the greatest challenges in using the resilience concept is probably that it has become a buzzword.[109, 110] Hence, the original meaning easily gets lost in contexts where it otherwise could have furthered a path towards sustainable development. It is easy to draw parallels to other trendy concepts such as sustainable development where well conceptualized notions will be claimed by many different disciplines and stakeholder groups. Eventually the concepts will become simplified into a buzzword as highlighted by Park (2011)[111] in his article about paradigm creep and buzzword mutations in forest management. However, Park also recognizes that the resilience concept offers greater clarity for management of complex systems if used as an umbrella to set strategic management goals, provided that specific aspects or capacities of the systems are clearly defined; e.g., plant diversity.

42. In order to be a useful complement to other approaches for sustainable dryland and drought risk management, it is important that the resilience concept bring greater insight and maneuverability of complex systems. In development and emergency response contexts, vulnerability frameworks have been used for the last couple of decades. Vulnerability is often defined in terms of deficits of resources to cope with hazards and vulnerability definitions encompass the likelihood of exposure to a hazard, susceptibility to damage, and capacity to recover[112]. With this definition, resilience is part of vulnerability expressed in the capacity to recover and the susceptibility to damage as we will develop further in section 2.4.2. However, both vulnerability and resilience are interpreted in a number of ways and their relationship depends on definitions[113]. Whether resilience frameworks for analysis and management of complex systems will be a positive step is therefore to a large degree a question about definitions. Furthermore, the vulnerability notion is generally used with the assumption of a linear relationship between hazards and impacts while resilience frameworks for social-ecological systems tend to recognize the non-linearity and be based on the notion of critical thresholds[114]. This also reflects that 'resilience' in

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[108] Chapin III, F.S. (2009) "Managing Ecosystems Sustainably: The Key Role of Resilience" in Chapin III, F.S. et al. (eds.) Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in A Changing World, pp. 29-55, Springer, New York

[109] Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

[110] Reghezza-Zitt, M. et al. (2012) "What Resilience Is Not: Uses and Abuses" Cybergeo: European Journal of Geography, Environnement, Nature, Paysage, 621 cybergeo.revues.org/25554,

[111] Park, A. (2011) "Beware Paradigm Creep and Buzzword Mutation" The Forestry Chronicle 87(3) pp. 337-344

[112] As noted by Vincent (2004) in natural disaster studies vulnerability normally refers to a specific hazard while in socio-economic research vulnerability is used in a more general manner. Vincent, K. (2004) "Creating an Index of Social Vulnerability to Climate Change for Africa" Working Paper 56, Tyndall Centre for Climate Change Research, Norwich

[113] See for instance Reghezza-Zitt, M. et al. (2012) "What Resilience Is Not: Uses and Abuses" Cybergeo: European Journal of Geography, Environnement, Nature, Paysage, 621 cybergeo.revues.org/25554, Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton, and Rose, A. (2009) "Economic Resilience to Disasters" CARRI Research Report 8, Community and Regional Resilience Institute, Oak Ridge

[114] Adger, W.N. et al. (2011) " Resilience Implications of Policy Responses to Climate Change" WIRE's Climate Change, Volume 2, September/October 2011, pp 757-766 onlinelibrary.wiley.com/doi/10.1002/wcc.133/pdf

complex systems is a process rather than a state. This dynamic aspect[115] of resilience makes it more apt as a management tool than vulnerability. However, some of the recent attempts to develop resilience assessment frameworks deliberately disregard the process aspect because it renders measurement more complicated[116].

43. Among the criticisms of vulnerability frameworks is their focus on negative direct and immediate impacts from stress. In contrast, resilience frameworks highlight indirect and direct positive impacts over a longer timeframe[117]. Being part of vulnerability, a resilience framework therefore offers more details than traditional vulnerability analyses and puts more focus on capacities. Recent reviews of the use and usefulness of the resilience concept have highlighted that the attractiveness of using resilience is the positivity[118] of the concept. In an introduction to the usefulness of the concept for disaster risk management, Paton (2006) actually frames the text with a quote from Mahatma Ghandi on the importance of positive words, behavior, habits, and values[119]. However, as stressed by Béné et al. (2012)[120] ”It would be short-sighted to adopt resilience because it seems on the face of it a positive quality, and in the process drop vulnerability, owing to its negative connotations”. Likewise, when resilience makes its way into development and risk management frameworks it is often used as an antonym to vulnerability. This easily leads to circular arguments: 'low resilience because of high vulnerability' and vice-versa[121] and thus offering no further insight.

44. Recognizing resilience as part of vulnerability means that enhancing resilience is not enough on its own to reduce overall vulnerability. Fraser et al. (2011)[122], on the other hand, suggest a more limited perspective of resilience arguing that vulnerability assessment frameworks for dryland livelihood systems should comprise assessment of agro-ecosystem resilience, socio-economic connectedness, and institutional capacity to provide crisis relief. This application reflects an often-cited shortcoming of the resilience concept, namely its inability to capture and reflect social dynamics and particularly power

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[115] When applied in human psychology, it has been argued that resilience is a pattern and that it technically is incorrect to talk about a resilient person. Rather, a person might have a resilient pattern, Masten, A. S. & J. L. Powell "A Resilience Framework for Research, Policy, and Practice" in Luthar, S. (Ed.)(2003) "Resilience and Vulnerability: Adaptation in the Context of Childhood Adversities" Cambridge University Press, New York pp.1-28

[116] Cutter, S.L., et al. (2008) ”Community and Regional Resilience: Perspectives from Hazards, Disasters, and Emergency Management" CARRI Research Report 1, Community and Regional Resilience Initiative, Oakland Ridge resilientus.org/library/FINAL_CUTTER_9-25-08_1223482309.pdf

[117] Mechler, R. et al. (2008) "From Risk to Resilience – The Cost-Benefit Analysis Methodology" Institute for Social and Environmental Transition, Kathmandu

[118] See for instance Miller, F. et al. (2010) "Resilience and Vulnerability: Complementary or Conflicting Concepts?" Ecology and Society Vol. 15, no. 3; Béné, C. et al. (2012) ”Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton ids.ac.uk/files/dmfile/Wp405.pdf; and Tousignant, M. & N. Sioui (2009) "Resilience and Aboriginal Communities" Journal of Aboriginal Health November pp. 43-61

[119] Paton, D. (2006) ”Disaster Resilience: Building Capacity to Co-Exist with Natural Hazards and their Consequences" in Paton, D. & D. Johnston (Eds.) (2006) "Disaster Resilience: An integrated Approach" Charles C. Thomas, Springfield pp. 3-10

[120] Béné, C. et al. (2012) ”Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

[121] Klein, R.J.T. et al. (2004)”Resilience To Natural Hazards: How Useful Is This Concept?" EVA Working Paper No. 9, Potsdam Institute for Climate Impact Research, Potsdam

[122] Fraser, E.D.G. et al. (2011) ”Assessing Vulnerability to Climate Change in Dryland Livelihood Systems: Conceptual Challenges and Interdisciplinary Solutions" Ecology and Society 16(3): 3. dx.doi.org/10.5751/ES-03402-160303

structures[123]. However, again this is a definitional issue and the most commonly identified general resilience characteristics do not limit institutional capacity to crisis management as we will see in section 2.4.2.

45. In principle, the integration of resilience should address the shortcoming of many risk management frameworks in terms of planning for the unknown and thereby recognizing the limit of predictability. The concept of resilience was therefore also part of the outcome of the 2005 World Conference on Disaster Reduction: the "Hyogo Framework for Action 2005-2015"[124] with the subtitle "Building the Resilience of Nations and Communities to Disasters". However, in practice the application of resilience as an identifiable and measurable process in development and risk management contexts tends to be used more in headlines than in actual operational outlines for disaster risk management.

### *2.4.1 Defining Resilience*

46. In the use of resilience to explain the functioning of complex systems, there have been numerous suggestions for a general definition; e.g., within the Resilience Alliance[125], which has been a leading voice in the conceptualization of resilience of social-ecological systems. According to the Alliance, resilience of socio-ecological systems is the "capacity to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes." Within this definition, resilience encompasses three interrelated components: the ability to absorb perturbations and still retain key functions; the ability of self-organization; and the capacity to learn, to change and to adapt. Whether this definition renders the concept more operational is being questioned by some researchers[126]. To understand the variety of resilience definitions, we present some commonly used definitions of resilience from different contexts in Annex 2. The compilation also reflects the recent historical development of the perception of resilience.

47. In the popularized manner in which 'resilience' has been used over the last years, there is often reference to the Latin roots of the word, namely 'resilio'[127] in the meaning to bounce back. The 'bouncing back' image is useful for certain forms of resilience; e.g., the resilience of a physical construction such as a skyscraper refers to the building's ability to resist wind impact and return to its original form[128]. However, the image of returning to the pre-stress form is less adequate when it comes to social-ecological context, where bouncing back might be negative. First of all, the original conditions might not be a desired state; e.g., poor land management is a driver of disastrous impacts of disturbances such

[123] Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

[124] unisdr.org/we/coordinate/hfa

[125] The Resilience Alliance is an international network of scientists with roots mainly in ecology and ecological economics working towards greater insight into the function of social-ecological systems and the policy process of sustainable development. resalliance.org/

[126] Klein, R.J.T. et al. (2004)"Resilience To Natural Hazards: How Useful Is This Concept?" EVA Working Paper No. 9, Potsdam Institute for Climate Impact Research, Potsdam

[127] Resilio is a compound word of 're' and 'salio' meaning to jump back. In Latin it is also used to signify to shrink, withdraw, and recede.

[128] Engineering resilience is about robustness and does not address the ability to change state.

as droughts. If resilience to drought means bouncing back after a drought event, then it is not necessarily desirable. Second, in development contexts the objective is that societies constantly improve while bouncing back might imply a step back for systems that have been hit by a disturbance compared to other systems. To address this problem, some researchers have therefore started introducing the concept of 'bouncing forward' as a critical quality of resilience of social-ecological systems[129,130,131.132,133]. The notion of bouncing forward, furthermore, reflects that complex social-ecological systems are not based on system equilibrium or 'normality' but characterized by emergence.

48. Closely linked to the 'bouncing forward' notion is systems' capacity for adaptation and learning where changes and stress will be used as opportunities for improvement. The concept of 'evolutionary resilience' has been suggested as the systems' capacity to learn, change, adapt, and transform; i.e. for situations where resilience management is about innovation and transformation capacity and ultimately adaptive management. The lack of integration of evolutionary change in ecosystem management has been highlighted in recent debates about the role of evolution in biodiversity protection[134]. Here evolutionary resilience is seen in the context of ecological state theory and defined as the ability of populations to maintain critical functions while adapting to a changing environment. However, some researchers question individuals and communities' interest in adaptive capacity. In his general review of the increased attention to 'resilience' and its use in development contexts Béné (2012)[135], for instance, refers to the suggestion of the Nobel winning economist Amartya Sen that people will come to terms with their deprivations and reduced wellbeing. However, by defining adaptation and learning in terms of improvement as suggested by 'bouncing forward' this 'fatality' challenge should not come to bear.

49. Accepting the notion of 'bouncing forward' means that many statements about dryland communities' high level of resilience should be questioned. Those statements are typically based on dryland communities' extraordinary ability to maintain function in an adverse environment. However, at best many dryland communities will bounce back but maintain vulnerability to adversities. Studies in the Sahel have even shown a downward spiral where communities have become increasingly vulnerable and do not fully recover from one disaster before the next hits[136]. Likewise, for ecological resilience in the

[129] Davoudi, S. (2012) "Resilience: A Bridging Concept or a Dead End?" Planning Theory & Practice 13(2) pp. 299-307 in Davoudi, S. & L. Porter (Eds.) (2012) "Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice" Planning Theory & Practice 13(2) pp. 299-333

[130] Shaw, K. & K. Theobald (2011) "Resilient Local Government and Climate Change Interventions in the UK" The International Journal of Justice and Sustainability 16(1) pp. 1-15

[131] Dodsman, D. et al. (2009) "Building Resilience" in WRI (200) "Into a Warming World – State of the World 2009" Woldwatch Institute, worldwatch.org/node/5982 pp. 151-168

[132] Martin-Breen, P. & J.M. Anderies, (2011) "Resilience – A Literature Review" Rockefeller Foundation, New York, rockefellerfoundation.org/news/publications/resilience-literature-review

[133] Lavell, A. et al. (2012) "Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 25-64

[134] Sgro, C.M. et al. (2011) "Building Evolutionary Resilience for Conserving Biodiversity under Climate Change" Evolutionary Application 4(2) pp. 326-336

[135] Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

[136] ICRC (2006) "Regional Livestock Study in the Greater Horn of Africa", International Committee of the Red Cross, Nairobi

drylands, Holling (1996)[137] describes how the absorption capacity[138] might be high while ecological resilience is decreasing in semi-arid grasslands in eastern and southern Africa. Under natural conditions, the diversity of plants allow some resilience to stressors such as drought. When the grasslands are put under cattle ranching management, the biodiversity decreases while still allowing for immediate efficiency and short-term constancy in production. However, the systems' overall functions decrease and hence also the ecological resilience over the longer term. In a literature review on rangeland resilience and drought in South Africa, Vetter et al. (2009)[139] note that undesirable ecosystem states in the rangelands can be highly resilient and require high management input to change to a more desirable state.

50. Based on the current resilience discourse and the need for a resilience concept that can promote sustainable dryland and drought risk management, we suggest the following generic definition of resilience. The definition reflects the notions of bouncing forward, learning, adapting, changing, and transforming and is applicable for dryland ecosystems where communities and individuals will be reliant on dryland ecosystem services:

> *A set of capacities of an individual, communities, or systems to survive, adapt, and follow a positive trajectory in the face of external and/or internal changes, even catastrophic incidents, and rebound strengthened and more resourceful while retaining essentially the same functions. The set of resilience capacities forms a continuous and dynamic process*[140] *encompassing both proactive and reactive abilities vis-à-vis change based on constant monitoring, analyzing, learning, and rolling planning. The resilience process might lead to new configurations of the system and graceful degradation of certain components when necessary. The capacities can be fostered through interventions and policies.*

51. The following observations further clarify what resilience is according to the suggested definition:

- Resilience is a means towards sustainable dryland and drought risk management and thus has a focus on socio-economic and manageable aspects,
- Resilience is a positive characteristic,
- Resilience is a complex, dynamic, and continuous process,
- As a continuous process, resilience covers all phases from pre-stressor, during the stress, post-stress, and in between stresses, and
- Resilience can be expressed globally to stressors in general or to specific stressors such as climate change, drought, or political instability.

137 Holling C.S. (1996) "Engineering Resilience versus Ecological Resilience" in Schulze, P.C. (Ed.) (1996) "Engineering Within Ecological Constraints" National Academy Press, Washington D.C. pp. 31-44

138 Systems capacity to assimilate harmful substances while maintaining some functions.

139 Vetter, S. (2009) "Drought, Change and Resilience in South Africa's Arid and Semi-Arid Rangelands" South African Journal of Science 105 (1-2) pp. 29-33

140 Norris, F.H. et al. (2008) "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness" American Journal of Community Psychology, 2008, 41 pp. 127-150

52. Some critics have highlighted that the emerging definitions of resilience can be used as political statements to promote individualism, self-reliance, and small government[141]. However, the suggested definition for resilience in dryland social-ecological systems does not necessarily imply self-reliance and small government. Moreover, the most prevalent theory on social-ecological systems includes the notion of nesting with subsidiarity as a characteristic of resilience; i.e., that management issues will always be handled by the least centralized units capable of addressing the issues effectively[142]. As pointed out by Marshall (2007)[143] decentralized environmental governance experience in Australia shows that all levels should have sufficient access to all capacities and thus be empowered and enabled by other levels. On the other hand, in a study on urban climate change resilience, Tanner et al. (2009)[144] note that decentralization of decision-making creates room for conflicts and delays between agencies and can thus hamper resilience planning and cause longer response times. This could be counterbalanced, though, with the benefits of greater participation and well-adapted responses and the right balance of decentralization, participation, subsidiarity, and efficiency will always be context specific. For our resilience definition, it should therefore also be recognized that many of the characteristics of resilience are based on social values and norms. As such, when looking at resilience from a community perspective there might be both individual winners and losers because of different preferences and resources. Applying the resilience concept will therefore always mean some prioritization and compromises regarding boundaries and weighing of the resilience of different stakeholders, as is the case for all system approaches.

### *2.4.2 Measurability of Resilience*

53. A system's resilience only emerges fully after a stressor has had its impacts on the system, e.g. a drought or changes in market prices. In principle, a system's resilience can therefore only be measured after an identifiable disturbance to the system has taken its course. Moreover, a baseline needs to have been established against which the impact of the disturbance can be measured to determine the resilience. Likewise, the timeframe for resilience assessments needs to be considered; e.g., a dryland farming community impacted by a drought incidence might have a decrease in the current production cycle but learn from the incidence and adapt new drought risk management components such as improved early warning systems and drought tolerant crops. However, the result of the learning and adaptation will only manifest itself several years after the drought event. A resilience assessment after one year might therefore conclude that the system has a low resilience while the same assessment after three years could show a high resilience. On the other hand, most longitudinal disaster studies show that with a long

141 Shaw, K. (2012) "Reframing Resilience: Challenges for Planning Theory and Practice" Planning Theory & Practice 13(2) pp. 307-312 in Davoudi, S. & L. Porter (Eds.) (2012) "Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice" Planning Theory & Practice 13(2) pp. 299-333

142 Berkes, F. (2007) "Understanding Uncertainty and Reducing Vulnerability: Lessons from Resilience Thinking" Natural Hazards (41) pp. 283-295. Berkes shows that after decades of centralized colonial-style governance Inuit hunter-trapper communities have low climate change resilience with little capacity for self-organization

143 Marshall, G.R. (2008) "Nesting, Subsidiarity, and Community-Based Environmental Governance Beyond the Local Level" International Journal of the Commons 2(1) pp. 75-97

144 Tanner, T. et al. (2009) "Urban Governance for Adaptation: Assessing Climate Change Resilience in Ten Asian Cities" IDS Working Paper 315, Institute of Development Studies, Brighton

enough time span most impacted communities will return to normal function[145]. High resilience then becomes a matter of responsiveness, including the time span required to mobilize resources to contain disaster impacts. It can therefore be useful to distinguish between recovery and resilience trajectories where a recovery trajectory involves a long time of dysfunctioning while a resilience trajectory is a more stable return to normal functioning with a short time or transient dysfunctioning[146].

54. As any other assessment of nested systems, scale is critical for assessments of social-ecological systems such as drylands and resilience assessments would need to consider boundary issues, for instance with identification of relevant system actors. Overall, identifying time and special scales for analysis of complex social-ecological systems is challenging as the systems are characterized by complex dynamics, delays, and unpredictable feedback loops within and between system components. Scale mismatches thus constitute a constant challenge when analyzing complex systems. Not only will different elements naturally be defined by different scales; e.g., a community can have a different space scale than the corresponding local government administrative unit and the ecosystem. But the scales are also constantly evolving and scale mismatches are typically a result of social reorganization processes[147], for instance from poorly designed policies.

55. Stressors such as droughts seldom come as single events. Rather, social-ecological systems are exposed to multiple interacting and interrelated internal and external change processes, perturbations, and stressors/stresses. Many dryland communities in Sub-Saharan Africa, for instance, are threatened by multidimentional poverty, instable political structures, climate change, multiple natural disasters, etc. In order to circumvent the very complex frameworks that would be required for a full assessment of system resilience, many attempts to assess resilience of social-ecological systems have focused on one or a few aspects, e.g., analyzing only one stressor. However, because of the complex and non-linear functioning of social-ecological systems, such a simplification could undermine the overall resilience in the long-term as the analysis might provide misguided policy information[148].

56. To overcome many of these challenges in defining the premises for resilience assessments, research has identified a number of common characteristics for resilience of social-ecological systems. These characteristics allow to assess resilience in relative and general terms instead of absolute values. Likewise, the general assessments do not quantify the disturbance or define what 'return to normal function' means. As such, the assessments recognize that resilience of social-ecological systems is a continuing changing process rather than a well-defined outcome. Drever et al. (2006)[149] suggest that the resilience concept is "inherently somewhat inexact" and to measure it, it is necessary to specify various characteristics. With the resilience definition for sustainable dryland and drought risk management sug-

[145] Norris, F.H. et al. (2008) "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness" American Journal of Community Psychology, 2008, 41 pp. 127-150
[146] Ibid.
[147] Cumming, G.S. et al. (2006) "Scale Mismatches in Social-Ecological Systems: Causes, Consequences, and Solutions" Ecology and Society, 11(1):14 ecologyandsociety.org/vol11/iss1/art14/
[148] Adger, W.N. et al. (2011) "Resilience Implications of Policy Responses to Climate Change" WIRE's Climate Change, 2, pp. 757-766 onlinelibrary.wiley.com/doi/10.1002/wcc.133/pdf
[149] Drever, C. R. et al. (2006) "Can Forest Management Based on Natural Disturbances Maintain Ecological Resilience?" Canadian Journal of Forest Research 36(9) pp. 2285-2299.

gested above, we follow this line in suggestions for resilience assessments. The definition is deliberately general and will only be meaningful when different capacities and characteristics are defined.

57. From our literature review, there seems to be a general agreement that the following manageable characteristics are critical for a system's general resilience. That the characteristics are manageable means that they are means and not ends. E.g., 'robustness' and 'resistance' are often mentioned as characteristics of resilient complex systems. However, they are generally static properties with little to no possibilities for changes[150]. The characteristics in the table are not prioritized, they are not mutually exclusive, they will often be inter-dependent, and it is the totality of the characteristics that determine the level of resilience[151] of a system. The level of importance of each characteristic in this totality will be context specific and not all characteristics are relevant for all systems.

**Table 1:** Resilience Characteristics of Social-Ecological Systems and Management Implications

| Characteristic | Management Implications | Examples Of Indicators For Resilience Assessments Of Social-Ecological Systems |
|---|---|---|
| Acceptance of uncertainty | Management based on continuous monitoring of internal and external changes of the ecosystem, learning through fast negative feedback, and rolling planning | Effectiveness of early warning systems for constant monitoring<br>Adaptive management |
| Adaptive capacity | Ability to prepare and plan for change and adjust to actual or expected stressors and trends, in order to moderate harm, mitigate worst impacts, or exploit beneficial opportunities | Early warning systems<br>Innovations<br>Risk assessments |
| Connectedness | Ability to interact / relate to other elements pertaining to the system itself as well as other related systems across temporal and spatial scales | Number of suppliers in a farming system<br>Network participation<br>Time perspective of management decisions |
| Coping capacity | Ability to reduce negative impacts from stress and disturbances through recognition of event and potential impacts, evaluation, and action and maintenance of a response capacity | Resources that can easily be mobilized / Asset accounts<br>Management skills |
| Diversity | Aiming for ecological, social, and political variety allowing increased options and reducing risks, e.g. through scaling up: quantitatively (e.g., replicating), functionally (different outputs/products), organizationally (more diversified network and governance structures), skills and knowledge, etc. | Biodiversity<br>Number of different uses of ecosystems<br>Stakeholder diversity<br>Institutional diversity (polycentric and multi-layered institutions)<br>Number of suppliers |
| Feedbacks | Identifying critical feedbacks that might be related to system thresholds, including 'missing feedbacks' such as the lack of economic implications for pollution and 'existing | System connections, including multi-scale connections<br>Learning |

[150] Bruneau, M. et al. (2003) "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities" Earthquake Spectra, Vol. 19 (4), pp. 733–752

[151] Mancini, A. & G. Bonanno (2009) "Predictors and Parameters of Resilience to Loss: Toward an Individual Differences Model" Journal of Personality 77:6, December 2009 pp 1805-1832

| CHARACTERISTIC | MANAGEMENT IMPLICATIONS | EXAMPLES OF INDICATORS FOR RESILIENCE ASSESSMENTS OF SOCIAL-ECOLOGICAL SYSTEMS |
|---|---|---|
| | feedbacks' whether recognized, ignored, or unknown. Identifying negative and positive feedbacks that and establish most important connections. | |
| Flexibility | Capacity to respond smoothly to change without unnecessary delays | Degree of decentralized decision-making<br>Level of multi-level and multi-directional communication system between all management and decision-making units<br>Level of modularity |
| Governance | Ensuring an enabling environment for informed decision-making while aiming at optimal distribution of wellbeing according to the social norms, including decentralized environmental governance based on participatory mechanisms with attention to power asymmetries in existing institutions | Equity, participation, transparency, decentralization, responsiveness, legitimacy and accountability, predictability |
| Learning capacity[152] | Capacity to learn from internal and external experience and adjust and identify challenges as opportunities to maintain and develop | Degree of experiments and innovation<br>Information systems<br>Institutional memory<br>Structures to continuously build on acquired learning<br>Degree of documentation and use of local knowledge and local innovation<br>Social and professional networks |
| Modularity | The system comprises a loose network of individual functional parts or modules that can evolve independently | Shared correlation with specific risks<br>Number of organizational units and structures |
| Networked systems | Panarchy as opposed to hierarchical systems | Number of hierarchical decision-making centers / units |
| Redundancy | Ability within the system for substitution and replacement | Network of independent socio-economic units with decision-making capacity<br>Biodiversity |
| Responsiveness | Capacity to contain losses and avoid disruption | Time required to mobilize and use necessary resources to respond to change |
| Resources | Economic/financial, physical/infrastructure, natural/ecological, technical / knowhow, social, and organizational resources that can be accessed by the system to respond to change | Asset accounts<br>Social networks<br>Extra-local ties and networks<br>Time required to mobilize specific resources |
| Risk awareness | Capacity to recognize, accept, understand, and analyze potential stressors | Early warning systems<br>Communication systems |

[152] Most people will link learning capacity to human beings. However, ongoing research at the University of Nebraska seems to confirm the 'learning' capacity of drought tolerant plants. Research on the mustard plant *Arabidopsis* shows that pre-exposure to drought alters the RNA molecules in the plant cells making the plant more tolerant for subsequent drought. For more information see news article, 14 March, 2012 from Institute of Agriculture and Natural Resources, University of Nebraska ianrnews.unl.edu/static/1203140.shtml

| CHARACTERISTIC | MANAGEMENT IMPLICATIONS | EXAMPLES OF INDICATORS FOR RESILIENCE ASSESSMENTS OF SOCIAL-ECOLOGICAL SYSTEMS |
|---|---|---|
| | | Public awareness and training<br>Risk assessment standards<br>Planning mindset |
| Self-organizing capacity | Ability to restructure system governance; i.e., institutions and organizations influencing the functioning of the system to adapt to changes | Local networks<br>Vertical and horizontal multi-level partnerships |
| Social capital | Social organization, such as networks, norms, and trust that facilitate coordination and cooperation for mutual benefits[153] | Leadership<br>Social networks, associations, and formal and informal groups<br>Number and strengths of intra-and inter community ties and linkages<br>Level of social inclusiveness<br>Sense of community<br>Shared values and history<br>Level of stakeholder participation in ecosystem management |
| Subsidiarity | Management issues will always be handled by the least centralized units capable of addressing the issues effectively | Level of decentralization |
| Transformative capacity | The capacity to alter fundamental attributes of a system including value systems, regulatory, legislative, or bureaucratic regimes, financial institutions, and technological or biological systems. Transformation fundamentally changes system structures and processes[154] without sacrificing provision of ecosystem services[155] | Analyzing and planning capacity<br>Quality of information systems<br>Flexibility<br>Innovativeness<br>Leadership |

58. For many of the characteristics, the interdependency is important. Redundancy, for instance, is not sufficient if there is no social capital to ensure communication among the different resources[156]. It should also be noted that in specific contexts, it can be difficult or even meaningless to draw a distinction between some of the characteristics. For instance, while some scholars will differentiate between coping and adapting capacities as short- and long-term responses respectively[157], the dynamic nature of social-ecological systems and the characteristics might make such a distinction irrelevant in many livelihood contexts[158].

[153] Tousignant, M. & N. Sioui (2009) "Resilience and Aboriginal Communities." Journal of Aboriginal Health November pp. 43-61
[154] Olsson, P. et al. (2006) "Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems" Ecology and Society 11 (1): 18 ecologyandsociety.org/vol11/iss1/art18/
[155] Folke, C. et al. (2002) "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations" The Environmental Advisory Council to the Swedish Government, sou.gov.se/mvb/pdf/resiliens.pdf
[156] Tousignant, M. & N. Sioui (2009) "Resilience and Aboriginal Communities." Journal of Aboriginal Health November pp. 43-61
[157] See for instance UNU (2011) "World Disaster Report – 2011" United Nations University ehs.unu.edu/file/get/9018
[158] Mortimore, M. (2010) "Adapting to Drought in the Sahel: Lessons for Climate Change" WIRE's Climate Change 1, pp. 134-1433

59. To illustrate the relative importance of some of the key resilience characteristics, the state of the system, and the level of resilience, Béné et al. (2012) suggest a simplified framework that is reflected in Figure 1. The framework can be seen as a part of a broader resilience analysis, where all relevant characteristics would need to be assessed simultaneously to present the overall resilience. Furthermore, the assessment and analysis of each relevant characteristic individually will facilitate management for resilience and ultimately management for sustainable development.

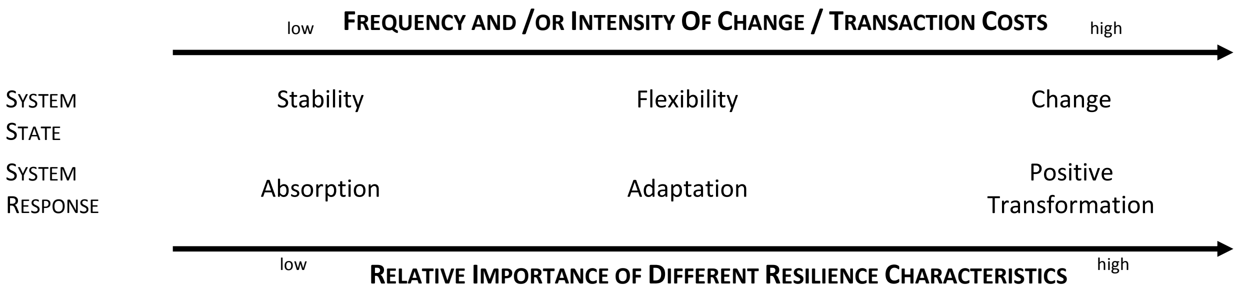


**Figure 1:** Relation between resilience, intensity of change, system state, and system responses. Adapted from Béné et al. (2012)[159]

60. The figure should only be seen as a simplification of the basic principles for illustrative purposes. In order to have a comprehensive understanding of different measures' impact on the resilience of social-ecological systems a holistic and multidimensional resilience assessment framework would be required. The framework should integrate other key resilience characteristics including learning, feedbacks, and self-organizing capacity and should differentiate between the states of the systems to understand the impacts of the different measures. Change will typically be the result of repetitive multi-stressors that can put the system in different simultaneous states. This phenomenon is known, for instance, in the Sahel region in Africa where emergency responses are required simultaneously with long-term development efforts in response to a wide range of short- and long-term stressors such as price inflations, climate change, and political unrest. Likewise, based on a literature review, Anderies et al. (2006)[160] conclude that there are often multiple interacting regime shifts in the same social-ecological system with impacts from many different variables that can interact in different ways. According to Vetter et al. (2009)[161] continuous grazing seems to increase the likelihood that drought might cause a state change in the rangelands. Moreover, alternative states will often start as small, isolated patches. Measuring resilience in social-ecological systems is thus particularly complicated[162].

[159] Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

[160] Anderies, J.M. et al. (2006) "Fifteen Weddings and a Funeral: Case Studies and Resilience-Based Management" Ecology and Society 11(1): 21 ecologyandsociety.org/vol11/iss1/art21/

[161] Vetter, S. (2009) "Drought, Change and Resilience in South Africa's Arid and Semi-Arid Rangelands" South African Journal of Science 105 (1-2) pp. 29-33

[162] Lavell, A. et al. (2012) "Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special

61. Based on the notions of critical natural capital as introduced in section 2.1.3, Brand (2009)[163] notes that the critical natural capital represents the part of ecosystems that has to be maintained to ensure ecosystem functioning for future generations. It thus also represents the resilience of ecosystems. Accordingly, the author suggests that resilience can best be estimated using the concept of alternative stable states and ecological thresholds identified through critical natural capital. Moreover, it is assumed that a few key variables control ecosystem dynamics and resilience, particularly the so-called slow variables. Slow variables have a slow turnover rate in space and time such as abundance of woody species and their threshold values would represent the resilience of the systems. However, it can be questioned if controlling slow variables can actually be identified in practice. Similarly, what constitutes critical natural capital is a subjective decision based on definition of certain boundaries such as critical for whom, for what, as well as time and scale boundaries. The use of critical natural capital for resilience assessments needs to be tested in practice.

### *2.4.3 Assessing Resilience in Practice*

62. A literature review reveals a number of documented assessments of resilience in social-ecological systems. The assessments have been carried out over the last decade and use different degrees of established assessment frameworks. Many of the assessments are only intended to be illustrative to show the meaning and importance of resilience for management of complex social-ecological systems, while others represent attempts to develop general analytical frameworks. The vast majority of the documented resilience assessments of social-ecological systems are qualitative while some partial assessments are based on more quantifiable measures, for instance based on scores.

63. In Part 2 of this White Paper, we have assembled a selection of recent resilience assessments showing the variety of approaches that are being applied. Many of the articles that present resilience assessments do not offer clear definitions of the resilience concept that has been applied. This obviously limits the general usefulness of the assessment results. Moreover, the literature review found several assessments based on vulnerability frameworks that are now renamed resilience frameworks. While this might reflect that the authors consider resilience as the reverse of vulnerability but in positive terms, the lack of clear definitions and structure limit their usefulness for identification of specific factors that strengthen resilience per se. In a literature review of assessments of social-ecological resilience, Vetter et al. (2009)[164] identify two different approaches. One approach focuses on the thresholds between different ecological states and the factors that might cause a state change. The other general approach applies a holistic approach defining resilience in relation to sustainability and focusing on production of knowledge, social learning, and adaptive management of complex systems shaped by cross-scale interactions, nonlinear feedbacks, and uncertainty. In addition to the two broader approaches presented by

Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 25-64

[163] Brand, F. (2009) “Critical Natural Capital Revisited: Ecological Resilience and Sustainable Development” Ecological Economics, 68, 2009 pp. 605-612

[164] Vetter, S. (2009) “Drought, Change and Resilience in South Africa's Arid and Semi-Arid Rangelands” South African Journal of Science 105 (1-2) pp. 29-33

Vetter et al., we also find that a clear distinction can be made between general resilience assessments and assessments focusing on specific resilience characteristics, e.g., through simplified assessment frameworks. This approach reflects the conclusions of Glaser et al. (2012)[165] summarizing the findings of a recent international symposia on social-ecological systems[166] showing that the complexity of social-ecological systems makes it necessary to focus on specific problems in delineated geographic areas.

64. For disaster risk management contexts resilience studies focus on social aspects, while few studies take an integrated social-ecological system approach. The disaster resilience studies have led to the development of the notion of 'community resilience' or 'social resilience', which refers to processes that can only be truly examined by looking at collective responses to disturbances[167]. A 2010 review[168] of literature addressing community or social resilience showed that most research is theoretical and few attempts have been made for empirical research and testing of conceptual frameworks. Moreover, most analysis frameworks for disaster resilience have been developed for developing countries such as the DROP framework (disaster resilience of place) based on five resilience characteristics: social capital, economic well-being, institutional aspects, social network and connection, and infrastructure status[169].

### *2.4.4 Economic Valuation of Resilience of Social-Ecological Systems*

65. From a conceptual point of view, the costs of resilience are linked to the costs of the different resilience characteristics highlighted in section 2.4.2, such as learning, and maintenance of redundancy and diversity. The benefits will include the additional values from improved resilience in terms of avoided losses and growth. Translating these intangible characteristics into quantitatively or qualitatively measurable items requires indirect measures, for instance in forms of indicators. For the economic valuation of the social, cultural, and environmental costs and benefits some methodologies have been developed, including investment and financial flows, scenario-based impact assessments, vulnerability assessments, adaptation assessments, risk management assessments, economic integrated assessment models, multi-criteria analysis; computable general equilibrium models; cost-benefit analysis; cost effectiveness analysis, and portfolio/real options analysis. However, most of these methodologies have been developed for specific contexts and are often only addressing some resilience aspects or specific geographic locations without assessing indirect costs and benefits beyond the location. Moreover, the economic assessment methodologies are generally based on gradual change while a main characteristic of social-ecological systems is the non-linearity and there is little agreement about the usefulness of the

[165] Glaser, M. et al. (2012) "New Approaches to the Analysis of Human-Nature Relations" in Glaser, M. et al. (eds.) (2012) "Human-Nature Interactions in the Anthropocene – Potential of Social-Ecological Systems Analysis" Routledge, New York pp. 3-12

[166] http://dg-humanoekologie.de/www/dghde/

[167] Wickes, R. et al. (2010) "Community Resilience Research: Current Approaches, Challenges and Opportunities" in Priyan, M. & A. Yates (Eds.)(2010) "Recent Advances in National Security Technology and Research – Proceedings of the 2010 National Security Science and Innovation Conference" Australian Security Research Centre, Deakin pp. 62-78

[168] Wickes, R. et al. (2010) "Community Resilience Research: Current Approaches, Challenges and Opportunities" in Priyan, M. & A. Yates (Eds.)(2010) "Recent Advances in National Security Technology and Research – Proceedings of the 2010 National Security Science and Innovation Conference" Australian Security Research Centre, Deakin pp. 62-78

[169] Tulane University's Disaster Resilience Leader Leadership Academy & Université d'Etat d'Haiti (2012) "Evaluation de l'Aide Humanitaire en Haïti sous l'Angle de la Résilience" Tulane University, New Orleans

methods among environmental, ecological, and disaster economists[170]. As a result, there have been very few attempts so far to value policies and practices aiming at strengthening social-ecological resilience. Likewise, Mäler & Chuan-Zhong (2010)[171] note that while many recent papers dealing with the valuation of ecosystem services include some thoughts about resilience, resilience has generally not been considered as a genuine economic value.

### *2.4.5 Managing Drylands and Drought Risk for Resilience*

66. As highlighted in table 1, characteristics of resilience in complex social-ecological systems have management implications. Ecosystems that might seem healthy and fully functional with steady provision of services might suddenly flip to new states when critical thresholds for absorption of internal and external stress are reached[172]. While flips might be observable in environmental systems, they are more difficult to identify in socio-economic systems[173]. This implies that management should be flexible and adaptive, with a high level of redundancy and diversity, and with access to effective information systems of both the internal and the external environment. In fact, managing for constant yields in social-ecological systems can lead to a gradual decrease in system resilience[174].

67. Management for resilience means management based on incomplete information about an uncertain and unpredictable future. It is thus very different from typical management techniques in traditional business models such as streamlining and simplification. However, history has shown the negative impact when these traditional models are used in complex social-ecological systems. Monocropping, for instance, has led to land degradation, greater vulnerability to both natural and socio-economic stressors, and signs of low resilience. On the other hand, many traditional land use models that have shown resilience for centuries have used crop diversification as a central element of long-term management strategies. While most land users now agree that monocropping should not be part of sustainable land use strategies, there are other management components that might have been streamlined over the years leading to a decrease in the system's resilience, e.g., the reliance on single suppliers instead of a diversified supplier chain. This means that managing for resilience implies long-term strategies rather than the just-in-time models applied to maximize short-term profit[175]. Managing for resilience therefore calls for structures that promote long-term land use management strategies such as legislation and financial structures to favor long-term investments.

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170 Handmer, J. et al. (2012) "Changes in Impacts of Climate Extremes: Human Systems and Ecosystems" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 231-290

171 Mäler, K.-G. & L. Chuan-Zhong (2010) "Measuring Sustainability under Regime Shift Uncertainty: A Resilience Pricing Approach" Environment and Development Economics 15, pp. 707-719

172 Schroll, H. et al. (2009) "Resilience Is More Than an Elastic Jump" The Journal of Transdisciplinary Environmental Studies, 8(1) pp. 1-2

173 Martin-Breen, P. & J.M. Anderies, (2011) "Resilience – A Literature Review" Rockefeller Foundation, New York, rockefeller-foundation.org/news/publications/resilience-literature-review

174 Holling C.S. (1996) "Engineering Resilience versus Ecological Resilience" in Schulze, P.C. (Ed.) (1996) "Engineering Within Ecological Constraints" National Academy Press, Washington D.C. pp. 31-44

175 Lee, B. et al. (2012) "Preparing for High-impact, Low-probability Events - Lessons from Eyjafjallajökull" Chatham House, London

68. Many in the development community will argue that when communities manage ecosystems for long-term productivity it not only strengthen ecosystem resilience but also community resilience[176]. While such a relationship might seem intuitively appealing, it can also be argued that in the agricultural intensification process where ecosystems are being managed for long-term productivity for a limited group of landowners there is no overall ecosystem resilience guaranteed neither social resilience. Managing drylands for resilience is thus not just a matter of long-term natural resource planning. Rather, it requires a holistic approach with well-defined sustainability goals for the integrated social-ecological system and often for the whole society. To this end, there is a need for broader policies to govern the process such as defined in the action programs for the implementation of the UNCCD.

69. In the business world, resilience is often described with the terminology of 'business continuity planning' or 'continuity of operations planning'. Continuity planning includes inter alia risk management with threat analysis, impact scenario development, solution design, implementation and maintenance, and regular testing / assessment / updating. Kaplan & Mikes (2011)[177] suggest to address risks according to three different categories depending on the level of controllability: 1/'known knowns' (things that we know we know), 2/'known unknowns' (some things we know we do not know), and 3/'unknown unknowns' (surprises or immeasurable future events also referred to as 'black swans'). From a management perspective, the 'known knowns' can be eliminated, the 'known unknowns' reduced through resilience measures such as adaptation, while effective management will address the 'unknown unknowns' through increased overall resilience, including risk awareness, flexibility, transformability, social networks, learning from past experiences, and innovation. These different characteristics also reflect the findings of Tameer & Bring (2012)[178] in their review of organizational conditions favoring effective management of the unknown unknowns in the public water sector confronted with climate change. The study shows the importance of frontline staff being empowered to change corporate responses to a changing environment. The different techniques come at a price, though, and effective management must weigh capacity to endure loss with the costs of resilience measures. Bernett (2001)[179] therefore suggests that any management strategy should begin with a formalized and systematic assessment of the 'known knowns', the 'known unknowns' and the 'unknown unknowns'. This will facilitate management and policy decisions about relative importance to be given to each situation. This should be compared with the price of action vs. non-action. But in some risk environments, both the price of taking action and of the price of inaction are potentially high, making it difficult to form decisions on the basis of either a precautionary approach or traditional cost-benefit analysis. In such circumstances, identification of least- or no-regret options is likely to be critical[180].

[176] WRI et al. (2008) "World Resources: Roots of Resilience – Growing the Wealth of the Poor" World Resource Institute, Washington D.C.

[177] Kaplan, R.S. & A. Mikes (2011) "Managing the Multiple Dimensions of Risk: Part I of a Two-Part Series" Balanced Scorecard Report 13(4) pp. 1-6

[178] Tameer, C. J.A.M. & M.A. v.d. Brink (2012) "Organizational Conditions for Dealing with the Unknown Unknown" Public Management Review 15(1) pp. 43-62

[179] Barnett, J. (2001) "Adapting to Climate Change in Pacific Island Countries: The Problem of Uncertainty" World Development 29(6) pp. 977-993

[180] Lee, B. et al. (2012) "Preparing for High-impact, Low-probability Events - Lessons from Eyjafjallajökull" Chatham House, London

70. Rydzak & Chlebus (2007)[181] suggest that resilience management in a given organization should be based on identification of the desired state or configuration of the organization. If the organization is already in that state, the resilience should be increased to ensure continuity. On the other hand, if the current configuration is not considered to be optimal, the resilience should be lowered to facilitate transition of the production systems to the desirable configuration. The resilience management should be differentiated for the various processes and structures in the organization; e.g., resources (people, organizations, capital, etc.), crucial ecosystem services, crucial production methods, and policies and institutions. The authors suggest application of system dynamic models for resilience management, including disturbance analysis focusing on internal feedback loops and time delays that affect the behavior of the entire system.

71. Instead of looking at the different elements of the complex systems when designing management strategies for resilience, others suggest focusing on specific resilience characteristics, particularly learning and adaptation capacity. The role of learning in complex systems with many stakeholders is described in the social learning and co-management literature[182]. In fact, effective co-management - or partnership building as referred to in many UNCCD contexts - builds on resilience characteristics such as social capital, good governance, responsiveness in addition to learning, and adaptation. All these characteristics are dynamic and like 'resilience', 'co-management' or 'partnership building' are continuous changing processes defined by feedback learning over time[183]. *S*ocial learning takes place at different levels with different time-perspectives: 1/single-loop learning consists of correcting errors from routines or becoming better at how things are already done, i.e. improved efficiency; 2/double-loop learning consists of correcting errors by examining values and policies and thus integrating the context perspective, i.e. improved effectiveness; and 3/triple-loop learning consists of transformative change and is thus linked to the innovativeness and flexibility of the individual or organization[184]. Single- and double-loop learning can be planned and even designed in advance, but triple-loop learning cannot. Rather, triple-loop learning will include a high degree of trial and error, which should be taken into account when budgeting for effective management for resilience.

72. The importance of learning for cost-efficient management of social-ecological systems for resilience has been shown in various comparative resilience studies. Anderies et al. (2006)[185] shows, for instance, that in ecosystems where the management can inject new resources such as in the Everglades in Florida, USA, learning from mistakes is limited. On the other hand, the authors found that in systems where the management has limited resources at their disposal such as in the Northern Highlands Lake District in Wisconsin, USA and in the Kristanstad Vattenrike, Sweden, learning from former mistakes is

[181] Rydzak, R. & E. Chlebus (2007) "Application of Resilience Analysis in Production Systems – Bombardier Transportation Case Study" Paper presented at the 25th International Conference of the System Dynamics Society, Boston systemdynamics.org/conferences/2007/proceed/papers/RYDZA163.pdf

[182] See for instance Berkes, F. (2009) "Evolution of Co-Management: Role of Knowledge Generation, Bridging Organizations and Social Learning" Journal of Environmental Management 90 pp. 1692-1702

[183] Ibid.

[184] Armitage, D. et al. (2008) "Adaptive Co-Management and the Paradox of Learning" Global Environmental Change 18 (1) pp.86-98.

[185] Anderies, J.M. et al. (2006) "Fifteen Weddings and a Funeral: Case Studies and Resilience-Based Management. Ecology and Society 11(1): 21 ecologyandsociety.org/vol11/iss1/art21/

much greater. The authors argue that social-ecological systems with outside capital input prevent these systems from changing while systems with limited outside support has a higher adaptation capacity. On the other hand, outside resources can also promote system adaptation as shown in a study from Zimbabwe where outside resources in the form of tourist hunting and other paying hunters allowed the rangelands to attain new productive forms after the ecosystems had been degraded from overgrazing.

# 3. VALUATIONS OF SUSTAINABLE DRYLAND AND DROUGHT RISK MANAGEMENT

## 3.1 APPROACHES TO VALUATIONS OF COMPLEX SOCIAL-ECOLOGICAL SYSTEMS

73. From a neoclassic economic perspective, the best technique for monetary valuation of assets and services is in principle observed market prices. However, for many environmental goods and services market prices do not apply directly as discussed extensively during the first UNCCD Scientific Conference[186]. First of all, many dryland environmental assets and services are never traded in an open market and when they are, market prices do not include all externalities although some might be integrated in the market values through taxes, subsidizes, and other regulatory mechanisms. Secondly, many ecosystem services are normally considered as public goods[187] and free of charge to the individuals. So in spite of a general appreciation of ecosystem services such as maintenance and regulation, the services are mostly ignored in formal and informal environmental valuations[188]. Even when market prices do exist, they will normally not express the true economic value for the whole society of an environmental good or service. It should also be noted that economic valuations are based on incremental changes. Environmental goods and services that are slowly changing but in a non-linear way such as biodiversity and soil formation will therefore often be overlooked in valuation exercises.

74. But the challenge of economic environmental valuations goes far beyond assigning monetary values to the services. In fact, a major challenge remains the identification of all sources or types of values ensuing from the specific ecosystem. This will require an improved and quantified understanding of the functioning of ecosystems and the generation of services under different stressors[189]. For instance, environmental services are highly interconnected and interdependent so the valuation of the whole ecosystem is not just a matter of summing up the different ecosystem services. In a 2010 literature review of direct and derived impact of climate change on global agricultural productivity, Gornall et al.

[186] Winslow, M. et al. (2009) "Understanding Desertification and Land Degradation Trends" Proceedings of the UNCCD First Scientific Conference, 22–24 September 2009, Buenos Aires dsd-consortium.jrc.ec.europa.eu/documents/ProceedingsUNCCDFirstScientificConference.pdf

[187] The concept of public goods in economics stem back to economist and Nobel-prize winner Paul Samuelson who used the term 'collective consumption good' in 1954. Those goods were defined as goods which everybody can enjoy in common in the sense that each individual's consumption of such a good leads to no subtractions from any other individual's consumption of that good, i.e. non-rivalry. In its strictest sense, public goods are goods that are non-excludable (i.e., it is not possible to prevent people who have not paid for the good or service from benefitting from it) and non-rivalrous (i.e., the use of the good or service by one individual does not limit the amount of the good available for consumption by others). Environmental services are not just public goods but can be anything from private goods to pure public goods, including the intermediary groups: club goods (excludable and non-rivalrous – e.g., clean water) and common goods (non-excludable and rivalrous – e.g., public rangelands). In line with most environmental economics literature, we use the term 'public goods' in its broadest sense; i.e., everything that is not a private good (excludable and rivalrous).

[188] Eigenraam, M. et al. (2011) "Valuation of Ecosystem Goods and Services in Victoria, Australia" Paper presented at the UN/World Bank/EEA Expert Meeting on Ecosystem Accounts, 5-7 December 2011, London unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue10_Aus.pdf

[189] Bateman, I. J. et al. (2011) "Economic Analysis for Ecosystem Service Assessments" Environmental Resource Economics 48 pp. 177-218

(2010)[190] conclude that the aggregate impacts are not yet known, nor have many of the specific impacts been reliably quantified. E.g., while many studies have quantified direct climate change impact on agricultural yield from increased temperature stress levels, indirect stressors such changes in pests, weeds, and diseases are generally not considered.

75. As mentioned, more important than what is marketed and what is not, is the issue of externalities, i.e., all the unrecorded impacts and the associated market failures. While environmental economics initially focused on environmental damages from pollution and depletion of nonrenewable resources,[191] it is now mainly framed by ecosystem services. Over the years, environmental economists have presented a number of non-market market techniques for environmental valuations based on individual preferences; either revealed / observed[192] or stated / expressed[193] preferences. As noted in the Introduction (Chapter 2) environmental economics is based on neoclassical economics and the assumption that environmental goods and services enter individuals' preference structures in the same way as other goods or services. The utility approach is also reflected in the valuation of assets such as natural stocks based on expected returns, i.e., a natural stock with no expected future benefits has no value in economic terms. In order to assess expected returns, a number of assumptions must be made about future environmental flows. As the core of sustainability is about not compromising future returns these assumptions are critical for the reliability of valuations of sustainable dryland management.

## 3.2 TOTAL ECONOMIC VALUE

76. The notion of Total Economic Value facilitates the conceptual understanding of the comprehensiveness of environmental valuations, for instance of a new policy. Total Economic Value encompasses use as well as non-use (or passive) values, where use values include actual use (e.g. timber harvest), planned use (e.g., timber plantation), and optional use (e.g., the value of drylands for potential future exploitation). Non-use values refer to the willingness to pay for maintaining an environmental asset even though there is no actual, planed, or possible use[194]. While the use values are fairly easy to comprehend in terms of assigning values, passive use is less obvious. The nonuse is generally described in terms of 1/'existence values' (willingness to pay for the environment asset even though no human will use the asset), 2/'altruistic values' (willingness to pay for an environmental asset for the benefit of others), and 3/'bequest values' (willingness to pay for an environmental asset that future generations might benefit from). Whereas Total Economic Value might facilitate the understanding of the comprehensiveness of environmental economic values, the terminology might be misleading as it can be argued that intrinsic values of the environmental asset such as values of ecosystem regulating and maintenance ser-

[190] Gornall, J. et al. (2010) "Implications of Climate Change for Agricultural Productivity in the Early Twenty-First Century" Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554) pp. 2973-2989

[191] Mäler, K.-G., et al. (2008) "Accounting for Ecosystem Services as a Way to Understand the Requirements for Sustainable Development" Proceedings of the National Academy of Science 105(28) pp. 9501-9506

[192] Based on market prices for related marketed services; e.g., cost of travel to benefit from the recreational service from a forest.

[193] Based on information obtained for instance through surveys.

[194] Atkinson, G. & S. Mourato (2006) "Cost-Benefit Analysis and the Environment: Recent Developments" OECD, Paris

vices are not included. Others will argue though, that the non-use values will include an appreciation of intrinsic values.

## 3.3 Overview Frequently Used Valuation Techniques

77. Recent initiatives of economic valuation of drylands such as the Economics of Land Degradation (ELD)[195] and the 1st UNCCD Scientific Conference have generated important overviews of the potential application of major valuation techniques for drylands[196,197,198]. We will therefore limit ourselves to a brief overview of the most recognized valuation techniques with some general observations.

**Table 2:** Commonly Used Economic Environmental Valuation Techniques[199]

| Technique | Description | Examples of analyses | Observations |
|---|---|---|---|
| **Market-based methods – Direct observations** | | | Market prices only express the minimum amount people are willing to pay but not necessarily the real economic value. Complementary techniques might be necessary to capture non-use values. |
| Adjusted Market Prices | Market prices adjusted for taxes, subsidies, seasonal variations, etc. | Value of food production<br>Value of timber | Data for marketed goods such as food and timber easily available, but the full consideration of all distortions can be challenging. |
| Cost of Production / Biophysical measurement | Using a production function where inputs are ecosystem services, which are valued through their contribution to the output. | Production response to different levels of desertification<br>Production function analysis to estimate a dryland ecosystem's contribution to drinking water | Establishing the cause-effect linkages is challenging – need for transdisciplinary work.<br>Risks for double counting. |
| **Market Based: Indirect Methods / Inferred Market Prices / Revealed Preferences** | | | Revealed preferences can only capture use values while stated preferences can cap- |

[195] eld-initiative.org/

[196] Ephraim N. et al. (Eds.) (2011) "The Economics of Desertification, Land Degradation, and Drought Toward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150

[197] Winslow, M. et al (2011) "Understanding Desertification and Land Degradation Trends" Proceedings of the UNCCD First Scientific Conference, 22–24 September 2009, Buenos Aires, Argentina unccd.int/Lists/SiteDocumentLibrary/CST/NewCST/Proceedings-1stUNCCDSciConf.pdf

[198] Akhtar-Schuster, M. et al. (Eds.) (2010) " Monitoring and Assessment of Desertification and Land Degradation: Knowledge Management, Institutions and Economics" White Paper of the DSD Working Group 3 unccd.int/Lists/SiteDocumentLibrary/CST/NewCST/White%20Paper%20of%20the%20DSD%20Working%20Group%203.pdf

[199] For more information see for instance Ephraim N. et al. (2011) "The Economics of Desertification, Land Degradation, and Drought Toward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150, Liu, S. et al. (2010) "Valuing Ecosystem Services" Annals of the New York Academy of Sciences, 1185 pp. 54–78, which presents a review of the ecosystem valuation over the last 50 years with a focus on utilitarian values while recognizing that there are also intrinsic values of ecosystems, and Farber, S.C. et al. (2002) "Economic and Ecological Concepts for Valuing Ecosystem Services" Ecological Economics 41 pp. 375-392

| TECHNIQUE | DESCRIPTION | EXAMPLES OF ANALYSES | OBSERVATIONS |
|---|---|---|---|
| | | | ture both use and non-use values. |
| Avoided Damage Costs / Prevention Costs / Replacement costs / Substitute Costs | Estimate values of environmental goods or services based on either the costs of avoiding damages due to lost services or goods, the cost of replacing ecosystem services, or the cost of providing substitute services | Cost of avoiding food insecurity through drought mitigation measures<br>Cost of soil conservation measures<br>Costs of water purification in the absence of ecosystems | Do not provide information of people's willingness to pay but based on assumption that if people are willing to incur the costs of avoidance, prevention, replacement, or substitution the value must be at least those costs. |
| Hedonic Prices / Related Goods | Prices in markets related to environmental goods and services | Housing markets reflecting the location; e.g., closeness to a water source | Price formation on, for instance, housing markets is complex. |
| Human Health | The contribution of environmental goods and services to human health | Cost of food insecurity, incl. malnutrition from drought<br>Cost of vector-borne diseases | The relationship between human health and ecosystem services is very complex and not fully understood. |
| Opportunity Cost | The value of the best alternative | Value of the possible benefit of not investing in land conservation measures, e.g., alternative investments | Mainly useful for comparing different land uses where total land use value is considered with no break-down. |
| Residual Values | Use of market prices for final goods and intermediary inputs | Stumpage value of timber is derived from market prices for finished lumber [200] | Not applicable for all residual products. |
| Travel Cost | Market goods are complements to the environmental goods and services | Public willingness to pay to travel for recreational value of a dryland forest | Complexity of price formation for travel costs; e.g., distance to ecosystem, quality of roadway, and gasoline prices. |
| **Survey-based methods / Stated Preferences / Non-market behavior based** | | | To be informative the use of stated preference methods requires that respondents have prior experience or understand the full implications of the survey[201]. Close collaboration with survey experts necessary.<br>Rely on hypothetical situations and hence they suffer from hypothetical biases. |
| Bidding Game | Based on willingness to pay or accept compensation – | Landowners' willingness to accept compensation for | Might be more suitable for economies where barter is |

[200] Babulo, B. et al. (2006) "Economic Valuation Methods of Forest Rehabilitation in Exclosures" Journal of the Drylands 1(2) pp. 165-170

[201] Atkinson et al. (2012) notes that "while stated preferences may provide sound valuations for high experience, use-value goods, the further we move to consider indirect use and pure non-use values, the more likely we are to encounter problems. Paradoxically, then, where SP [stated preferences] techniques are most useful is also where they have the potential to be less effective." Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47

| TECHNIQUE | DESCRIPTION | EXAMPLES OF ANALYSES | OBSERVATIONS |
|---|---|---|---|
| | respondents are asked repeated questions about their willingness to pay where each question raise the price with a certain amount | tree plantation on cultivated land | important such as developing countries.[202] |
| Contingent Valuation | Willingness to pay for a certain service or good<br><br>Willingness to accept compensation for a certain good or service | Landowners' willingness to pay for soil conservation<br>Compensation farmers would be willing to accept for not cultivating drylands | Respondents might underestimate the willingness to pay if they think they might actually have to pay for the service. Multiple surveys have shown that willingness to accept systematically exceeds willingness to pay. |
| Choice Modeling[203] | Choices between different levels of environmental goods at different prices to reveal willingness to pay – respondents can either rank, score, or choose most preferred option based on certain characteristics of the alternatives, including economic value | Identification of most valued land restoration technique<br>Ranking different ecosystem service scenarios, e.g., choosing between dryland scenarios with differing levels soil conservation measure | Choice modeling is being used more and more[204] for environmental valuation – when used for economic valuation the method requires some complementary valuation.<br>Choice modeling is particularly suited for multidimensional changes. |

78. For more detailed examples of the application of the various techniques, we refer to the Environmental Valuation Reference Inventory (EVRI)[205], which is a global repository of environmental valuations with almost 4,000 studies. The database allows searches for valuation technique, geographic location, and environmental assets such as land. An overall objective of the EVRI database is to facilitate the application of the so-called Benefits Transfer Approach[206] described for instance in the Millennium Ecosystem Assessment.[207] Through the benefits transfer approach valuation estimates for non-market values obtained in one context are used in another irrespective of the applied technique. Considering the complexity of ecosystems, the benefits transfer approach is controversial despite the general recognition that the approach is time and resource saving[208]. In spite of the challenges surrounding the benefits transfer approaches, they are widely used and according to Pearce et al. (2006)[209], they constitute the "bedrock of practical policy analysis" because of resource constraints. In their recent review of ecosys-

[202] Christie, M. et al. (2012) "An Evaluation of Monetary and Non-Monetary Techniques for Assessing the Importance of Biodiversity and Ecosystem Services to People in Countries with Developing Economies" Ecological Economics 83 pp. 67-78
[203] Choice modeling is a further development of conjoint analyses.
[204] Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47
[205] evri.ca
[206] As mentioned by Atkinson et al. (2012) the terminology 'benefits transfer' might be misleading as the approach is used for both costs and benefits assessments. The authors therefore refer to "transfer of valuation estimates" Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47
[207] Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C.
[208] See for instance Nemec, K.T. & C. Raudsepp-Hearne (2012) "The Use of Geographic Information Systems to Map and Assess Ecosystem Services" Biodiversity and Conservation pp. 1-15
[209] Pearce, D. et al. (2006) "Cost Benefit Analysis and the Environment – Recent Developments" OECD, Paris

tem service valuations, Atkinson et al. (2012)[210] note that the 2011 national ecosystem assessment in the United Kingdom[211] uses benefit transfers techniques at many levels. E.g., the increase in the value of provisioning services as a result of agricultural intensification is used to inform the calculation of green house gas emissions and the value of cultural services such as recreation. According to the authors, the use of benefits transfer approaches have allowed highly disaggregated and spatially sensitive data and thereby improved the value for policy decision-making. It should also be noted that up-scaling of data from a small segment of an ecosystem to the whole ecosystem can be seen as benefits transfer[212]. For the use of benefits transfer approaches for valuation of sustainable dryland and drought risk management policies and practices, criteria for when the approach can provide reasonable approximations would need to be developed. In the examples of valuations of sustainable dryland drought risk management policies and practices presented in Part 2 of the White Paper, we discuss the challenges of using the benefit transfer approach for valuations in China.

79. Several scholars have pointed out that the valuation techniques should not be considered as alternatives and there is no hierarchy of them[213]. Rather, there is no perfect technique that captures all values of ecosystem services. Some techniques are more suited to specific services than others are and different techniques perform differently in different contexts[214]. A mixture of techniques will therefore be required for valuation of sustainable dryland and drought risk management. Not only a mixture of economic valuation techniques but also a blend of economic, social, behavioral, and other techniques. This has led to the suggestion that as a decision-making support tool, valuations should include multi-criteria analyses for comparison of alternatives through weighted scores for characteristics that are normally based on incompatible measurements. As such, multi-criteria techniques allow the integration of interests of multiple stakeholder groups and multiple objectives. The criteria can be established in a transparent and participatory manner with involvement of decision-makers at different levels. Moreover, the different stakeholder forums that are typical in valuations using multi-criteria analysis favor transparency, early warning, and learning and adaptation[215]. In this way, multi-criteria analyses can be critical for strengthening resilience. In the end, though, the choice of valuation techniques will have policy implication but will to a large degree have to depend on the national institutional structures and systems and particularly on availability of relevant information. Moreover, the choice of techniques should consider stakeholder interests and the target audience for the valuation.

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[210] Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47

[211] uknea.unep-wcmc.org . The UK National Ecosystem Assessment is considered as the most comprehensive national economic environmental valuation.

[212] Schägner, J.P. et al. (2012) "Mapping Ecosystems Services' Values: Current Practice and Future Prospect" Fondazione Eni Enrico Mattei Working Paper 59 papers.ssrn.com/sol3/papers.cfm?abstract_id=2160714

[213] E.g. Brondizio, E.S. & F.W. Gatzweiler (2010) "Socio-Cultural Context of Ecosystem and Biodiversity Valuation" in Kumar, P. (Ed.) (2010) "The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations" Earthscan, Routledge, New York, pp. 149-182

[214] Christie, M. et al. (2012) "An Evaluation of Monetary and Non-Monetary Techniques for Assessing the Importance of Biodiversity and Ecosystem Services to People in Countries with Developing Economies" Ecological Economics 83 pp. 67-78

[215] Özkaynak, B. et al. (2012) "The Identity of Ecological Economics: Retrospects and Prospects" Cambridge Journal of Economics 36(5) pp. 1123-1142

80. In a recent evaluation of the most commonly used environmental valuation techniques Christie et al. (2012)[216] address the particular challenge of the techniques' value in the contexts of developing countries. For policy-making and development of good practices, the authors highlight a number of non-economic valuation techniques that could be more useful in developing countries than direct and indirect economic valuation techniques. According to the authors non-economic techniques used for environmental valuation in developing countries are mainly based on techniques developed in rural sociology such as participatory rural appraisal. While these techniques might provide useful input for policy-making, they are typically based on a simplified language to facilitate outsiders' understanding of local rationale. In this process, critical information might easily be ignored.

81. Over the last years, more and more software programs for ecosystem management have been introduced to facilitate for instance environmental valuations for decision-making[217]. One example is the software InVEST (Integrated Valuation of Environmental Services and Tradeoffs) developed by the Natural Capital Project,[218] which is run by universities and environmental groups in the United States. The InVEST modeling tool is based on ecological production functions[219] used to quantify ecosystem services generated in different systems. The software toolbox is being validated in different countries where land degradation is a critical challenge such as China and Tanzania. Integrated software tools such as InVEST offer important input to decision-making processes. However, they are still limited by the number of environmental services covered, the timeframe, and the data quantity and quality required for acceptable results. If not used very carefully and with appropriate disclaimers and explanations their use might be seriously misleading for decision-makers. According to Nemec & Raudsepp-Hearne (2012)[220] the integrated tools for environmental analyses such as InVEST should be considered as works in process. More scientific research and development are needed for better integration and explanation of stochastic, scale-dependent, and non-linear processes with threshold effects.

## 3.4 Premises and Boundaries for Environmental Valuations

82. While the potential and limits of different valuation techniques are generally recognized and many stakeholders will have an intuitive understanding of the information the techniques might provide, the valuators need to define a number of general premises and boundaries regarding what should be valuated. Clear understanding of these premises and boundaries is critical for the usefulness of any environmental valuation and should be clearly communicated to the users of the results. In the following, we highlight some of major challenges in defining and describing environmental valuations.

[216] Christie, M. et al. (2012) "An Evaluation of Monetary and Non-Monetary Techniques for Assessing the Importance of Biodiversity and Ecosystem Services to People in Countries with Developing Economies" Ecological Economics 83 pp. 67-78
[217] Wainger, L. & M. Mazzotta (2011) "Realizing the Potential of Ecosystem Services: A Framework for Relating Ecological Changes to Economic Benefits" Environmental Management 4 pp. 710-733
[218] naturalcapitalproject.org/InVEST.html
[219] Nelson, E. et al. (2009) "Modeling the Tradeoffs Between Ecosystem Services and Biodiversity" Frontiers in Ecology and the Environment 7(1)pp.4-11
[220] Nemec, K.T. & C. Raudsepp-Hearne (2012) "The Use of Geographic Information Systems to Map and Assess Ecosystem Services" Biodiversity and Conservation pp. 1-15

### 3.4.1 PROCESSES, OUTPUTS, OR OUTCOMES?

83. In the logic of ecosystem functioning processes, outputs, and outcomes - or activities, services, and benefits - have all values on their own. As highlighted by Kumar et al. (2010)[221], policy-makers are in principle only interested in the final benefits, i.e., the final outcomes from the chain 'ecosystem processes-services-benefits', where the benefits will be the direct expression of impacts on well-being. For landowners, the picture might be different, as they in principle would recognize the value of processes. While the relationship between 'processes-services-benefits' is recognized, the cause relationship can be difficult to establish. For instance, there is not necessarily a one-to-one relationship between processes and outputs; e.g., vegetation cover can generate several regulating outcomes such as flood protection and soil erosion control. On the other hand, many outputs and outcomes - or ecosystem services and benefits - are the result of different processes[222].

### 3.4.2 TIME SCALES

84. People will draw benefits from environmental assets such as forests and healthy ecosystems many generations from now and there will typically be future costs related to present natural resource management decisions. E.g., natural resource management policies are normally designed to regulate for an indefinite future. In principle, only history can show if there are any clear time limits to the impact from environmental goods and services. However, the reliability of assessments decreases the further they go into the future. This means that any valuation exercise has to define the boundaries for the exercise; e.g., analyzing timeframes of 20 years. In some cases, the natural resource management aspects to be valuated might include investment in physical capital with an expected time limit that will then be partially used as the timeframe for the analysis. Still, other parts of the valuation exercise will have to address future costs and benefits beyond the time limit of that physical capital. For a land tenant, the timeframe to be applied for the valuation of future services will usually be the number of years he or she expect to use the land. But the land tenants would also consider costs and benefits beyond their own use of the land as it will influence the environmental capital value or the price of the land.

85. For economic valuations of public policy decisions, the time frame can be considered as intra-generational[223], i.e. decades long. Various macro-economic models have been suggested to address inter-generational timeframes. Among the often-cited models are the dynamic Ramsey-Cass-Koopmans optimal growth model, which operates with a finite number of agents with infinite time horizons and the Diamond overlapping-generations model, which operates with an infinite number of agents with finite time horizons. The agents could be households that are seen as relative stable units who are concerned about the welfare of future generations within the Ramsey framework. In contrast, within the framework of the overlapping-generations model, births will lead to new economic agents whose pref-

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[221] Kumar, P. et al. (2010) "Guidance Manual for the Valuation of Regulating Services" United Nations Environmental Program, University of Liverpool, and Indian Institute of Forest Management hqweb.unep.org/pdf/Guidance_Manual_for_the_Regulating_Services.pdf

[222] Ibid.

[223] National Center for Environmental Economics (2010) "Guidelines for Preparing Economic Analyses" U.S. Environmental Protection Agency yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf

erences present generations cannot foresee or plan for and the models therefore ignore bequest motives, i.e., willingness to pay for future generations. This is contrary to the Ramsey framework that assumes altruistic bequest motives. The macroeconomic models are based on complex mathematics and require skilled economists to use them correctly. What is important to retain here is that the choice of model can have critical impacts on the outcome and hence on the long-term policies.

86. In addition to addressing the timeframe, the valuators need to identify a weighting factor to make the different time streams of costs and benefits comparable. This is normally done through the so-called discounting process where the value of future costs and benefits are estimated at present values by applying discount rates to calculate the net present value[224]. The net present value is calculated as the current and future costs and benefits, where the future benefits typically are calculated on an annual basis by calculating the expected costs and benefits with the discount rates. For private decisions, the discount rates reflect the interest rate that individuals, households, or companies could obtain by not tying up the capital in the investment. As such, the discount rate will include a risk factor and the expected inflation rate and is therefore contextual and dependent on individual choices. For public policy decisions, the discount rate or the social discount rate will reflect expected future costs and benefits for society as a whole. The social discount rate should reflect the time before policy impacts take place, the social welfare impact, and the rate at which future utility is discounted with time. However, the identification of these factors will normally imply a great level of uncertainty. The need for social discounting is particularly important when there is a significant difference between the timing of the costs and benefits[225] as is the case in forestation projects and many other sustainable dryland management practices.

87. The choice of the discount rate and timeframe can be critical for the decision-making. E.g., the main benefits of forestation for timber production will typically happen several decades after the plantation. Applying a discount rate of 3% to a timber harvest valued at 100 unit 10 years from now corresponds to a net present value of 74 units. Increasing the discount rate to 3.5% for the harvest after 10 years would return a net present value of 71 units. For a harvest, 30 years after plantation the 3% discount rate corresponds to a net present value of 41 units while the 3.5% discount rate to 36 units. This simple illustration shows how critical both the choice of discount rate and the timeframe is for the economic valuations of environmental costs and benefits. However, there is little formal guidance on how to choose the most appropriate discount rate and timeframe. Still, the discount rate is one the most contentious issues of economic environmental valuations and can lead to misguided policies and investments if its meaning is not well communicated to the users of the valuations. Typical discount rates for economic environmental valuations are 4 to 10%[226] for shorter to medium term timeframes. For intergenerational assessments, applied discount rates are typically lower. Furthermore, some governments suggest declining social discount rates[227] for intergenerational valuations to reflect assumptions

[224] There are alternative methods such as annualized values and net future values but all based on discount rates. According to the US Environmental Protection Agency, annualization of costs is useful for evaluating non-monetized benefits that are constant over time. National Center for Environmental Economics (2010) "Guidelines for Preparing Economic Analyses" U.S. Environmental Protection Agency yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf

[225] National Center for Environmental Economics (2010) "Guidelines for Preparing Economic Analyses" U.S. Environmental Protection Agency yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf

[226] Liu, S. et al. (2010) "Valuing Ecosystem Services" Annals of the New York Academy of Sciences, 1185 pp. 54–78

[227] Intergovernmental Panel on Climate Change ipcc.ch/publications_and_data/ar4/wg3/en/ch2s2-4-2-1.html

about uncertainly and systematically declining growth over time. While it is recognized that the impact of the uncertainties about the discount rate can be clarified somewhat through sensitivity analyses[228], a review of ecosystem valuations over the last 50 years showed that sensitivity analyses are not carried out in a routine and rigorous manner[229].

88. The contentious nature of a specific discount rate is the background for the dispute among practitioners and scientists about the findings and recommendations in the Stern Review on the Economics of Climate Change[230] released by the Government of the United Kingdom in 2006. The review concluded that unabated climate change could cost the world at least 5% of the Gross Domestic Product (GDP)[231] each year. Lord Stern used the Ramsey framework and thus assumed that present generations will pay the mitigation costs for the benefits of future generations seeking intergenerational equity. Moreover, the calculation is based on the assumption that some investment decisions are irreversible. The analysis uses an annual social discount rate of 1.4%[232] on the basis of a time preference of 0.1, the elasticity of marginal utility as 1, and an annual growth rate of 1.3. The models and different assumptions have been highly debated since the release of the study. In the review, Stern argues that the current generation has an ethical obligation to place the same value on future generations' costs and benefits as the current generation. The more recent global valuation of biodiversity, "The Economics of Ecosystems and Biodiversity" (TEEB)[233], suggests that a number of factors should be considered when choosing the social discount rate, including ethical values, the nature of the asset, and best estimates of future technological changes and well-being. Moreover, TEEB argues that when evaluating tradeoffs between natural and human-made assets it is acceptable to use different discount rates.

89. It should also be noted that the choice of time-frame and discount rate is independent of the economic valuation per se of specific goods and services; e.g., the valuation of the benefits from the forestation mentioned above would include an estimation of expected productivity, future sale prices, and assessment of costs and other benefits related to the forest over the years such as soil conservation values.

### *3.4.3 Spatial scales*

90. People benefit from environmental goods and services at various spatial scales[234] and the spatial terms need to be defined for environmental valuations. E.g., water and food will typically benefit more stakeholders living far away from the source and the case is similar for negative impacts such as siltation. To overcome the spatial challenges some will argue that economic valuations should be based

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228 Sensitivity analyses assess the impact that changes in a certain parameter will have on the model's conclusions.
229 Liu, S. et al. (2010) "Valuing Ecosystem Services" Annals of the New York Academy of Sciences, 1185 pp. 54–78
230 webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm
231 Gross Domestic Product is a measurement for the monetary value of the aggregated economic activity in a country over a one-year period. By its design, GDP does not directly take into account environmental and social costs of production.
232 The Second Assessment Report (AR2) of the Intergovernmental Panel on Climate Change (IPCC) suggests a social discount rate of 2-4%. ipcc.ch/publications_and_data/ar4/wg3/en/ch2s2-4-2-1.html
233 teebtest.org/
234 Hein, L. (2006) "Spatial Scales, Stakeholders and the Valuation of Ecosystem Services" Ecological Economics 57 pp. 209-228

on measurable output and not outcome. This might be adequate for the need for direct land management purposes, while for policy purposes there will be more interest in the outcome or impact. In the background paper for the Economics of Land Degradation initiative, Nkonya et al. (2011)[235] suggest to use the concept of on- and off-site effects for valuations related to sustainable dryland management where on-site effects are the directly observable effects within the limits of the drylands being analyzed. However, this approach is not immune to spatial scale challenges as 'observable' can take many forms in many different locations.

91. In a 2012 review of practices for mapping the economic values of ecosystem services, Schägner et al. (2012)[236] note that there is a significant growing number of spatial economic valuations of ecosystems in Europe, North America, and China. This increase in spatial valuations has been possible due to advancement of geographical information systems with information on both the supply site and the beneficiaries of ecosystem services. Spatial valuations of ecosystem services can provide critical information for policymaking and a number of recent spatial valuations particularly refer to land use policies. Still, most of the reviewed mapping exercises do not present scenarios or other frameworks to make them more directly useful for policymaking. Around half of the reviewed studies use proxies to identify the supply of ecosystem services, particularly land use/land cover (LULC). The quantification of the ecosystem services is then based on generally established causal links, for instance through expert opinions. The vast majority of the studies use unit values; i.e., a constant value of ecosystem services is applied for the whole area that is being valued. Hence, these studies ignore the differentiation there might be in different geographical areas as a function of different stakeholder interests. It should also be noted that most of the reviewed mapping exercises of ecosystem service valuations do not present any confidence levels of the results or other indications on the accuracy of the studies. Considering that errors in value mapping might be high, the lack of presentation of accuracy of the studies, limit their values for policymaking[237]. Moreover, the studies do not consider the implications of the characteristics of complex ecosystems, such as non-linearity, tipping points or thresholds, and resilience. It is expected that the coming years will see method development for spatial economic valuations of ecosystem services. Software tools such as the InVest described above offer methodologies for mapping of economic values of ecosystem services.

92. Another aspect of the spatial challenge is the valuation of systems or regions that integrate different land uses. In a study of spatial variation of the economic environmental values in a geographical transect in Northern China, Yuan et al. (2012)[238] analyze nine different ecosystem services[239] in six different land use systems: forest, grasslands, farmland, wetland, water body, and barren land. Each ecosystem service is assigned a special weighing factor according to the specific land use, e.g., food produc-

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[235] Nkonya, E. et al. (2011) "The Economics of Desertification, Land Degradation, and Drought Toward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150

[236] Schägner, J.P. et al. (2012) "Mapping Ecosystems Services' Values: Current Practice and Future Prospect" Fondazione Eni Enrico Mattei Working Paper 59 Available at papers.ssrn.com/sol3/papers.cfm?abstract_id=2160714

[237] Ibid

[238] Yuan, Y. et al. (2012) "Spatial-Temporal Variation of Ecosystem Services in Response to Land Use Changes: Case Study in the 38°N Ecological Transect of Northern China" Journal of Food, Agriculture & Environment 10(2) pp. 794-802

[239] Food production, Raw material production, Gas regulation, Climate regulation, Water regulation, Waste treatment, Soil formation and retention, Biodiversity protection, and Recreation and culture.

tion in grasslands and farmland has weigh factors of 0.43 and 1.00 respectively. The weighing factors were obtained through an expert consultation[240] among Chinese ecologists and allow comparability of different land uses and can as such provide important input to land use policies.

### 3.4.4 WHOSE VALUES?

93. The different and generally accepted economic valuation techniques still leave a big question for many, namely, how to make economic valuations of complex systems with a multitude of different stakeholders who hold different values? And how to deal with conflicting interests? Ecosystem services literature often refers to pollination as an obvious ecosystem service that benefits many land users. However, as pointed out by Sogoff (2011)[241] different land users might have conflicting interests in pollination. A seedless orange is typically four times more expensive than varieties with seed. As oranges are self or wind pollinated growers are wary of the possibility of bees cross-pollinating with pollen from crops producing seeded oranges. In the semi-arid San Joaquin Valley in California, the relationship between the beekeepers and orange producers has therefore become contentious. On the other hand, almond growers on the west side of the San Joaquin Valley hire beekeepers to ensure pollination of their crops. After the almond pollination season in the spring, beekeepers move to the eastern part of the Valley so the insects can forage on the orange trees. The example shows how the exchange value of a service-providing unit may vary according to socioeconomic and cultural contexts, for instance with regard to changes in taste and technology. There is now a new self-pollinating almond variety under development. If that variety will be successfully introduced it will change the roles of ecosystem services and the users and providers again. The example therefore also shows the importance of clearly identifying different stakeholder interests, the potential conflicts, and the dynamic nature of the interests and conflicts in the communication of the valuations.

## 3.5 HOW RELIABLE ARE ECONOMIC VALUATIONS OF COMPLEX SYSTEMS?

94. As pointed out in the ecological and economic foundation for the 2010 initiative The Economics of Ecosystems and Biodiversity (TEEB)[242] the confidence levels of monetary valuations of complex systems with high value plurality will be very low. According to the authors, the values for policy decision-makers of such valuations can therefore be questioned[243]. In fact, this raises some bigger questions: is it better to have some information with a low level of confidence than no information at all? Is the scientific community able to communicate the full meaning of the assumption framework for the valuations, including potentially excluded externalities and the levels of uncertainty in the assessments? And will

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[240] Xie, G. et al. (2008) "Expert Knowledge Based Valuation Method of Ecosystem Services in China" Journal of Natural Resources 23(5) pp. 911-919

[241] Sagoff, M. (2011) "The Quantification and Valuation of Ecosystem Services" Ecological Economics 70 pp. 497-502

[242] The TEEB initiative is a major international assessment of the economic value of biodiversity. This groundbreaking initiative was launched in 2007 by the G8 (Group of Eight (of the World's largest economies)and the EU and the reports were publicized in 2010. teebtest.org/

[243] E.g. Brondizio, E.S. & F.W. Gatzweiler (2010) "Socio-Cultural Context of Ecosystem and Biodiversity Valuation" in Kumar, P. (Ed.) (2010) "The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations" Earthscan, Routledge, New York, pp. 149-182

the direct land-users, the policy-makers, the support services, or other dryland development stakeholders understand the premises for the valuations? Kumar et al. (2010)[244] show the huge difference in generally recognized estimations of the economic value of the environmental service pollination for agriculture globally. These estimations range from US$ 120 to 200 billion annually[245]. As we will discuss in the concluding remarks, communication challenges of scientific results are rarely raised in papers on valuation techniques for sustainable natural resource management. Some will argue that many assessments are not really aids to decision-making but rather direct decision-making because of lack of transparency about the assumption framework.

95. One of the first attempts to present the global value of ecosystem services date back to 1997 when Costanza et al. (1997)[246] suggested that the earth provides ecosystem services at an amount of US$ 16-54 trillion annually. This number was based on a synthesis of more than 100 economic environmental valuations using a range of the valuation techniques presented in table 2. The authors recognized the important limitations of the method used for the study, including the extrapolation and aggregation at a global scale and the synthesis of studies using different methods that were based on a number of different assumptions. Moreover, many landscapes were left out from the synthesis, including deserts[247] and croplands because of lack of valuation studies. Not surprisingly, the study generated a huge amount of discussion and criticism and maybe the biggest value of the study was to show the important challenges of global economic environmental valuations and the communication of the results; challenges that are still valid today. Freeman (2010)[248], for instance, questions the basic premises of the study describing it more or less as a comparison between a world with and without ecosystem services, which is not a meaningful question. According to Atkinson et al. (2012),[249] the huge controversy that followed the 1997 study might be the reason for the apparent continued hesitation among environmental economists to present aggregated global data on the value of environmental services.

96. The challenges of uncertainties for environmental economic valuations are not limited to the global scale valuations. For instance, among economists and other scholars working on predictive models for climate change impact and adaptation, there has been growing attention to the uncertainty cascade. This implies that adaptation planning is based on decision-making defined by a complexity of uncertainties with multiple feedbacks from the variety of environmental, socioeconomic, and climate change information sources that have to be considered. A special challenge is the downscaling of global predictions or scenarios to local levels and the combination with local land use models. Likewise, the uncertainty impact of temporal downscaling from long-term to short-term predictions still has to be in-

[244] Kumar, P. et al. (2010) "Guidance Manual for the Valuation of Regulating Services" United Nations Environmental Program, University of Liverpool, and Indian Institute of Forest Management hqweb.unep.org/pdf/Guidance_Manual_for_the_Regulating_Services.pdf

[245] Measured in 1994 US$.

[246] Costanza, R. et al. (1997) "The Value of The World's Ecosystem Services and Natural Capital" Nature 387 pp. 253-260

[247] It is not clear from the paper what classification has been used for the 16 biomes analyzed. As such, there is no definition for what constitutes 'deserts'.

[248] Freeman, A. M. III (2010) »The Wealth of Nature: Valuing Ecosystem Services" Paper presented at the 2010 IDRC-EEPSEA Impact Conference, Economy and Environment Program for South East Asia, Hanoi, Vietnam , February 26 & 27, 2010 web.idrc.ca/uploads/user-S/12792703701Hanoi-Paper_(Rick_Freeman)-Final-7-10.pdf

[249] Atkinson, G. et al. (2012) "Recent Advances in the Valuation of Ecosystem Services and Biodiversity" Oxford Review of Economic Policy 28(1) pp. 22-47

vestigated[250]. Overall, limited research has gone into the combination of uncertainties related to global climate change with sector and regional specific uncertainties, for instance for crop and economic models[251]. For the agricultural sector, crop and economic models have been based on assumptions of linear development without analyzing uncertainties for assumptions about farm size, farm policy, and future crop and livestock productivity in non-linear complex systems with multiple feedbacks.[252]

97. To overcome the challenges of linking different models at different levels, new research initiatives are working on Representative Agricultural Pathways (RAP)[253] combining global scenarios for climate change impact with more region-specific agricultural and economic development conditions. This should increase the ability to analyze the uncertainty cascade. Likewise, within the framework of the CGIAR Consortium of the International Research Centers, recent initiatives focus on how to make global predictions useful for local sustainable land management. However, much of this work is still at a conceptual level, and currently there is limited scientific evidence for quantification of multi-scale and multi-model uncertainties linked to management of complex social-ecological systems. It should also be noted, that recent research about the role of uncertainty in decision-making for climate change adaptation for water management indicates that the multiple uncertainties might also cancel each other out[254].

[250] Walthall, C.L. et al. (2012) " Climate Change and Agriculture in the United States: Effects and Adaptation" USDA Technical Bulletin 1935, United States Department of Agriculture, Washington, DC.

[251] Refsgaard, J.C. et al. (2013) "The Role of Uncertainty in Climate Change Adaptation Strategies—A Danish Water Management Example" to be published Mitigation and Adaptation Strategies for Global Change 18(3) pp. 337-359

[252] Walthall, C.L. et al. (2012) "Climate Change and Agriculture in the United States: Effects and Adaptation" USDA Technical Bulletin 1935, United States Department of Agriculture, Washington, DC.

[253] See for instance the Agricultural Model Intercomparison and Improvement Project (AgMIP) coordinated by Columbia University Earth Institute Center for Climate Systems Research. AgMIP focuses on yield and technical aspects of agriculture, with a primary focus on climate impacts and economic applications. agmip.org

[254] Refsgaard, J.C. et al. (2013) "The Role of Uncertainty in Climate Change Adaptation Strategies—A Danish Water Management Example" to be published Mitigation and Adaptation Strategies for Global Change 18(3) pp. 337-359

# 4. COST BENEFIT ANALYSIS

98. For many years, cost-benefit analyses[255] have been part of compulsory feasibility assessments for major investment projects of the World Bank and other multilateral financial institutions. Likewise, many OECD countries have legislation requiring that cost-benefit analyses be conducted for "significant new policies and policy reforms."[256] Cost-benefit analyses compare the costs of implementing the policy or practice with the accrued positive and negative benefits. In conventional investment contexts, benefits are the additional outcomes generated by analyzed intervention. In risk management contexts benefits are the risks that are reduced, avoided, or transferred[257].

99. Cost-benefit analyses are based on neoclassical economics with no judgments about individual preferences and the assumption that individuals will seek maximum utility according to consistent, constant, and rational preferences. Moreover, individual preferences are not influenced by preferences of other individuals or social institutions. Advocates for the approach argue that rather than politicians, consumers should determine the costs and benefits of ecosystem functions and services[258]. Cost-benefit analyses for environmental goods and services are therefore based on market-based valuation techniques as presented in table 2 in Chapter 3. In line with the neoclassical economic approach, cost-benefit analyses normally builds on summation of individual preferences while in some cases the preferences of a group might be different than the preferences of all individuals; e.g., the value of a forest for a community whose social system and culture are linked to the value of that forest[259].

100. There are many critics of the cost-benefit approach particularly related to its neoclassical economic foundation and the challenges of using neoclassical economics to complex social-ecological systems. Moreover, the challenges of the different premises and boundaries outlined above for economic environmental valuations often cause major controversies in the interpretations of cost-benefit analyses. Still, a cost-benefit analysis is probably the most widely used appraisal technique for public investments and public policies including environmental and natural resource policies. According to Pearce et al. (2006),[260] appeals of cost-benefit analyses include that they 1/offer a rational way of addressing environmental costs and benefits, 2/integrate different and often conflicting stakeholder interests, 3/highlight the relative value of different alternatives, 4/show the optimal scale of a policy, and 5/include the relative value of future costs and benefits. The authors, furthermore, argue that the use of the individual's preferences makes the approach 'democratic'. However, they also recognize that especially the foundation on the individual utility maximization is highly controversial. Others have highlighted the special challenges of economic valuation of ecosystem services as described in chapter 3, including the special characteristics of social-ecological systems such as non-linearity and limited substitutabil-

[255] Some scholars particularly in the United States use the term 'benefit-cost analysis.' The terms are synonymous.
[256] Dietz, S. & C. Hepburn" (2010) "On Non-Marginal Cost-Benefit Analysis" Centre for Climate Change Economics and Policy Working Paper No. 20, University of Leeds and the London School of Economics and Political Science cccep.ac.uk/Publications/Working-papers/Papers/20-29/Working_Paper20.pdf
[257] Mechler, R. et al. (2008) "From Risk to Resilience – The Cost-Benefit Analysis Methodology" Institute for Social and Environmental Transition, Kathmandu
[258] Liu, S. et al. (2010) "Valuing Ecosystem Services" Annals of the New York Academy of Sciences, 1185 pp. 54–78
[259] Ibid.
[260] Pearce, D. et al. (2006) "Cost Benefit Analysis and the Environment – Recent Developments" OECD, Paris

ity of natural resources for human-made resources. While recognizing the severe limitations of cost-benefit analyses for ecosystem services, Wegner & Pascual (2011)[261], also acknowledge that the method is widely used. The authors therefore suggest the adoption of a framework with a heterogeneous set decision-making instruments that better account for the different characteristics of ecosystem services. The challenge, though, remains how to communicate assessment results based on many different approaches, including a mixture of qualitative and quantitative methodologies based on different value sets.

101. In principle, cost-benefit analyses include all direct and indirect social, environmental, and economic costs and benefits and are thus different from rate of return assessments or financial appraisals that only consider financial gains for the specific operation. However, the identification of the many externalities and even the monetization process is complicated and many values are typically left out, which is another major criticism of the application of the approach. Likewise, cost-benefit analysis frameworks do not address the distribution of costs and benefits either within or between generations. Overall, as all other economic valuation approaches, cost-benefit analyses are only as good as the accessible information allows and assumptions of causal links can be misguiding when the information base is sketchy. E.g., the increasing drought losses recorded by re-insurance companies over the last years is not necessarily due to a decrease in precipitation but might be the result of non-climatic factors, such as increasing water withdrawals[262]. In an overview of the methodologies and case studies carried out under the DESIRE project,[263] Schwilch et al. (2012)[264] recognize the value of cost-benefit assessments when analyzing sustainable land management interventions. However, the authors find that a lack of data is a hindrance to their application. Moreover, the lack of a standard framework for economic assessments defining what should be integrated as costs and benefits leads to subjective assessments that can be difficult to interpret and challenging to communicate to assessment users.

## 4.1 Alternative Methods to Cost-Benefit Analyses

102. Over the years, critics of the use of cost-benefit analysis for environmental management have offered alternative methods such as the Safe Minimum Standard Approach first suggested by resource economist S.V. Ciriacy Wantrup in 1952. The approach indentifies a target for specific ecosystem services, e.g., net zero land degradation as proposed by the UNCCD Secretariat, and then minimizes the costs for achieving this target. However, the safe minimum standard approach is also challenged by a number of issues similar to those of cost-benefit analysis. E.g., the identification of intergenerational

[261] Wegner, G. & U. Pascual (2011) "Cost-Benefit Analysis in the Context of Ecosystem Services for Human WellBeing: A Multidisciplinary Critique" Ecosystem Services Economics (ESE) Working Paper Series #13, United Nations Environmental Programme, Nairobi

[262] Handmer, J. et al. (2012) "Changes in Impacts of Climate Extremes: Human Systems and Ecosystems" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 231-290

[263] DESIRE: EU-funded project (www.desire-project.eu) – "Desertification mitigation and remediation of land – A global approach for local solutions" focusing on Sustainable Land Management (SLM). The project covered 17 semiarid project sites in 13 countries.

[264] Schwilch, G. et al. (Eds.)(2012) "Desire for Greener Land - Options for Sustainable Land Management in Drylands" WOCAT wocat.net/fileadmin/user_upload/documents/Books/DESIRE_BOOK_low_resolution.pdf

costs, i.e., the cost of sacrifice in terms of consumption of current generations for future generations[265]. Another major challenge when applying the approach is related to cost transparency and ensuring that all stakeholders have full information. Still, cost-benefit assessments can be a valuable complementary guide to decision-making, particularly for comparing alternative options rather than tools for exact economic value of a given investment. In their detailed study on cost-benefit analysis for environmental valuations, Pearce et al. (2006)[266] provide a short comparative analysis of other widely used valuation approaches for decision-making[267]. According to the authors, only the multi-criteria analysis is as comprehensive as the cost-benefit analysis and may even be more comprehensive while the other approaches have a more limited scope. The approaches should therefore not be considered as substitutes for each other. We have discussed the multi-criteria approach further above in section 3.3.

265 Stoneham, G. et al. (2000) "Mechanisms for Biodiversity Conservation on Private Land" Department of Sustainability and Environment, Melbourne dse.vic.gov.au/__data/assets/pdf_file/0015/103047/ba_report_final.pdf

266 Pearce, D. et al. (2006) "Cost Benefit Analysis and the Environment – Recent Developments" OECD, Paris

267 Environmental Impact Assessments, Strategic Environmental Assessments, Life Cycle Analysis, Risk Assessment, Comparative Risk Assessment, Risk-Benefit Analysis, Risk-Risk Analysis, Health-Health Analysis, Cost-Effective Analysis, and Multi-Criteria Analysis.

# 5. ACCOUNTING SYSTEMS FOR VALUATION OF ECOSYSTEMS

## 5.1 NATIONAL SYSTEMS FOR ENVIRONMENTAL ACCOUNTING

103. For ecosystem valuations, ecosystem accounting techniques have been developed to measure the specific costs and benefits related to ecosystem services and the natural capital of ecosystems. Much of the work around ecosystem accounting techniques has focused on ensuring that natural resources will be fully integrated into the national account systems. Almost all countries in the world apply the System of National Accounts (SNA) developed by the UN as an international standard for comparable measurements of economic activities. The SNA is based on aggregate indicators of income, investments, and consumption and provides comprehensive information for economic analysis, decision-making, and policy design, implementation, and monitoring and evaluation. It is critical for environmental accounting to recognize that SNA is based on quantity and price measurements[268]. This applies easily for economic sectors such as the housing market or car production. However, for the environmental sector challenges arise both for quantification and monetization as highlighted in Chapter 3.

104. To ensure a more complete reporting on the state of the environment, the SNA framework has been expanded with a standard on environmental accounting. After two decades of work the System on Environmental Economic Accounting (SEEA)[269] was adopted by the UN Statistical Commission in 2012. The adopted system is based on harmonization of environmental accounting of the UN, the European Union, OECD, and the World Bank and the International Monetary Fund. SEEA follows the general economic accounting principles of the SNA and integrates the environment through four categories of accounts: 1/Flow accounts for movements between the economy and the environment of products, natural resources, ecosystem inputs and residuals or wastes from economic activities, 2/Stock accounts for environmental assets: natural resources, land, and ecosystems, 3/Environmental transaction accounts recording charges, taxes, and subsidies, and 4/Adjustments for depletion, degradation and defensive expenditures such as research and information systems[270].

105. By integrating environmental and economic issues, SEEA not only provides a standard for economic valuation of environmental issues but also greatly increases source data for socio-economic-ecological analyses through data coherence.[271] The application of SEEA could therefore improve our understanding of complex dryland social-ecological systems and hence improve monitoring and analyses of policies and practices for sustainable dryland and drought risk management. While SEEA is a great improvement in terms of valuing sustainable dryland management, a number of challenges remain

[268] Boyd, J. & S. Banzhaf (2007) "What are Ecosystem Services? The Need for Standardized Environmental Accounting Units" Ecological Economics 63 pp. 616-626

[269] United Nations Statistics Division (2012) "System of Environmental-Economic Accounts (SEEA)" unstats.un.org/unsd/envaccounting/seea.asp

[270] Stoneham, G. et al. (2012) "Creating Physical Environmental Asset Accounts from Markets for Ecosystem Conservation" Ecological Economics 82 pp. 114-122

[271] Australian Bureau of Statistics (2012) "Completing the Picture – Environmental Accounting in Practice" Australian Bureau of Statistics, Canberra www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/2910B851D04B7DA2CA2579F900124AA9/$File/4628055001_may%202012.pdf

linked to data availability and collection. The data challenge is not limited to countries with low statistical capacity[272] but is real in many OECD countries as well. Moreover, the accounting classification still includes some inconsistencies. For instance, changes in stocks from one period to another will be recorded; e.g., deforestation, soil depletion, and decreasing water resources. However, many of these land degradation processes are considered as environment-to-environment flows. As such, for the time being they are not presented in the supply and use tables,[273] which record changes in the value of the environment sector. Likewise, the attribution of environmental taxes and subsidies is often recorded in the core national account and not directly in the environmental accounts. Some of these inconsistencies are expected to be addressed in the latest revision of SEEA, which is expected early 2013. The implementation of SEEA is being monitored inter alia by the Committee of Experts on Environmental-Economic Accounting (UNCEEA).

## 5.2 National Systems for Ecosystem Services Accounting

106. Overall, there are still a number of issues that need to be addressed before accounting for ecosystem services will explain the paths to sustainable development. For instance, accounting is in principle about marginal values and not total values and critical elements such as resilience are not fully accounted for. Mäler (2008)[274] recognizes that it is theoretically possible to include ecosystem services in national accounts but argues that the dynamic nature of social-ecological systems and society's appreciation of services, make it practically impossible. Instead of a unified system, the author therefore suggests to select representative ecosystems and develop standardized methods for different systems.

107. After the publishing of the Millennium Assessment[275] in 2005, there has been an increasing demand for integrating an ecosystem approach into environmental accounting. In order to develop a standard for ecosystem services accounting, an experimental framework is currently being developed and tested[276] in the context of the SEEA central framework[277]. It is expected that a revised version of SEEA with integration of ecosystem services will be endorsed in 2013[278]. One of the challenges has been

[272] To monitor and compare national statistical capacity, the Word Bank calculates a set of key indicators for each country based on a diagnostic framework of methodology, data sources, and periodicity and timeliness. Countries are scored against specific criteria in these areas, using input provided by the countries and / or publicly available information. Countries with low statistical capacity are typically also countries suffering from unsustainable dryland and drought risk management. bbsc.worldbank.org/bbsc/SelectColorParameter

[273] European Commission, et al. (2012) "System of Environmental-Economic Accounting - Central Framework" White Cover Publication, United Nations, New York unstats.un.org/unsd/envaccounting/White_cover.pdf

[274] Mäler, K.-G., et al. (2008) "Accounting for Ecosystem Services as a Way to Understand the Requirements for Sustainable Development" Proceedings of the National Academy of Science 105(28) pp. 9501-9506

[275] Hassan, R. et al. (Eds.) (2005) "Ecosystems and Human Wellbeing: Current State and Trends" Island Press, Washington D.C.

[276] The testing is spearheaded by the global partnership WAVES – the Wealth Accounting and the Valuation of Ecosystem Services (WAVES). The pilot countries include dryland countries, e.g. Australia and Botswana. wavespartnership.org/waves/

[277] UNSD et al. (2011) "SEEA Experimental Ecosystem Accounts: A Proposed Outline, Road Map and List of Issues" Paper prepared by UNSD, EEA and the World Bank and presented at the 17th Meeting of the London Group on Environmental Accounting, 12-15 Sept., 2011, Stockholm unstats.un.org/unsd/envaccounting/londongroup/meeting17/LG17_9a.pdf

[278] Haines-Young, R. & M. Potschin (2011) "Common International Classification of Ecosystem Services (CICES): 2011 Update" Paper prepared for the expert meeting on ecosystem accounts organized by the UNSD, the EEA and the World Bank, Dec., 2011, London,

to create ecosystem accounts that will capture ecosystems' changing capacity to provide goods and services and deal with challenges of defining a normal functioning ecosystem, including environmental structures, processes, and function. According to the Australian Bureau of Statistic[279], for instance, environmental information related to ecosystem functions remains "patchy" with inconsistent definitions, independence from any framework, and lack of representativity in time, space, and subject matter. The experimental framework is based on the Common International Classification for Ecosystem Services (CICES)[280] suggested by the European Environmental Agency[281]. It should be noted that among the 'pending issues' to be defined in the classification tools are costs and benefits derived from natural hazards such as droughts.

108. While there is a well-established body of environmental valuation techniques, the direct application of those techniques for economic-environmental accounting purposes require delineations and standards for measurable quantification compatible with other accounting. It will be necessary to establish principles for clearly distinguishing between intermediary services and final outputs; e.g., between regulating and provisioning services and establish measurable links between services / goods and related stocks to avoid double counting. Such links can be challenging to establish considering the non-linearity of ecosystem functioning. Likewise, for standard accounting purposes, it is necessary to decide which type of valuation techniques to use; e.g. demand-based or cost-based, which discount rate to apply, etc.[282]

109. As part of the Australian Bureau of Statistic's integrated environmental-economic accounts a special land account with environmental, economic, and social data is being piloted in Victoria and Queensland regions in Australia. The Great Barrier Reef Catchment[283] on the coast of Queensland covers almost 30 million ha of both wetlands and drylands. The initial accounts include data relating to land, physical and monetary land use, and land cover by different sectors and changes over time. It is expected that the land account will provide critical information relating to policy development and implementation of policies and practices aiming at sustainable dryland and drought risk management. Moreover, it is expected that the accounts will be used by the Government for overall resource allocation be-

cices.eu/wp-content/uploads/2009/11/CICES_Update_Nov2011.pdf

[279] Australian Bureau of Statistics (2011) "Linking the Environment and Economy: Towards an Integrated Environmental-Economic Account for Australia" abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4655.0.55.0012010?OpenDocument

[280] As part of the European Environment Agency's Land and Ecosystem Accounting (LEAC) project the Common International Classification of Ecosystem Services (CICES) was proposed in 2009 to link ecosystem service assessments to economic accounts. CICES is based on existing ecosystem classification systems such as the Millennium Ecosystem Assessment (MA) and the Economics of Ecosystems and Biodiversity (TEEB). The suggested classification includes both biotic and abiotic outputs from ecological systems that are used or consumed by people. To prevent double accounting, CICES does not include what the Millennium Ecosystem Assessment classifies as 'supporting services'. A 2011 CICES proposal suggests a hierarchical classification with three themes: provisioning, regulating and maintenance, and cultural. These themes are then subdivided into major service classes such as nutrition and energy for provisioning services, service groups (e.g. terrestrial plant and animal), and service types (e.g. commercial cropping).

[281] Haines-Young, R. & M. Potschin (2011) "Common International Classification of Ecosystem Services (CICES): 2011 Update" Paper prepared for the expert meeting on ecosystem accounts organized by the UNSD, the EEA and the World Bank, Dec., 2011, London, cices.eu/wp-content/uploads/2009/11/CICES_Update_Nov2011.pdf

[282] Pittini, M. (2011) "Monetary Valuation for Ecosystem Accounting" Paper presented at the UN/World Bank/EEA Expert Meeting on Ecosystem Accounts, 5 -7 December 2011, London unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue10_UK.pdf

[283] abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4609.0.55.001Main+Features12011?OpenDocument

tween different areas of public interests[284]. According to the plans, other issues will be integrated into the account in the future such as biodiversity and carbon related data. The land account will also be tested in other regions.

110. A recent study from Victoria in Australia[285] on the valuation of environmental conservation through auctions as a market mechanism shows that such systems can provide valuation information on a number of ecosystem services. Landholders can bid on the auctions to provide a certain set of government purchased ecosystem services such as land-desalinization and biodiversity. The auction value is considered to represent the market value of conservation. However, a number of limitations remain, including the limited and uneven coverage of such conservation measures, lack of information on opportunity costs for the landholders, and an oversight system to prevent double counting. The study argues that the design and creation of environmental markets will benefit from the definitions of environmental stocks and flows in the SEEA.

## 5.3 Ecosystem Accounting and the UNCCD

111. The emerging SEEA classification and accounting system could offer solutions to some of the challenges and inconsistencies with information about sustainable dryland and drought risk management. For SEEA purposes, land is considered as the space of opportunity and distinguished from soil and land cover. Moreover, degradation is measured in terms of physical depletion of natural stocks but does not fully account for all potential changes, for instance related to institutional and system capacity. Likewise, depletion is not recorded when there is a reduction in the quantity of an environmental asset due to unexpected events such as losses due to extreme weather or pandemic outbreaks of diseases. These reductions are recorded as catastrophic losses. To fully benefit from SEEA, some harmonization with the UNCCD framework will be needed. Overall, though, the development and application of these new classification systems should be of great benefit for economic valuations of sustainable land management. Moreover, the classifications can be used as checklists for ensuring that all relevant elements are taken into account when valuing the costs of sustainable dryland and drought management.

112. Finally, it should be noted that many countries without sufficient statistical capacity for implementation of SEEA have established integrated monitoring systems to support the implementation of the Millennium Development Goals (MDG). Particularly, the system DevInfo[286] offers uniform and integrated databases for organizing, storing, and disseminating national data from the different government ministries and departments as well as UN agencies. The system supports a minimum standard set of indicators including the 48 MDG indicators. Moreover, the DevInfo software supports an unlimited number of indicators, which are typically identified through a dialogue among different line ministries and major users of the system according to specific and emerging needs. As such, the system can be used for

[284] Eigenraam, M. et al. (2011) "Valuation of Ecosystem Goods and Services in Victoria, Australia" Paper presented at the UN/World Bank/EEA Expert Meeting on Ecosystem Accounts, 5-7 December 2011, London unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue10_Aus.pdf

[285] Stoneham, G. et al. (2012) "Creating Physical Environmental Asset Accounts from Markets for Ecosystem Conservation" Ecological Economics 82 pp. 114-122

[286] Devinfo is a database system developed by the UN www.devinfo.org

monitoring and valuation of a number of elements relevant for sustainable dryland and drought risk management. DevInfo is fully operational in many dryland countries, e.g., Senegal, India, and Argentina.

# 6. POLICIES AND PRACTICES PROMOTING SUSTAINABLE DRYLAND AND DROUGHT RISK MANAGEMENT AND THEIR VALUATIONS

## 6.1 VARIETY OF POLICIES AND PRACTICES

113. As laid out in the Preamble to this White Paper, drylands constitute an enormous variety. Policies and practices to promote sustainable dryland and drought risk management are therefore abundant as can be witnessed in the national reports to the UNCCD. Moreover, many general policies and practices that are not defined directly in terms of drylands, drought risk, or land degradation will provide effective contributions to sustainable dryland and drought risk management, for instance social policies and infrastructure projects. The literature review for the preparation of this White Paper shows an important plurality and methodological diversity in assessments of policies and practices even within specific fields such as environmental policies. The approaches vary from participatory assessments based on stakeholder surveys and focus groups to sophisticated theoretical models for scenario analyses based inter alia on predefined indicators and valuation techniques as described in Chapter 3. The models are often developed independently from the policies and their usefulness and reliability vary greatly. While there is an increase in mandatory ex-ante evaluations of policies, for instance within the European Union, the mandate is not followed with guidelines or standard frameworks.[287] To respond to the need for general frameworks, a new body of work starts to emerge suggesting frameworks for policy evaluations.

114. It would go far beyond the scope of this White Paper to even attempt a classification of relevant policies and practices or analyze the different policy assessment and valuation frameworks that are being developed and applied. Instead, we have selected examples of valuations of policies and practices described in recent literature. The selection is presented in Part 2 of this White Paper. The examples showcase opportunities and challenges for assessments with special focus on economic valuations. The examples also show the great variety in valuation methods and that the concept of value is essentially subjective and context specific. This also means that there is no blueprint for measuring social and economic values and that the many different approaches might all be fitting for specific contexts.

115. While we have tried as much as possible to focus on drylands and drought affected areas, we find that much of the literature reviewed for this White Paper use concepts such as droughts and arid lands very loosely. E.g., in some documents 'arid lands' are used for dry subhumid areas while others use the term for all drylands together. 'Droughts' frequently refer to reduced rainfall trends and not droughts in the sense of the UNCCD. Likewise, many 'land degradation' estimates are only based on soil degradation as shown in the background study for the Economics of Land Degradation (ELD) initiative.[288]

[287] Esteban, M. et al. (2009) "La Evaluación de la Política Regional Europea. Análisis Empírico de las Metodologías Aplicadas Investigaciones Regionales" Investigaciones Regionales 14 pp. 157-183

[288] Nkonya, E. et al. (2011) "The Economics of Desertification, Land Degradation, and Drought To-ward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150 ifpri.org/sites/default/files/publications/ifpridp01086.pdf

116. It should also be noted, that in line with the current 10-year Strategy of the UNCCD (2008-2018),[289] recent global initiatives in support of economic valuations of sustainable dryland management tend to take a broader focus and include 'land degradation' as such in their goals and objectives. This is the case, for instance, of the ELD initiative and the OSLO[290] Consortium of academic institutions, UN agencies, and other institutions working on the value of responsible land use. However, documents from these same initiatives are typically framed with references to the special challenges of drylands in terms of marginalization, poverty, food insecurity, etc., which is also the justification for the UNCCD itself. On the other hand, that land degradation is particularly concentrated in the drylands, has been challenged by recent global research. In the context of the global project Land Degradation Assessment in Drylands (LADA)[291], research on desertification and land degradation in general[292], for instance, shows a weak correlation between aridity and land degradation in the period 1981 to 2003 and indicate that 78% of the observed global land degradation was in humid regions. But it is also recognized that current methodologies for assessing global land degradation have a number of shortcomings.

117. Finally, we will discuss some major instruments that are being increasingly applied for the implementation of policies to promote sustainable dryland and drought risk management where economic environmental valuations play a critical role, namely markets for ecosystem services and adaptation to climate change.

## 6.2 Markets for Ecosystem Services

118. Environmental policies typically emphasize preserving status quo while adaptation increasingly focuses on maintaining ecosystem functions and services[293]. To complement and reinforce protection and conservation legislation, more and more attention is given to market-based instruments to create economic incentives for ecosystem conservation efforts and thereby allowing for adaptive management. This has been translated into markets for ecosystem services, including schemes for payment for ecosystem services. Such schemes refer to voluntary transactions through which landowners or land managers are compensated for the delivery of well-defined ecosystem services or land uses. On the other hand, the beneficiaries of the ecosystem services will pay for them. The basic principle is that the health of the ecosystems is a global good and landowners or land managers should therefore be compensated for providing certain ecosystem services that might not otherwise be in their direct economic interest. The title 'markets for ecosystem services' might be somewhat misleading as such markets do not function as regular open markets governed by supply and demand. Pattanayak et al. (2010)[294] therefore also questions the use of the term market-based systems. Because the traded ecosystem services are typically

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[289] The 10-year Strategy was adopted by the Conference of the Parties to the UNCCD in 2007 unccd.int/Lists/OfficialDocuments/cop8/16add1eng.pdf
[290] Offering Sustainable Land-use Options theoslo.net/
[291] Implemented and executed by UNEP and FAO from 2006 to 2011fao.org/nr/lada/
[292] Bai, Z.G. (2008) "Proxy Global Assessment of Land Degradation" Soil Use and Management 24 pp. 223–234,
[293] Schramm, D. & A. Fishman (2010) "Legal Frameworks for Adaptive Natural Resource Management in a Changing Climate" The Georgetown International Environmental Law Review, 22 pp. 491
[294] Pattanayak, S.K. et al. (2010) "Show Me the Money: Do Payments Supply Environmental Services in Developing Countries?" Review of Environmental Economics and Policy 4 (2) pp. 254–274

public goods[295], the markets do not determine the price automatically. The lack of a price-determining mechanism therefore calls for governments to play a critical regulating role in markets for ecosystem services[296]. Many of the challenges identified in assessments of schemes for payment of ecosystem services are what economists typically describe as market failures including information asymmetry[297]. Other implementation challenges include monitoring and ignorance about indirect impacts and how to ensure additionality, i.e. how to ensure that providers might not have carried out conservation efforts anyway[298]. Moreover, the expectations might change the baseline situation; e.g., farmers might deforest areas to get payments for reforestation[299]. In general, private arrangements for other ecosystem services than water purification are not common, which is mainly explained by institutional challenges or failed market mechanisms.

119. One of the most well known markets for ecosystem services is the Clean Development Mechanism negotiated under the UN Framework Convention on Climate Change (UNFCCC). But the number of markets at local, national, and international scales keep rising particularly for the following services: ecological tourism, water provision, carbon storage, pollination of crops, and biodiversity.

120. There are still many challenges that hinder payment for ecosystem services to be implemented as an ecosystem protection approach. E.g., who should pay for the services of clean water for poor villagers in rural areas in Africa? Who should be compensated when land tenure is not well defined? Should payment for ecosystem services only include landowners or should the target be land-users in general? And who should pay for clean air and carbon storage services that benefit the public as such?

121. Over the last years, more and more case studies have been publicized on the experience with payments for ecosystem services in developing countries, particularly in Latin America and South East Asia. One the most cited payment schemes for ecosystem services is from Costa Rica, where payment for ecosystem services was introduced in 1996 as part of the third generation of the national forest legislation. The focus is forest conservation and the scheme covers the following ecosystem services: carbon sequestration, hydrological services, biodiversity protection, and scenic beauty. The funding is provided by donors, taxes on fuel sale, and environmental service buyers. Around 500,000 ha forests are now under the scheme and payments to landowners are made over a 5-year period with landowners committing to manage their forests according to management plans for 20 years[300].

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[295] In line with most literature on markets for ecosystem services, we use the term "public goods" in its broadest sense, i.e., including 'common goods' such as water.

[296] Duraiappah, A.K. (2006) "Markets for Ecosystem Services - A Potential Tool for Multilateral Environmental Agreements" International Institute for Sustainable Development, Manitoba iisd.org/pdf/2007/economcs_markets_eco_services.pdf

[297] Information asymmetry implies landowners have more information about opportunity costs than buyers do and missing markets making it difficult to valuate opportunity costs.

[298] Engel, S. et al. (2008) "Designing Payments for Environmental Services in Theory and Practice: An Overview of the Issues" Ecological Economics 65 pp. 663-674

[299] Pattanayak, S.K. et al. (2010) "Show Me the Money: Do Payments Supply Environmental Services in Developing Countries?" Review of Environmental Economics and Policy 4 (2) pp. 254–274

[300] Ibid.

122. However, the experience with payments for ecosystem services is mixed in other countries[301]. Most of the schemes are implemented by governments or third party donors. While the objective might be clearly established in terms of environmental sustainability, limited attention has been given to evaluating the efficiency and effectiveness of the programs, except for carbon payments[302]. On the other hand, user-funded schemes are more likely to be monitored in terms of effectiveness. The valuation of the ecosystem services can be seen as dual: for the buyer the valuation is based directly on the ecosystem service as a production input such clean water while the valuation at the level of the provider is based on an analysis of the land use opportunity cost. In their assessment of 14 schemes, Wunder et al. (2008) [303] therefore also defines payment for ecosystem services as a voluntary transaction of a well-defined environmental service or a land use likely to secure that service. The assessment showed that payments were generally based on the cost of the provision of the ecosystem service, i.e., the land use opportunity cost rather than the value of the ecosystem service. Hence, single service schemes generate in principle the same revenues as multiple service schemes. The lack of valuations of the total economic value of specific land use furthermore challenges assessments of the costs-efficiency of payment for ecosystem services schemes. We have presented more detailed examples of valuations of payment for ecosystem services in Part 2 of this White Paper.

## 6.3 Adaptation to Climate Change

123. As part of the global agenda for climate change adaptation, ecosystem-based adaptation has been introduced as a concept focusing on small-scale adaptation measures, typically for small farmers and rural communities, often framed in terms of resilience building. It is still mainly an intuitive concept in the sense that there is no common definition, but a general recognition that ecosystem based adaptation refers to the explicit use of ecosystem services in local scale adaptation efforts.

124. In practice, ecosystem based adaptation can be seen as a combination of ecosystem based management and climate change adaptation. Reported cases are often very similar to integrated land use management such as agro-forestry techniques promoted since the 1970s. E.g., a recent scientific literature review of ecosystem-based adaptation with forests and trees[304] highlights the experience referred to as farmer-managed natural regeneration in the Sahel. Farmer-managed natural regeneration is based on assisted natural regeneration of seeds and living tree stumps of a variety of traditional and drought resistant trees. The technique has contributed significantly to the 'greening of the Sahel' that has been observed over the last decades[305]. The trees are cultivated with crops for food and cash and

[301] Dosteus L. et al. (2012) "Towards Operational Payments for Water Ecosystem Services in Tanzania: A Case Study from the Uluguru Mountains" Oryx, 46 , pp. 34-44
[302] Wertz-Kanounnikoff, S. et al. (2011) "Ecosystem-Based Adaptation to Climate Change: What Scope for Payments for Environmental Services?" Climate and Development 3(2) pp. 143-158
[303] Wunder, S. et al. (2008) "Taking Stock: A Comparative Analysis of Payments for Environmental Services Programs in Developed and Developing Countries" Ecological Economics 65 pp. 834-852
[304] Pramova, E. et al. (2012) "Forests and Trees for Social Adaptation to Climate Variability and Change" WIREs Climate Change 3 pp. 581-596
[305] Sendzimir, J., et al. (2011) "Rebuilding Resilience in the Sahel: Regreening in the Maradi and Zinder Regions of Niger" Ecology and Society 16(3):1http://dx.doi.org/10.5751/ES-04198-160301

the systems have shown greater drought resilience and improved crop yields[306]. Pramova et al. (2012)[307] explains the success of the Niger agro-forestry experience with its low cost and flexibility allowing communities to test it combined with institutional incentives. Still, the authors conclude that the overall costs and benefits of the technique remains to be determined – as do most experience with ecosystem based adaptation with forests and trees.

[306] Pramova, E. et al. (2012) "Forests and Trees for Social Adaptation to Climate Variability and Change" WIREs Climate Change 3 pp. 581-596

[307] Ibid.

# 7. CONCLUDING REMARKS

## 7.1 USE OF SCIENTIFIC KNOWLEDGE FOR SUSTAINABLE DRYLAND AND DROUGHT RISK MANAGEMENT DECISION-MAKING PROCESSES

125. The need to strengthen the scientific foundation for valuations of policies and practices for sustainable dryland and drought risk management is the premise for the second UNCCD Scientific Conference. As we have seen in this paper, a substantial body of work has been developed over the last years to operationalize concepts related to sustainable dryland and drought risk management. With the increased recognition that drylands are complex social-ecological systems, many scholars put emphasis on the need for integrated, transdisciplinary, and dynamic models that can reflect the characteristics of complex systems, including the inherent uncertainty and unpredictability.

126. However, the question is not just about the scientific foundation per se but also about the relationship between the scientific foundation and the policy-making at all levels including the use of science in public policy. As highlighted in a recent paper on the use of science in public policy[308], there will always be a number of nonscientific reasons for what is used in policy making such as personal and political beliefs and values as well as extrapolation from general experience. In a literature review on use of scientific knowledge for sustainable land management, Stringer & Daugill (2013)[309], for instance, point to lack of capacity and infrastructure as a major barrier for lack of incorporation of scientific research in national reports on the implementation of the UNCCD. Moreover, there is still a lingering question about what constitutes good science; e.g., what does value-neutral, independent, and fact-based mean for complex system research? And at what stages of the policy-making processes should it be used[310]. Science serves different purposes when applied in policy-making: tactically when it supports already made policy statements[311], conceptually when it informs policy-makers' reasoning, or instrumentally when it solves a specific problem. While there are no boundaries among these different uses, it is important to understand why or how science is being used for policy-making towards sustainable dryland and drought risk management; e.g., does scientific knowledge that is being used tactically have the same value as scientific knowledge used instrumentally? And is use of scientific knowledge in policy-making less worth because it is imposed, which might lead to policy-makers 'googling' for the 'most fitting' scientific paper? According to Prewitt et al. (2012) science's role with respect to policy includes to identify the problem, measure importance of problem, assess alternative responses, and evaluate likely positive and negative consequences of policy actions. The paper furthermore suggests that social science has never fully addressed issues related to when, why, how, and even whether science is used in

[308] Prewitt, K. et al. (Eds.) (2012) "Using Science as Evidence in Public Policy" The National Academies Press, Washington D.C.
[309] Stringer, L. C. & A. J. Dougill (2013) "Channeling Science Into Policy: Enabling Best Practices From Research on Land Degradation and Sustainable Land Management In Dryland Africa" Journal of Environmental Management 114 pp. 328-335
[310] Sutherland, W.J. (2012) "A Collaboratively-Derived Science-Policy Research Agenda" PLoS ONE, 7(3) plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0031824
[311] According to Gormley (2011) "the use of the use of scientific information by public officials, when it occurs, is more likely to involve justification (reinforcement of a prior opinion) than persuasion (conversion to a new opinion)" Gormley Jr., W.T. (2011) "From Science to Policy in Early Childhood Education" Science
333 (6045) pp. 978-981

public policy making. A key challenge is communication: is the scientific knowledge communicated correctly to reach the appropriate levels in the decision-making processes, for instance? And how to communicate results about complex systems?

127. The challenge of communicating scientific knowledge in an action-oriented manner has been highlighted in the climate change debate. The information flow about the dire future if no effective policy measures are taken immediately to curb the $CO^2$ emission rate has seemed endless for years. Most policy-makers recognize and accept the findings of the Intergovernmental Panel of Climate Change (IPCC). Still, the information flow has not led to effective communication. At the 40-years anniversary of the groundbreaking publication "Limits to Growth" in 2012 the authors identified some of the communication challenges that have led to lack of effective follow-up to the policy recommendations for sustainable development. For instance, while half of the 12 scenarios presented in the "Limit to Growth" would lead to an equilibrium state, the interpretation of the study both in the mass media and in some scientific literature has described the inevitability of a future collapse. One of the communication challenges identified by the authors is that the underlying principles and assumptions of scenarios are rarely understood. This questions the whole idea of using scenarios when communicating scientific information.

128. When it comes to complex systems such as drylands and social-ecological systems in general, the role of scientific knowledge to facilitate policy-making takes new dimensions. Understanding of the dynamics of complex systems is itself complicated and difficult to grasp for most people. Science therefore has a great role in explaining the functioning of complex systems and their characteristics such as their resilience to external or internal changes. Through approaches such as data mining, network analyses, scenario modeling, and sensitivity analyses, science can provide more insight for policy-makers, for instance of the social and economic consequences of a new policy. At the same time, because of typical characteristics of complex systems such as non-linearity and non-predictability, science will provide information that is probabilistic rather than deterministic; i.e., policy-makers will have to understand the importance of an estimate and the many unknowns[312]. This will require effective communication to policy-makers.

129. Kumar et al (2010)[313] suggest policy-making values of different indicators for ecosystem regulating services based on data availability and the intuitive understanding of the indicator. E.g., the notion of evapotranspiration, which is central for the UNCCD's definition of desertification, is considered to have medium value as a conveyer of information for policymaking. However, it is still a weak indicator as there is a lack of data for it to be useful. Such information is critical for science communication. Similar findings have led Prewitt et al. (2012)[314] to suggest that in understanding the role of science in policy-making it might be useful to consider scientists and policy-makers as divided by language, values, norms, reward systems, and social and professional affiliations. To bridge these two 'opposing' communities the

[312] Complexity science is defined in the workshop report as the interdisciplinary scientific field "devoted to understanding, predicting, and influencing the behaviours of complex systems"
[313] Kumar, P. et al. (2010) "Guidance Manual for the Valuation of Regulating Services" United Nations Environmental Program, University of Liverpool, and Indian Institute of Forest Management
hqweb.unep.org/pdf/Guidance_Manual_for_the_Regulating_Services.pdf
[314] Prewitt, K. et al. (Eds.) (2012) "Using Science as Evidence in Public Policy" The National Academies Press, Washington D.C.

authors suggest different facilitating measures, which all boil down to communication and facilitation of an intermediate institution such as a think tank and platforms such as the UNCCD Scientific Conferences. Given the role for such intermediary institutions, it will be critical that the institutions will have a good understanding of communication as more than simple interaction and information exchange and that they will have the right tools to facilitate good communication. Alternative or complementary models to the model with an intermediary institution(s) between the science and policy-making community include the increasing use of embedding scientists at policy-making at senior government levels, e.g. as ministerial advisors[315] to summarize and communicate scientific knowledge to the policy-makers: translation, brokering.

130. In the end, it is important to recognize that policy-making processes are complex; context specific; have many interdependent and interconnected actors at many levels, and that it will be influenced by a number of sources of information, including different scientific results that might even be contradictory. The science community, the policy-makers, and the direct land-users are all part of an integrated system with many different feedback loops both within and between these different subsystems. For economic valuations of sustainable dryland and drought risk management to be effective, it will be important that these feedback loops are understood and managed effectively.

## 7.2 Recommended Research Priorities to Strengthen Economic Valuations of Sustainable Dryland and Drought Risk Management

131. Inspired by the research questions suggested by Groot et al. (2010)[316] for integration of the concept of ecosystem services and values in landscape planning, management, and decision-making, we would like to suggest the following set of research issues to further the use of economic valuations of sustainable dryland and drought risk management. The recommendations for future research priorities are addressed policy-makers at different levels, including different national sector and governance institutions as well as the Committee of Science and Technology of the UNCCD:

- Understanding and quantification of how dryland ecosystems generate services: typology, relationship between services, indicators and benchmark values, temporal and spatial distribution of services;
- Understanding of complex dryland systems: modeling of the dynamic relationship between dryland system elements, feedback loops, resilience indicators, identification of potential thresholds, identification of bottlenecks for resilience assessments of the dryland systems;
- Understanding socio-economic-political factors shaping the economic impact of land degradation such as market systems, communication and information systems, research, development, and extension services, financial services, transportation, education, etc.. ;

[315] Sutherland, W.J. (2012) "A Collaboratively-Derived Science-Policy Research Agenda" PLoS ONE, 7(3) plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0031824

[316] Groot, de R.S. et al. (2010) "Challenges in Integrating the Concept of Ecosystem Services and Values in Landscape Planning, Management and Decision Making" Ecological Complexity 7(3) pp. 260-272

- Understanding the policy development environment: mapping of local, national, regional, and global policies relevant for sustainable dryland and drought risk management, including their interrelationships, relative importance, and maneuverability;
- Understanding the relationships between dryland ecosystems and other ecosystems: tradeoffs and synergies in development aspects, including mutually reinforcing goods and services;
- Understanding economic and social valuation of sustainable dryland and drought risk management: classification of assessment techniques with minimum set of indicators, guidelines for approaches, including stakeholder participation, temporal and spatial scales, discounting rates, simplified standard presentation of valuation summaries, guidelines for policy appraisals, reliability of valuations based on multiple sources, identification of bottlenecks for integrated valuations, use and non-use values of dryland ecosystems, monitoring of the use of scientific research for policymaking and monitoring;
- Understanding decision-making processes for sustainable dryland and drought risk management, including policy formulation, effective communication strategies between research community, dryland users, policy makers, and other stakeholders;
- Understanding the uncertainty cascade linked to sustainable dryland and drought risk management: mapping sources and nature of uncertainty, describing causes of uncertainties, and identify multiple uncertainty feedback loops. Similar to former IPCC assessment reports (AR), for the preparation of the fifth assessment report (AR5) scheduled to be released in 2014, there is a special guidance note for treatment of uncertainties[317]. The latest guidance note suggests a framework for how to communicate the level of confidence and could be used as a basis for communication scientific evidence on valuations related to sustainable dryland and drought risk management.

[317] Mastrandrea, M.D. et al. (2010) " Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties" Intergovernmental Panel on Climate Change ipcc-wg1.unibe.ch/guidancepaper/ar5_uncertainty-guidance-note.pdf

# PART 2: EXAMPLES OF FRAMEWORKS AND CONCRETE ASSESSMENTS AND VALUATIONS

# Resilience Assessments of Complex Systems

## 1. Social Protection Framework

Béné et al. (2012)[318] apply a simplified framework with three resilience characteristics described in section 2.4.2 for an assessment of the role of social protection schemes for promoting resilience[319]. The qualitative assessment addresses both short- and longer-term interventions for protection, prevention, promotion, and transformation[320]. The assessment is based on evaluations carried out by others. These evaluations are not necessarily framed in terms of resilience and the role of protection schemes to strengthen resilience is not straightforward. The protection scheme in Ethiopia, for instance, takes an integrated social-ecological approach to food insecurity with a focus on asset building[321] including restoration and protection of the drylands and drought risk reduction activities. According to a review of responses to land degradation in Ethiopia[322] farmers gladly provided free labor for conservation and restoration in the drylands. Most likely, the cash transfer provided by the program allowed farmers to have more resources and thereby strengthening their resilience. However, based on existing evaluation reports, Béné et al. conclude that the positive impacts from the program have not necessarily transformed the farm units to cope with future droughts. This does not mean, though, that the resilience has not been enhanced. Rather, the examples shows the importance of defining time boundaries for resilience assessments.

## 2. Resilience Alliance Framework

The Resilience Alliance has developed a set of workbooks for resilience assessments in social-ecological systems[323] for practitioners and scientists with suggestions for how to assess existing and new policies. The assessment framework focuses on adaptive environmental management, participatory learning, and hierarchical frameworks as a basis of the general resilience analysis. In practical terms, the suggested approach includes five stages that are flexible and can be adapted to the specific context: 1/describing the system, 2/system dynamics, 3/interactions, 4/system governance, and 5/acting on the assessment. The identification of the system dynamics offer an important understanding of the feedback loops between and within the different social and ecological sub-systems, which in the end is critical for understanding the processes for sustainable dryland and drought risk management. The workbooks have been

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318 Béné, C. et al. (2012) ”Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes” IDS Working Paper 405, Institute of Development Studies, Brighton

319 Four well-known schemes that have been analyzed broadly in development literature are assessed: ‘Oportunidades’ in Mexico, ‘Productive Safety Nets Program and the Household Asset Building Program’ in Ethiopia, ‘Child Support Grant and State Old Age Grant in South Africa, and ‘The Challenging the Frontiers of Poverty Reduction/Targeting the Ultra Poor’ in Bangladesh

320 Protective measures providing relief from deprivation, Preventive measures seeking to avert deprivation, Promoting measures aim to enhance real incomes and capabilities, and promote improved opportunities and livelihoods, and Transformative measures addressing social equity and exclusion.

321 Conway, D. & L. Schipper (2011) “Adaptation to Climate Change in Africa: Challenges and Opportunities Indentified in Ethiopia” Global Environmental Change 21 pp. 227-237

322 Kumasi, T.C. & K. Asenso-Okyere (2011) “Responding to Land Degradation in the Highlands of Tigray, Northern Ethiopia” IFPRI Discussion Paper 01142, International Food Policy Research Institute, Washington D.C. ifpri.org/sites/default/files/publications/ifpridp01142.pdf

323 resalliance.org/index.php/resilience_assessment

applied in different contexts. In a 2010 / 2011 assessment of the resilience of pastoral social-economic systems in northern Afghanistan challenged by overgrazing,[324] Haider et al. (2012) conclude that the "concept of social-ecological resilience helps capture the dynamics of change, uncertainty and the inter-relationships between complex social and ecological systems". Furthermore, the authors find that a resilience framework is particularly relevant in highly unstable contexts such as Afghanistan. According to the authors, major shortcomings of the approach include the lack of tools for assessing power asymmetries, their influence on resilience and tools for strategic planning towards reliance. Moreover, the authors call for greater diversity of the case studies carried out by the Resilience Alliance.

### 3. Sustainable Livelihood Framework

In development contexts, the sustainable livelihood framework integrates capacities required for resilience, including capacities to learn and adapt, social networks, leadership, diversity, redundancy, and financial and physical resources. The sustainable livelihood framework was developed in the 1990s to address the complex economic, social, and ecological choices confronting rural households[325]. While not necessarily expressed explicitly, the approach addresses resilience and helps understand how factors that strengthen sustainable livelihoods such as access to credit and skills also offer multiple layers of resilience to cope with various disturbances. According to a resilience assessment from Tanzania, different layers of resilience from individual to global levels can be identified for the social system. All these different layers enable people to overcome adversity[326]. The complex structure of capacities, assets, and resources contribute to resilience[327]. Similar to vulnerability frameworks, the sustainable livelihood frameworks are not based on outcome analysis, which on the one hand might make them more easily operational. On the other hand, the frameworks do not allow for proper process assessments of resilience and thus make them less interesting from a management perspective. Moreover, many economists have questioned the use of the sustainable livelihood approach for comparative analysis as the approach is based on qualitative assessments.

Alinovi et al. (2010)[328] apply information from sustainable livelihood assessments for analysis of household resilience to food insecurity in Kenya. The assessment is based on data from the Kenya Integrated Household Budget Survey 2005-06. By using panel data at household level, the authors can combine linear and non-linear economic models. The authors define resilience as "the ability of the household to maintain a certain level of well-being (for example, food security) withstanding shocks and stresses, de-

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324 Haider, L.J. et al. (2012) "Interacting Traps: Resilience Assessment of a Pasture Management System in Northern Afghanistan" Planning Theory & Practice 13(2) pp. 312-319 in Davoudi, S. & L. Porter (Eds.) (2012) "Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice" Planning Theory & Practice 13(2) pp. 299-333

325 Plummer, R. & D. Armitage (2007) "A resilience-Based Framework for Evaluating Adaptive Co-Management: Linking Ecology, Economics And Society in a Complex World" Ecological Economics 61 pp. 62-64

326 McAlpine, K. (2009) "Enhancing Resilience in Tanzanian Children and Youth that are Separated from their Families" Mkombozi Research Report January 2009, Mkombozi, Moshi mkombozi.org/publications/research_report/2009_11_01_research_report_resilience_ENG.pdf

327 ICRC (2004) "World Disasters Report 2004 – Focus on Community Resilience" International Federation of Red Cross and Red Crescent Societies, Geneva

328 Alinovi, L. et al (2010) "Livelihoods Strategies and Household Resilience to Food Insecurity: An Empirical Analysis to Kenya" background paper for the conference on "Promoting Resilience through Social Protection in Sub-Saharan Africa", organised by the European Report of Development, Dakar, 28-30 June, 2010. erd.eui.eu/media/BackgroundPapers/Alinovi-Romano-D'Errico-Mane.pdf

pending on the options available to the household to make a living and its ability to handle risks." Moreover, it is assumed that resilience to food insecurity depends primarily on access to assets, income generating activities, basic social services, and social protection. In addition, the authors assume that access to agricultural production assets, non-agricultural assets, and agricultural practice and technology as critical for resilience. The resilience is then calculated as a weighted sum of these components. The result of the analysis show negative resilience for pastoralists and smallholder farmers while large-holder farmers are the most resilience. While the authors recognize the important dynamic aspect of resilience, they apply a static analysis because of lack suitable data set. Based on a cluster analysis, the households are grouped into six major livelihood groups: agro-pastoralists, small-holder farmers, large-holder farmers, entrepreneurs, wage employees, and pastoralists.

## 4. Changes in the Natural Capital Stock

Some authors argue that resilience should be considered as a capital stock as it provides an insurance against reaching an undesired state[329]. This is explained further by the positive and negative feedback loops among the various components of the social-ecological systems. The resulting impact can result in the system changing state when the impacts reach a certain thresholds. If the initial state is considered better than the new state, it is important for preventing the system from reaching the threshold. The largest impact a system can absorb without flipping into a new state is referred to as ecological resilience. As a stock, it has an accounting price, which is roughly the change in the net present value of expected future ecosystem services resulting from a marginal change in resilience today. Mäler et al. (2008)[330] describe how these resilience accounting principles have been applied to resilience assessments in the Goulburn-Broken Catchment in Southeast Australia. The intensive use of irrigation for vegetable production has resulted in increased salinity in the groundwater. It the groundwater reaches two meters from the surface the vegetable production will collapse. The resilience towards salinity is thus defined as the distance between the current groundwater level and 2 meter under the surface and the value of the resilience would be the management costs of maintaining that distance.

## 5. Critical Natural Capital

With the assumption of thresholds, ecological resilience is one of the key factors[331] defining the critical natural capital, i.e., ecological assets that perform important and irreplaceable environmental functions. Ferrari et al. (2012)[332] apply the concepts of critical natural capital and ecological resilience suggested by Brand (2009)[333] for an analysis of the impact of economic activities on the sustainability of estuarine wetlands of the Gironde Estuary region in France. The study focuses on selected ecosystem services: fish

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[329] Mäler, K.-G. et al. (2008) "Accounting for Ecosystem Services as a Way to Understand the Requirements for Sustainable Development" Proceedings of the National Academy of Science 105(28) pp. 9501-9506

[330] Mäler, K.-G. et al. (2008) "Accounting for Ecosystem Services as a Way to Understand the Requirements for Sustainable Development" Proceedings of the National Academy of Science 105(28) pp. 9501-9506

[331] Other key factors of critical natural capital: socio-cultural relevance, the economic value or the ecological importance

[332] Ferrari, S. et al. (2012) "Critical Natural Capital, Ecological Resilience and Sustainable Wetland Management: A French Case Study" Paper presented at the 2012 Montreal Natural Resources and Environmental Economics Workshops, Centre Interuniversitaire de Recherche en Economie Quantitative, Montreal

[333] Brand, F. (2009) "Critical Natural Capital Revisited: Ecological Resilience and Sustainable Development" Ecological Economics 68(3) pp. 605-612

resources and water provision. The authors show that these two services depend on 12 critical natural capitals and estimate what they refer to as the 'resilience potential' based on simulations. The authors recognize the challenges of a static approach to identify the resilience in dynamic complex systems.

### 6. Land Management Indicators

While agreeing with other researchers that agro-ecosystems are too complex to indentify and measure resilience, Cabell & Oelofse (2012)[334] suggest a set of indicators to assess the resilience of different agro-ecosystems. The 13 indicators are characterized as 'behavior indicators', i.e., indicators for land management measures such as number of suppliers reflecting the connectedness. The indicators are framed according to the four phases of adaptation of social-ecological systems: growth, conservation, release, and reorganization / renewal. According to the authors, the spatial boundaries of the agro-ecological systems should be defined according to the space of the production, distribution, and consumption of food fuel and fiber at a scale where the individual farmer can have an influence. While the suggested indicator framework is not applied to an overall resilience assessment, the authors show examples of how the different management measures reflected in the indicators can be seen as having an impact on the resilience of systems. Social capital, for instance, has been key to the success of home gardens in Cuba.

### 7. Agro-Ecosystem Change

Perrings & Stern (2000)[335] argue that for a managed ecosystem an agro-ecosystem change in the long-term productivity can be measured. They used a Kalmar filter, which is a linear quadratic estimation combined with non-linear correction models for a study on loss of resilience in semi-arid rangelands in Botswana to take into account that the underlying ecosystem is non-linear reflecting the discontinuities and threshold effects. The study used economic modeling for the resilience of the rangeland towards three typical stressors: rainfall deficit, and decrease in the off-take prices and cost of livestock holdings. By using the corrected Kalmar filter, the authors showed that permanent degradation of the range due to loss of resilience occurs sporadically but is not substantial, implying greater margin for sustainable range management based on resilience observation through predictive models.

### 8. Resistance Analysis

Brand (2009)[336] acknowledges that resilience cannot be measured directly but suggests that ecological resilience can be estimated through the resistance characteristic; i.e., the capacity of an ecosystem to resist disturbance and still maintain a specified state. The author recognizes that this may underestimate other characteristics such as capacities for re-organization. For the resilience assessment, the author highlights the assumption of thresholds and that ecosystems can shift non-linearly between alternative

[334] Cabell, J. F. & M. Oelofse (2012) "An Indicator Framework for Assessing Agroecosystem Resilience" Ecology and Society 17(1): 18., dx.doi.org/10.5751/ES-04666-170118
[335] Perrings, C. & D. I. Stern (2000) "Modeling Loss of Resilience in Agroecosystems: Rangelands in Botswana" Environmental and Resource Economics, 16, pp. 185-210
[336] Brand, F. (2009) "Critical Natural Capital Revisited: Ecological Resilience and Sustainable Development" Ecological Economics 68(3) pp. 605-612

stable states separated by the thresholds, e.g., savannahs may exhibit a grassy or woody state. Moreover, the authors argue that ecosystem dynamics can be explained by a few key variables; particularly the so-called slow variables that are controlling the ecosystem dynamic. Slow variables have a slow turnover rate in space and time such as soil moisture capacity and land occupation in the drylands[337]. However, it is questioned if there are actual examples where slow variables have been controlled in practice.

## 9. Socio-demographic Characteristics

In a study on the impact of economic activities on the resilience of social ecological systems, Forbes (2009)[338] studies the traditional reindeer pastures in northern Russia that are rich in oil and gas reserves. Thousands of exploration drill sites have been established over the last three decades. While the physical footprint of an oil or gas complex can be monitored, the indirect socio-economic impacts are widespread but difficult to monitor, as they will often be strongly influenced by other stressors; e.g., the post-soviet era has seen a rapid increase in the reindeer population and changes in herd management practices. Based on general observations of land cover, biomass, and socio-economic structures, the authors identify certain resilience characteristics that have been critical for what is seen as a high resilience of the reindeer herding industry. The indicators used for assessing the overall resilience include demography and youth retention among herders. The critical characteristics are management variables such as flexibility and self-organization of the communities. Moreover, the study shows that resilience characteristics might not have the same meaning for a sustainable environment and a sustainable socio-economic system, e.g., loss of biodiversity is not necessarily negative for the reindeer herding community. Rather than biodiversity, redundancy of certain ecosystem functions is critical for the resilience of the reindeer herding, for instance provision of high biomass.

## 10. Traditional Knowledge and Knowledge Integration

Based on a review of 47 selected papers and book articles on indigenous, local, and traditional knowledge and resilience in social-ecological systems, Bohensky & Maru (2011)[339] analyzed the use of certain concepts and themes, including resilience and knowledge integration[340]. The review showed that references to resilience are mostly conceptual rather than empirical and the papers present limited discussions about how knowledge integration might promote resilience. However, some of the papers presented evidence that development policies and externally driven ecological restoration lead to declining resilience partly as a result of limited knowledge integration. But the reviewed papers showed no evidence that knowledge integration or revitalization of traditional knowledge had been used to enhance resilience. This leads the authors to point to a general problem that most research on social-ecological resilience focuses on declining resilience instead of increasing resilience. Overall, the review was chal-

[337] Stafford-Smith, D.M., et al. (2009) "Drylands: Coping with Uncertainty, Thresholds and Changes in State" in Chapin III, F.S. et al. (Eds.) Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in A Changing World, pp. 171–195, Springer, New York

[338] Forbes, B.C. (2009) "High Resilience in the Yamal-Nenets Social–Ecological System, West Siberian Arctic, Russia" Proceedings of the National Academy of Science 106(52) pp. 22041-22048 pnas.org/content/106/52/22041.full?sid=a6664a92-a125-4236-b6b9-0b0e964c6d52

[339] Bohensky, E. L. & Y. Maru (2011) "Indigenous Knowledge, Science, and Resilience: What Have We Learned from a Decade of International Literature on "Integration"?" Ecology and Society 16(4): 6. dx.doi.org/10.5751/ES-04342-160406

[340] Integration of scientific with indigenous, local, or traditional knowledge.

lenged by the different uses and definitions of central concepts such as resilience and knowledge integration highlighting the difficulties in comparing resilience research.

### 11. Historical Meteorological and Demographic Records

Enfield (2012)[341] shows how multi-generational learning that is gradually accumulated has played a critical role for social-ecological resilience in different regions in Mexico. The study is based on historical records for three regions with different social-ecological systems: Chonchos Valley in the northern drylands, the Valley of Oaxaca in the sub-humid areas, and the sub-humid central highlands. The rich national archives document that Mexico has experienced climate variability and extreme events primarily in forms of floods and droughts for centuries. These events have led to a wide variety of adaptive strategies such as irrigation, mixed farming, and organized storing of grains to hedge against climate variability and the shared experiences of crisis have furthered innovation and collaboration among different sectors. The learning has had general impacts on all components of the social-ecological systems. Prolonged drought events, for example, have stimulated community groups to hold the government responsible for provision of basic services such as public health. On the other hand, the author also notes that some of the social unrest in the late 18$^{th}$ century coincided with prolonged droughts but also a growing inequality in the society. Still, the author suggests that it would be naïve to automatically see the societal breakdown as a result of the environmental challenges although they are closely interlinked.

### 12. Transformability of Governance and Management Structures

Based on five case studies from Sweden, USA, Thailand, and Australia, Olsson et al. (2006)[342] analyze the transformability of governance and management structures to respond to stresses such as demographic pressure, unsustainable land use, and land degradation. The study showed that governance structures transformed positively when there were social networks with participation of the scientific community, natural resource managers, and politicians. On the other hand, the authors also note that special interests in the ecosystems can be polarized during ecological stress and lead to escalating conflicts, which ultimately hinders ecosystem restoration, lowers resilience, and prevents sustainable management. Moreover, the study showed the importance of leadership for governance transformability towards sustainable ecosystem management. The leadership skills include strong communication and promotion of networks and social learning across sectors.

[341] Endfield, G. H. (2012) "The Resilience and Adaptive Capacity of Social-Environmental Systems in Colonial Mexico" Proceedings of the National Academy of Science, 109(10) pp. 3676-3681
[342] Olsson, P. et al. (2006) "Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems" Ecology and Society 11 (1): 18 ecologyandsociety.org/vol11/iss1/art18/

# Resilience Assessments in Disaster Risk Management Contexts

## 1. Community Resilience Index

Cutter et al. (2010)[343] suggest a set of composite indicators to measure disaster resilience through an overall resilience score and establish a baseline for community resilience in counties within the south-eastern United States. The authors underline that the conceptualization of resilience is still in its initial phases and the suggested metrics should not be seen as a final indicator model. Rather, the suggested framework should be further developed when more insight into the multidimensional and dynamic nature of resilience is accumulated. The multi-dimensional framework encompasses social, economic, institutional, infrastructural, ecological, and community elements and the overall resilience is calculated from the individual resiliencies such as institutional resilience. The selection of indicators is based on both resilience research and data availability and consistency. This second requirement was a major reason for the exclusion of ecological aspects. The data were normalized, standardized, and transformed to percentages, per capita, and density functions and variables were tested for independency. In total 36 variables were retained covering issues such as communication capacity, level of employment, mitigation measures, prior disaster experience, and shelter capacity. The counties in the study area were compared for their overall resilience score, which was then explained by underlying social, economic, institutional, infrastructural, and community resiliencies. According to the authors, the major shortcoming of the approach is insufficient, outdated, and incompatible data for countrywide analyses. In some cases, there would be local data but they could not be applied as it would influence the overall comparison. In addition to ecological data, it was found particularly difficult to obtain enough data for social resilience. Other research on community disaster resilience have reached similar conclusions. E.g., in his work for the development of an index to measure community disaster resilience in coastal southern areas in the United States, Mayunga (2009)[344] notes that even county level data are not sufficient for community level assessments. This causes particular problems considering that a great deal of the disaster risk management policy is based on community risk management. The shortage of compatible, updated, and reliable data will most likely be the major challenge for application of future resilience frameworks. The data challenge is global as we have also seen in many climate change studies. A 2010 global study[345] of the costs of adaptation that focus on droughts and floods could not make distinctions between regions, disaster type, etc. Moreover, local costs could not be included.

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[343] Cutter, S.L. et al. (2010) "Disaster Resilience Indicators for Benchmarking Baseline Conditions" Journal of Homeland Security and Emergency Management, 7(1): 51, Berkeley Electronic Press, bepress.com/jhsem/vol7/iss1/51

[344] Mayunga, J.S. (2009) "Measuring the Measure: A Multi-Dimensional Scale Model to Measure Community Disaster Resilience in the U.S. Gulf Coast Region" Ph.D. Dissertation, Texas A&M University repository.tamu.edu/bitstream/handle/1969.1/ETD-TAMU-2009-05-769/MAYUNGA-DISSERTATION.pdf?sequence=1

[345] Blankespoor, B. et al. (2010) "The Economics of Adaptation to Extreme Weather Events in Developing Countries" Center for Global Development, Washington D.C. cgdev.org/content/publications/detail/1423545

## 2. Principal Component Analysis

A 2012 evaluation[346] of the resilience impact of the humanitarian aid response to the January 2010 Earthquake in Haiti, applies a principal component analysis to identify a resilience framework based on seven resilience dimensions: wealth, debt and credit, coping behaviors, human capital, protection and security, community networks, and psychosocial status. By analyzing these seven dimensions, the study concludes that the humanitarian assistance did not improve resilience outcome and even seemed to have had a negative impact in some instances. This is explained partly by the lack of proper integration of Haitian people in the design of the disaster response activities.

## 3. Sense of Coherence Scale

Based on a general overview of the development of the resilience concept in the humanitarian community, Almedom (2011)[347] reviews the usefulness of the 'Sense of Coherence' (SOC-13) scale based on 13 simple questions for resilience assessments. The review covers 15 peer-reviewed journals on health, social, behavioral, and environmental sciences and the author concludes that the Sense of Coherence framework can be applied to different contexts. The Sense of Coherence scale was developed in the 1980's by sociologist Antonovsky who argued that a general positive outlook or proactive orientation has a positive influence on the individual's health. The sense of coherence is determined by the way individuals perceive the comprehensibility, manageability, and meaningfulness of their environment[348] and their coping resources such as social networks and knowledge. The original Sense of Coherence framework consists of 29 indicators and has been applied for different social interdisciplinary studies. A reduced version with 13 indicators that can be scored has been applied to assess resilience in quantitative terms in different humanitarian contexts; e.g., comparing displaced persons in war-torn Eritrea based on individual surveys with non-displaced[349].

## 4. Social and Psychological Characteristics

The positive outlook is also one of the key characteristics of resilient communities and individuals among rural people in Queensland, Australia. In a participatory action research study, Buikstra, E. et al. (2010)[350] identify eleven resilience characteristics[351] of individuals, groups, and communities that have confronted and responded positively to adversities such as drought, hailstorms, and bushfires. The resilience characteristics covered social, ecological, and economic aspects. The study showed that resilience is dynamic and a process that might change constantly as a function of the identified characteristics and the con-

[346] Tulane University's Disaster Resilience Leader Leadership Academy & Université d'Etat d'Haiti (2012) "Evaluation de l'Aide Humanitaire en Haïti sous l'Angle de la Résilience" Tulane University, New Orleans

[347] Almedom, A.M. (2011) "Profiling Resilience: Capturing Complex Realities in One Word" The Fletcher Forum of World Affairs Journal, 35 (1), pp. 145-155

[348] Eriksson, M. & B. Lindström (2005) "Validity of Antonovsky's Sense of Coherence Scale: A Systematic Review" Journal Epidemiol Community Health 59 pp. 460-466 jech.highwire.org/content/59/6/460.full

[349] Almedom, A. M. et al. (2007) "Use of 'Sense Of Coherence (SOC)' Scale to Measure Resilience In Eritrea: Interrogating Both the Data And The Scale." Journal of Biosocial Science 39(1)(2007) :pp. 91-107

[350] Buikstra, E. et al. (2010) "The Components of Resilience — Perceptions of an Australian Rural Community" Journal of Community Psychology 38(8) pp. 975-991.

[351] Social Networks and Support, Positive Outlook, Learning, Early Experience, Environment and Lifestyle, Infrastructure and Support Services , Sense of Purpose, Diverse and Innovative Economy, Embracing Differences, Beliefs Leadership

fronted adversities. The characteristics have been further developed in a toolkit[352] for strengthening resilience at individual, group, and community level. Other studies from Australia also assess the link between natural disasters and resilience. A qualitative research in South Australia looked into factors explaining how some farmers continue to farm in spite of prolonged droughts[353, 354]. The study focused on farmers' perception of the household 'getting by' or adapting during drought as a measure for resilience. More formally, resilience was defined as "a dynamic process wherein individuals display positive adaptation despite experiences of significant adversity or trauma." The research was based on a panel survey with two rounds of interviews with farm families organized 12 months apart as well as focus group discussions. The research showed that drought resilience was defined by a number of interrelated factors: personal stance, e.g., perceptions about the farming lifestyle; context, e.g., social networks; and resources and strategies, including drought risk management and service providers. Because of the interrelatedness of the factors defining resilience, policies and programs to strengthen resilience should be integrated and holistic in nature. During the two-year study, the researchers also learned that in order to assess resilience, the survey questions have to be formulated in a positive manner.

14. Among the critical findings of the two-year research was that farmers who stopped farming as a consequence of the adversities by either exiting or leasing can have positive outcomes perceived as 'getting-by'. This finding confirms an aspect of resilience that has been highlighted in some parts of the risk management literature, namely that persistence is not necessarily a good indicator for resilience. Allenby & Fink (2005)[355], for instance, suggest that resilience is the "capability of a system to maintain its function and structure in the face of internal and external changes and to degrade gracefully when it must." Likewise, in a study on national security towards manmade and natural disasters, Kahlan et al. (2009)[356] apply that definition and identify the 'capacity to degrade gracefully when it is unavoidable' as critical for resilient institutions and infrastructure. The capacity to degrade slowly and gracefully when it must is part of the system's robustness meaning that the functions of the system will not cease suddenly and thus allow for adaptation of external and internal dependent systems. In the case of the Australian farmers that chose to give up farming, they chose to exit or select based on careful analysis and planning; i.e., their cessation was slow and allowed for adaption in terms of finding alternative structures for the farms, e.g., other farm families. The fact that that former farmers were successful in either selling or leasing their units shows in principle sustainable alternative use of the drylands.

## 5. Policy Framework

15. The substantive amount of research and assessments in Australia on disaster risk management and resilience is linked to the "National Strategy for Disaster Resilience"[357] adopted in 2009. The strategy

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[352] Hegney et al. (2008) "Building Resilience in Rural Communities Toolkit" The University of Queensland and University of Southern Queensland, Toowoomba

[353] Greenhill, J. A. (2009) "Understanding Resilience in South Australian Farm Families" Rural Society 19(4) pp. 318-325

[354] King, D. et al. (2009) "The Resilience and Mental Health and Wellbeing of Farm Families Experiencing Climate Variation in South Australia" National Institute of Labor Studies, Adelaide

[355] Allenby, B. & J. Fink (2005) "Toward Inherently Secure and Resilient Societies" Science 309 (5737) pp. 1034-1036

[356] Kahan, J. H. et al. (2009) "An Operational Framework for Resilience" Journal of Homeland Security and Emergency Management, Vol. 6(1) Article 83, bepress.com/jhsem/vol6/iss1/83

[357] COAG (2011) "National Strategy for Disaster Resilience" Council of Australian Governments, Canberra em.gov.au/Documents/1National%20Strategy%20for%20Disaster%20Resilience%20-%20pdf.PDF

builds on existing assessments and it has led to new research and guidelines for strengthening community resilience. Recognizing the vast number of resilience definitions, the strategy does not provide a definition as such. Rather, it focuses on a set of common characteristics that have been developed through the substantive amount of participatory research on natural disasters and resilience. According to the strategy, the core characteristics of resilient communities are that they function well while under stress; adapt successfully; exhibit self-reliance; and have social capacity.

# ECONOMIC VALUATION OF SOCIAL-ECOLOGICAL RESILIENCE

### 1. RESILIENCE IN RURAL AREAS

Schouten et al. (2012)[358] suggest a set of criteria for an evaluation framework of policy objectives to analyze how rural development policies contribute to resilience in rural areas in the European Union. The framework focuses on the compulsory modulation budget, which aims directly at sustainable rural development. The continuing challenges in achieving sustainable development in rural areas show the need to strengthen adaptive capacity as reflected in the Lisbon Strategy's call for sustainable development as a main framework for decision-making. The authors apply the evaluation framework for an ex-ante evaluation of the policy objectives by measuring the policy variables in terms of amount of funds that can be seen as directly contributing to increased resilience. The assessment framework includes the following resilience characteristics: diversity, variability, modularity, acknowledging slow variables, tight feedbacks, social capital, innovation, overlap in governance, and ecosystem services. The application of the resilience framework for policy analysis showed that the policy funding for promoting sustainable rural development have positive resilience impacts on the following resilience characteristics "acknowledging slow variables", "tight feedback", and "different levels of governance". The analysis shows some directions for future development of policy assessment tools and the need for further research to improve the coherence and distinctiveness of the resilience characteristics. Moreover, more research is needed to optimize evaluations qualitative outcomes such as most of the resilience characteristics.

### 2. ECOSYSTEM RESILIENCE: DISCRETE CHOICE TECHNIQUES

According to a 2011 working paper by Scheufele & Bennett (2011)[359], their research for valuing ecosystem resilience in Australia was the first attempt to use discrete choice techniques[360] to value ecosystem resilience. Their measurement of resilience is based on the probability of systems changing states or alternatively remaining in the same state. The survey among different ecosystem stakeholder groups showed a good comprehension of the concept and that stakeholders are marginally willing to pay for ecosystem resilience.

[358] Schouten, M.A.H. et al. (2012) "A Resilience-based Policy Evaluation Framework: Application to European Rural Development Policies" Ecological Economics, 81, pp. 165-175

[359] Gabriela Scheufele, G. & J. Bennett (2011) "Valuing Ecosystem Resilience" Research Report No. 98, Environmental Economics Research Hub Research Reports, Australian National University, Canberra

[360] Discrete choice experiments use quantitative methods for eliciting preferences that can be used in the absence of revealed preference data. The method assumes economic rationality and utility maximization, which is a major point of criticism for its use for non-tradable items such as many ecosystem services.

## 3. Insurance Value

A 2009 working paper by Baumgärtner & Stunz (2009)[361] to assess the insurance value of resilience used economic modeling based on economic valuation of ecosystem services and risk theory and with a focus on income from ecosystem services. According to the authors, the total value of resilience includes the specific economic value of insurance; i.e., the value of reducing an ecosystem user's income risk from using ecosystem services under uncertainty. The research was based on the assumption of risk-adverse behavior and the total economic value of resilience is calculated as the rise in expected income as a function of higher level of resilience plus the insurance value of resilience. The authors suggest that insurance value of resilience is negative for low levels of resilience and positive for high levels of resilience. Translated into a dryland ecosystem this would mean that in a very vulnerable system added resilience does not translate into a net benefit when measured in terms of income. Rather, the higher the level of resilience, the more valuable is another unit of resilience.

## 4. Ecosystem Services

Bateman et al. (2011)[362] treat ecosystem resilience as a stock with a distinct asset value that can be degraded or improved over time. In this way, resilience should be considered as an ecosystem service. As an illustration, they present the results from a study by Mäler & Chuan-Zhong (2010)[363] who used a multi-sector growth model to identify the shadow price[364] of resilience based on cost-benefit analysis and shadow pricing of resilience in the Goulburn-Broken Catchment in southeast Australia described earlier. About 300,000 hectares in the lower part of the catchment are used for dairy pastures, agricultural production, and nature conservation. The problem is that the intensive land use has resulted in biodiversity losses and rising groundwater tables, which increases the risk of soil salinization. Soil degradation is then measured as the depth of soil for which saline intrusion is not a problem. The value of marginal resilience[365] is calculated as a shadow value through the cost of reversing prior degradation; i.e. loss of resilience compared to the changes in income from agricultural expansion.

Bateman et al. (2011)[366] show that the tradeoffs between drivers of degradation and resilience are not necessarily linear because of critical thresholds. As a result, once a certain degradation level is surpassed, the marginal value of resilience increases. While recognizing the importance of a resilience approach to sustainability, Bateman et al. (2011)[367] highlight the requirement for high degrees of information, e.g., to identify the thresholds. Consequently, analysis of the economic value of resilience migth

[361] Baumgärtner, S. & S. Strunz (2009) "The Economic Insurance Value of Ecosystem Resilience" Working Paper Series in Economics, No. 132, University of Lüneburg hdl.handle.net/10419/30223

[362] Bateman, I. J. et al. (2011) "Economic Analysis for Ecosystem Service Assessments" Environmental Resource Economics 48 pp. 177-218

[363] Mäler, K.-G. & L. Chuan-Zhong (2010) "Measuring Sustainability under Regime Shift Uncertainty: A Resilience Pricing Approach" Environment and Development Economics 15, pp. 707-719, November/2010

[364] The shadow price can be calculated as the opportunity cost of an activity or a resource measured as the market price for the best alternative use of the activity / resource. It is also used for 'willingness-to-pay' estimated through contingent methods or survey methods.

[365] Bateman, I. J. et al. (2011) "Economic Analysis for Ecosystem Service Assessments" Environmental Resource Economics 48 pp. 177-218

[366] Ibid.

[367] Ibid.

be overly complicated. Another major challenge in using the 'flip theory' as a resilience measure is to define when a system has flipped – when is it a new state? This is particularly complicated for the social component of social-ecological systems.

### 5. Safe Minimum Standard

Considering the complex nature of valuing resilience, Bateman et al. (2011)[368] suggest applying the safe minimum standard method for valuation of ecosystem services, including resilience. Green (2010)[369] used the safe minimum standard to assess the resilience value of mussel farming for the Baltic Sea. The resilience value is estimated as the value of changes in the reliability of reaching the predetermined environmental targets set by the policy makers and based on the assumption that minimizing total economic costs. New technology may lead to replacement as well as changes in resilience values, where the resilience value is calculated as the decrease in total cost for achieving a certain load reduction target at a minimum probability caused by the introduction of mussel farming as an abatement measure. The study shows the importance of including the resilience value but the author warns against the many simplifications that were necessary for the study.

### 6. Cost-Benefit Analysis

Venton & Siedenburg (2010) carried out a retrospective cost-benefit analysis of efforts to strengthen resilience among drought-affected farmers in northern Malawi[370]. The analyzed activities were increased diversification, capacity development, and introduction of adapted technologies activities. The analysis was based on qualitative assessments through interviews with farmers based on specific and pre-determined benefits: increased crop and livestock production, loss of education avoided, and loss of life avoided through improved nutrition. A number of assumptions are thus made regarding the value of both costs and benefits but overall, the authors showed that the different activities delivered US$ 24 of net benefits for every 1US$ invested. The authors note that during the time period considered there had been no major natural disasters. The assessment is thus based on direct benefits as observed by the farmers under normal conditions. Because a cost-benefit analysis is a complex and time-consuming endeavor, the analysis is limited to direct benefits and only covers three alternatives among the ten offered by the project. In the end, the analysis does not provide clear answers to the costs and benefits of strengthening resilience, as the resilience is never really defined. The many costs and benefits that are not accounted for make it difficult to use those kinds of 'budget' or 'rapid' 'cost-benefit analyses' for operational recommendations beyond the overall message that strengthening resilience is generally a good investment.

[368] Bateman, I. J. et al. (2011) "Economic Analysis for Ecosystem Service Assessments" Environmental Resource Economics 48 pp. 177-218

[369] Gren, I.M. (2010) "Climate Change and Resilience Value of Mussel Farming for the Baltic Sea" pp. 184-194 in Simard, S.W. (2010) (Ed.) "Climate Change and Variability" InTech, intechopen.com/books/climate-change-and-variability/climate-change-and-resilience-value-ofmussel-farming-for-the-baltic-sea

[370] Venton, C.C. & Siedenburg, J. (2010) "Investing in Communities – The Benefits and Costs of Building Resilience for Food Security in Malawi" Tearfund, tearfund.org/investingincommunities

# ECONOMIC VALUATIONS FOR SUSTAINABLE DRYLAND AND DROUGHT RISK MANAGEMENT

## 1. LATIN AMERICA AND THE CARIBBEAN

With the increasing focus on sustainable environmental governance, many countries have established procedures for systematic monitoring of policies and programs for sustainable management, including policies and programs developed to address desertification. The UN Economic Commission for Latin America and the Caribbean (ECLAC), and the Global Mechanism (GM) of the UNCCD are implementing a joint project to measure the economic value of land degradation under different climate change scenarios. The project aims to establish a baseline to facilitate future dryland policy and program evaluations. According to preliminary data from the project[371], agricultural productivity losses due to desertification are between 6 and 41% of the national agricultural GDP in the 14 countries[372] covered by the study. Moreover, the study predicts a substantial increase in the productivity lost over the coming decades as a result of climate change if no effective adaptation policies are implemented. The evaluation approach includes mapping of drylands, desertification, and vulnerability vis-à-vis climate change, shown according to different long-term scenarios as identified by the Interagency Panel on Climate Change (IPCC). The vulnerability is identified according to water requirements of major crops compared to rainfall trends and degraded lands are compared to non-degraded. Based on the physical estimations for production loss, quantitative economic models are used to calculate agricultural productivity for subsistence, traditional, and modern agricultural production units. The econometric model uses total factor productivity, i.e. the residual, often called the Solow residual, which accounts for effects in total output not caused by inputs. The total costs are calculated as the aggregated value and compared to national agricultural GDP. According to the preliminary results, a major constraint for the analysis is been the lack of compatible data at local level. Still, the baseline offers important possibilities for political decision-makers in the 14 countries to monitor impact of dryland development and risk policies and practices.

According to the national governance structure In Chile, a certain number of policies and programs are chosen annually for independent assessments of their efficiency and effectiveness. The 2009 round of evaluation of national policies and programs included the national program for restoration of degraded soils, which consists of six different subprograms with activities such as conservation practices and crop rotation. The 5-year program was launched in 2005 and follows a program focusing on incentives for sustainable agricultural use. Desertification is widespread in Chile, covering almost two-thirds of the territory with severe socio-economic costs at local and national levels. The country disposes of more local data than many other Latin American and Caribbean countries and the 2012 baseline study[373] carried out under the ECLAC / GM project showed important differences in costs of productivity losses at re-

[371] Morales, C. (2012) "Evaluación Económica De La Desertificación Y Degradación De Tierras En LAC" Project Note – Proyecto Conjunto CEPAL/Mecanismo Mundial, Santiago
[372] Panamá, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala, Belice, Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay and Perú.
[373] Morales, C. (2012) "Evaluación Económica De La Desertificación Y Degradación De Tierras En LAC" Project Note – Proyecto Conjunto CEPAL/Mecanismo Mundial, Santiago

gional level. According to the 2009 evaluation[374] of the national land restoration program, there are some conceptual and boundary challenges in the program, including definition of what is degraded land and there are no reliable desertification assessment following commonly agreed indicators. Linked to this problem is the lack of targeting according to the severity of land degradation. While the evaluation estimates the average cost of recovery and average cost per beneficiary for small and larger farmers, these values do not indicate anything about the efficiency of the program in terms of land recovery from desertification because of the lack of a proper desertification assessment. The evaluation results point to a general problem of socio-economic assessments of dryland ecosystems: recognized valuation methods and techniques exist but there is a general need for reliable, compatible, and localized data. Another challenge is the lack of clear definitions of boundaries for dryland ecosystems.

## 2. AFRICA

18. In the preparatory study for the Economics of Land Degradation initiative (ELD), Nkonya et al. (2011)[375] present case studies of economic valuation of the impacts of desertification in five dryland countries: India, Kenya, Niger, Peru, and Uzbekistan. The studies focus on selected desertification impacts in the countries such as salinity and soil erosion in Uzbekistan and selected crops, such as sorghum, millet, and rice in Niger. Using simulation models the studies generate profit loss data based on costs and returns for different land management options; e.g., tillage and fertilizer, leaching, livestock density, optimal use of mesquite and other tree products, or terraces on the hillsides. Based on extrapolations, the authors show the importance of desertification at national level in the selected countries; e.g., it is estimated that sustainable dryland management for major crops and livestock production in Niger would increase the GDP by more than 8%. However, as recognized by the authors, it should be noted that the studies are based on a number of assumptions and extrapolations, and the profit loss estimates should be used with great caution. Still, the study can be used as an advocacy tool for the importance of action versus non-action, and hopefully also for more investment in studies with greater details, including indications of confidence levels for the estimations.

Balana et al. (2012)[376] provide land use policy advice based on the results from a cost-benefit analysis of the use of measures to regulate access to common land in the semi-arid northern Ethiopia. The area is characterized by severe land degradation driven by deforestation, overgrazing, and cropping on steep hillsides. As a land restoration measure, areas are set aside for natural regeneration and excluded from direct farm and livestock use through legislation. Moreover, local guards have been recruited. The so-called 'exclosures' provide a number of on- and off-site benefits such as decreasing soil erosion and increasing soil fertility, trapping seasonal runoffs and thus avoiding sediment accumulations in the dams and increasing water filtration and carbon sequestration. Over the last decades, a large number of scien-

[374] DIPRES (2012), "Informe Final de Evaluación. Programa Recuperación de Suelos Degradados", Santiago de Chile, dipres.gob.cl/574/articles-49602_doc_pdf.pdf

[375] Nkonya, E. et al. (2011) "The Economics of Desertification, Land Degradation, and Drought Toward an Integrated Global Assessment" ZEF-Discussion Papers on Development Policy No. 150

[376] Balana B.B. et al. (2012) "Cost-Benefit Analysis of Soil and Water Conservation Measure: The Case of Exclosures in Northern Ethiopia" Forest Policy and Economics 15 pp. 27-36

tific papers have quantified the benefits from exclosure management[377]. The cost-benefit analysis carried out by Balana et al. (2012)[378] was based on data generated from other studies as well as expert opinions and the following indicators were applied: increase in biomass production in the exclosures, increase in crop yield off-site, prevention of reservoir sedimentation, and opportunity costs for land and labor. The official discount rate for public investment projects in Ethiopia is 10%. Arguing that environmental conservation projects should have lower discount rate, the authors applied a discount rate of 8% for the cost-benefit analysis and an analytical timeframe of 30 years. The analysis was carried out for three different land types classified according to their productivity. The final results were tested with a sensitivity analysis of different future opportunity costs. The conclusion of the study is that exclosures have higher net present values than use for cropping and livestock in less productive and semi-productive areas such as steep hillsides and highly degraded land. On the other hand, productive land cropping and/or livestock is a better economic option in all other areas. The authors recognize that the data used for the analysis constitute a mix of anecdotal information, different assumptions, and data from other ecosystems. Moreover, the long-term impacts are only partially and indirectly taken into account. E.g., exclusures can lead to increased pressure on the remaining open land, which eventually could increase land degradation. Likewise, a number of externalities such as carbon sequestration, increased biodiversity, and drought mitigation were recognized as economically important in the study but not considered due to lack of data. The results should therefore only be considered as indicative according to the authors.

Other recent studies in Ethiopia focus on the quantification and valuation of the carbon sequestration capacity of the exclosures. Mecuria et al. (2011)[379] carried out a field study comparing exclosures and their adjacent communal land and isolated forest fragments. The exclosures were grouped according to the year of their establishment and their carbon sequestration capacity was measure for both the soil and the above-ground biomass. The exclosures increased the carbon stock capacity with of 29% after five years of exclosure establishment and more than 60% after 10 years[380]. The authors conclude that further cost-benefit analysis should be carried out for the use of the results in land use policy and stress some potential drawbacks such as overgrazing on areas outside the exclosures. Moreover, other ecosystem benefits such as biodiversity might decrease with the age of the exclosures.

[377] See for instance Mekuria, W. & E. Aynekulu (2011) "Exclosure Land Management for Restoration of the Soils in Degraded Communal Grazing Lands in Northern Ethiopia" Land Degradation & Development doi.wiley.com/10.1002/ldr.1146

[378] Balana B.B. et al. (2012) "Cost-Benefit Analysis of Soil and Water Conservation Measure: The Case of Exclosures in Northern Ethiopia" Forest Policy and Economics 15 pp. 27-36

[379] Mekuria, W. et al. (2011) "Restoration of Ecosystem Carbon Stocks Following Exclosure Establishment in Communal Grazing Lands in Tigray, Ethiopia" Soil Science Society of America Journal 75(1) pp. 246-256. It should be noted that this study presents timeframes between exclosure establishment and measurement for 5, 10, 15, and 20 years. Other presentations of the study only present timeframes of 5, 10, and 15 years; e.g. Mekuria, W. et al. (2011) "Carbon Changes Following the Establishment of Exclosure on Communal Grazing Lands in the Semi-Arid Lowlands of Tigray, Ethiopia" in Filho, W. L (edt.) (2011) "Experiences of Climate Change Adaptation in Africa" Springer, Berlin pp. 111-132

[380] Mekuria, W. et al. (2011) "Carbon Changes Following the Establishment of Exclosure on Communal Grazing Lands in the Semi-Arid Lowlands of Tigray, Ethiopia" in Filho, W. L (edt.) (2011) "Experiences of Climate Change Adaptation in Africa" Springer, Berlin pp. 111-132

Mekuria et al. (2009)[381] carried out a survey among farmers and some 'experts' to assess their perceptions on the effectiveness of exclusures for soil conservation. The survey included both individual household questionnaire surveys and focus group discussions. The results were compared with physical assessments of soil conservation properties of exclures established 5 to 10 years before the assessment. The farmers were asked about their opinions on the severity of soil erosion, causes and importance, consequences, and effectiveness of exclosures to control soil erosion. It should be noted that one of the results from the physical assessment was that soil loss from the studied exclosures were still higher than the Ethiopian standards for soil loss to be tolerated without interventions. Both the physical assessment and the survey confirmed that exclosures are effective for soil conservation though some farmers suggested that complementary measures were necessary.

## 3. Europe

Ibáñez al. (2008)[382] test a model to predict desertification in the three land use types identified as susceptible to desertification in Spain's National Action Program (NAP) for the implementation of the UNCCD: rainfed crops in areas with high soil erosion risk, irrigated intensive agricultural,; and commercial rangelands. The model is based on an ecosystem services approach and include a selected number of factors identified by the authors as important such as opportunity costs, stocks of natural resources, renewal rates, natural resource demand, and costs and profits. The study showed that in rainfed areas with traditional crops such as grapes and olives, very high initial profits per hectare can cause the crop to quickly colonize all the suitable areas long before losses of productivity due to erosion become significant. In the case of irrigated crops and livestock production, profitability and technology are the only factors determining the thresholds between sustainability and long-term desertification given a definite stock of natural resources. Both cases show that high profit scenarios are able to determine final states of desertification for a human-resource system seeking short-term profit maximization in spite of the assumption of constant average environmental conditions.

In a cost-benefit analysis of the impacts of the European water policy, the Water Framework Directive from 2000[383], Alcon et al. (2012)[384] compare the use of reclaimed water with other uses in the region of Murcia, in the semi-arid southeastern Spain. The region is highly susceptible to droughts and has the third highest level of water stress in Europe. According to the authors, the novelty of the study is the incorporation on non-marketed ecosystem services such as reclaimed water. The reclaimed water was priced at the cost of transportation of the water while the cost for water treatment was assumed to be incorporated into the polluter pays regulation in force in the region. For the benefit analysis, distinctions were made between private and public benefits were private benefits were calculated through the yields and sale prices obtained from the different water sources. The public benefits were calculated for

[381] Mekuria, W. et al. (2009) "Effectiveness of Exclosures to Control Soil Erosion and Local Community Perception on Soil Erosion in Tigray, Ethiopia" African Journal of Agricultural Research 4 (4), pp. 365-377

[382] Ibáñez, J. et al. (2008) "Assessing Desertification Risk Using System Stability Condition Analysis" Ecological Modelling 23(2) pp. 180-190

[383] For further description of the water policy see ec.europa.eu/environment/water/water-framework/index_en.html

[384] Alcon, F. et al. (2012) "Incorporating Non-market Benefits of Reclaimed Water into Cost-Benefit Analysis: A Case Study of Irrigated Mandarin Crops in southern Spain" Water Resources Management http://link.springer.com/article/10.1007/s11269-012-0108-z/fulltext.html

the use of reclaimed water as the value of preserving the ecological status of the watershed, including the benefits of consuming locally produced products and agricultural employment. The prices were obtained from interviews with the local population, i.e., through a contingent approach.

## 4. ASIA

The Chinese Ecosystem Research Network was established in 1988 and covers 36 field research stations for various ecosystems throughout the country, including agriculture and grasslands[385]. In addition, there is a special national network for forest ecosystem research. With the development of ecosystem research, there has also been a growing interest for economic valuations of ecosystem services. This has led to publication of a number of studies over the last decade with different focuses; e.g., geographically, according to specific ecosystems, or for specific ecosystem services. However, many of the valuations are based on benefit transfers with results from other countries and are often seen as misguiding, for instance in terms of relative values attributed to different ecosystems. Xie et al. (2010)[386], for instance, describe that relative low value is given to arable land compared to wetlands, which does not reflect the political priorities in a developing country like China. Likewise, the authors show that by applying different classification systems for forest ecosystem services, there can be significant differences in the total economic value presented in different studies. Another important factor leading to different results is the location of the studies. The authors therefore suggest an alternative ecosystem service classification for valuations in China consisting of nine ecosystem services[387] based on other classification systems, particularly the one suggested by Costanza et al. (1997)[388].

The research has had an important impact at national level [389] showing, for instance, that ecological and environmental values of ecosystem services are often several times higher than the market values. The research has been an important input for sustainable land use policies, such as the National Forest Protection Program and the Sloping Land Conversion Program[390]. To improve the usefulness of the information from the valuation studies, the State Forestry Administration issued a standard for valuation of forest ecosystem services in 2008, including 14 specific ecosystem services such as hydrological regulation, soil fixation, dust retention, species conservation, and forest recreation. In their 2010 review of ecosystem service research in China, Zhang et al.[391] note that more than 90% of the substantial amount of research focus on different ecosystem services or different regions, while little is known about the complex relationships between ecosystem structures, processes, and services.

[385] Zhang, B. et al. (2010) "Ecosystem Services Research in China: Progress and Perspective" Ecological Economics 69 pp. 1389-1395

[386] Xie, G. et al. (2010) "Applying Value Transfer Method for Eco-Service Valuation in China" Journal of Resources and Ecology 1(1) pp.51-59

[387] Food production, Raw materials production, Gas regulation, Climate regulation / disturbance regulation, water regulation / water supply, waste treatment, erosion control / sediment retention / soil formation / nutrient cycling, pollination / biological control / habitat / genetic resources, recreation / cultural activies,

[388] Costanza, R. et al. (1997) "The Value of the World's Ecosystem Services and Natural Capital" Nature 38 pp. 253-260

[389] Liu, S. & R. Constanza (2010) "Ecosystem Services Valuation in China" Introduction to Special Section, Ecological Economics 69 pp. 1387-1388

[390] These programs are discussed further in the section of schemes for payment of ecosystem services.

[391] Zhang, B. et al. (2010) "Ecosystem Services Research in China: Progress and Perspective" Ecological Economics 69 pp. 1389-1395

Based on a study located in the peatlands in the in the center of China, Zhang & Lu (2010)[392] Suggest a framework for valuation of ecological, economic, and social values of ecosystem services. The ecosystem services are weighted according to the values assigned by the stakeholders. The major stakeholder group is local herders and livestock generates around 75% of the regions Gross National Product. Other critical stakeholder groups are tourists, residents, and beneficiaries of the carbon sink service of the area, considered as indirect beneficiaries in the analytical framework. The ecosystem services are classified according to their values and calculated for the following services: subsistence production from livestock, gas regulation based on calculation of net carbon production, carbon price, and economic value of carbon storage, water regulation based on calculation of water retention capacity and industrial water price, waste treatment based on shadow pricing, nutrient circulation from livestock excrements based on market prices of market fertilizers, and recreational values based on travel cost methods. When social welfare weights were assigned to the different services according to the number of people that are directly affected by the service there is a substantial increase of the gas and water regulation services. Overall, the gas and water regulation constitute more than 95% of the total value of the ecosystem services.

In the Philippines, ecosystem-based management has been adopted as a major strategy for sustainable natural resource management and is the basis for major national policies such as the 2011-2016 Philippine Development Plan.[393] The Plan recognizes the challenges of a lack of standards for environmental valuations in its special chapter on environment and natural resources. Moreover, according to the Plan several parameters used in specific environmental cost-benefit analyses are often contested. The Plan therefore provides a strategic framework laying out activities to streamline economic valuations of environmental resources and develop a system of natural resources accounting. This will facilitate the implementation of sustainable financing of ecosystem services for instance through fees and taxes. Moreover, the Plan outlines that payment for environmental services shall be institutionalized at national and local levels to promote natural resource protection.

Coxhead & Demeke (2004)[394] showed that economic policies can be used as instruments for promoting specific land use among poor farmers in remote areas. The study used farm level data from 1994-2002 for farms in villages in upper river valleys in the Philippines. An initial study had shown that there was relatively limited impact of farm product prices on the land use pattern. However, that study only used limited time series and very heterogeneous farms. The economic model used for the study was based on the assumption that farmers seek long-term profit maximization, and that farmers will allocate land according to prices. Allocation of land is primarily between maize and vegetable production. The study showed that tariff reduction in maize will reduce domestic prices by 25% and land cultivated by maize by 6.5%, which in principle could reduce deforestation pressure, loss of soil fertility, and downstream offsite damages. Similarly, expansion of labor-intensive industries will reduce land pressure.

[392] Zhang, X. & X. Lu (2010)“Multiple Criteria Evaluation of Ecosystem Services for the Ruoergai Plateau Marshes in Southwest China” Ecological Economics 69 pp. 1463-1470

[393] National Economic and Development Authority (2011) “Philippine Development Plan 2011-2016” National Economic and Development Authority, Pasig City http://www.neda.gov.ph/PDP

[394] Coxhead, I. & B. Demeke (2004) “Panel Data Evidence On Upland Agricultural Land Use in The Philippines - Can Economic Policy Reforms Reduce Environmental Damages? American Journal of Agricultural Economics 86 (5) pp. 1354-1360

# INTEGRATED VALUATION MODELS FOR LAND USE POLICY ADVICE

## 1. BIO-ECONOMIC MODEL

Holden et al. (2005)[395] apply a bioeconomic model to analyze impacts of different policies on land management and food security in the Ethiopian Highlands. The study area, the Andit Tid watershed, was chosen because of the availability of both socio-economic and biophysical data covering a period of 15 to 20 years, accumulated in the framework of a large soil conservation research program. The area has severely degraded drylands with market imperfections that affect land productivity. The bioeconomic model addressed the combined effects of land degradation, population growth, market imperfections, and increased risk of drought on household production, welfare, and food security. The analyzed policy options included access to credit for fertilizer, off-farm income, food-for-work interventions, and planting of eucalyptus trees. As highlighted by the authors modern bioeconomic models allow dynamic analyses of complex systems characterized inter alia by non-linearity in both internal and external factors. The study showed that credit for fertilizers may increase crop production considerably and that policies promoting off-farm income possibilities reduce incentives to invest in conservation while improving household welfare and food security. The use of the bioeconomic model allowed analysis of the complementarily of different policy initiatives and hence policy recommendations for integrated packages rather than separate policies.

## 2. SOCIO-ECONOMIC-METEOROLOGICAL-AGRICULTURAL MODEL

Fraser et al. (2012)[396] use an integrated model combining socio-economic, agricultural, and meteorological data to identify optimal land use in traditional wheat, rice, and maize cultivating areas around the world. The areas studied were identified as susceptible to intensified droughts as a result of climate change and the integrated model showed the adaptive capacity of the different regions based on the integrated analysis. According to the authors, most research on climate change impact on crop production is only based on bio-physical data, while those that do include socio-economic factors only look at GDP and demographics. However, the authors also note that recent work has shown the importance of land management on the sensitivity of crop production to climate change. E.g., Simelton et al. (2009)[397] identified different drought vulnerability categories based on land management factors in a study on sensitivity and resilience to drought for each of China's main grain crops. The land management factors included land set aside for farming, economic investment, and technical input such as labor and fertiliz-

[395] Holden, S. et al. (2005) "Policy Analysis for Sustainable Land Management and Food Security in Ethiopia A Bioeconomic Model with Market Imperfections" Research Report 140, IFPRI, Washington D.C. ifpri.org/sites/default/files/publications/rr140.pdf

[396] Fraser, E.D.G. et al. (2012) "'Vulnerability Hotspots': Integrating Socioeconomic and Hydrological Models to Identify Where Cereal Production May Decline Due to Climate Change Induced Drought" Working Paper No. 83, Centre for Climate Change Economics and Policy, University of Leeds, Leeds cccep.ac.uk/Publications/Working-papers/Papers/80-89/WP83_cereal-production-climate-change.pdf

[397] Simelton, E. et al. (2009) "Typologies of Crop-Drought Vulnerability: An Empirical Analysis of The Socio-Economic Factors That Influence The Sensitivity And Resilience To Drought Of Three Major Food Crops in China (1961–2001)" Environmental Science & Policy 12(4) pp. 438-452

er. In their global study, Fraser et al. (2012)[398] integrated factors related to type of government according to a democracy index, statistical information regarding rural population, cropland per capita, safe water, income level and distribution, fertilizer use, and agricultural productivity. The challenge with the model was the choice of closely interdependent indicators and the many indicators that were left out making interpretations and identification of cause-relationships complicated.

### 3. Plot-based Models

Radeloff et al. (2012)[399] compare the economic impact of four different policy scenarios: business-as-usual (baseline), subsidized afforestation, tax on deforestation, removal of agricultural subsidies, and increased urban land value. The studied land uses were crops, pasture, forest, and urban areas and land use based on data from US Department of Agriculture that maintains a natural resource inventory as well as satellite images on land use. The study used an econometric land use model based on plots, i.e., smaller pieces of homogeneous land quality. Plot-based models allow coverage of greater areas than parcel based models but normally ignore neighborhood effects; e.g., a forested area surrounded by agriculture is more likely to transit to agriculture than if surrounded by forest. Moreover, there is limited data availability for plot analyses. However, the plot-based model was chosen as econometric land use models[400] normally only covers limited areas and the aim of the study was to cover several ecosystems. Simulations were carried out for year 2051 and showed great land use changes with important urbanizations but also crop to forest and forest to crop changes. While the predicted changes in land use were substantial the differences between the four scenarios were not. This suggests that even relatively important policy interventions may only have limited power to change predicted trends in land-use change. E.g., increasing urban rent substantially or changing returns for other uses did not substantially change the rate of urbanization. The most sensitive land use to policy interventions was forestland showing positive impacts from afforestation subsidies.

## Valuation of Land Use Practices

### 1. Socio-Economic Assessments

While the physical footprint of land degradation and drought impact can be monitored through environmental indicators, the indirect socio-economic impacts are widespread, difficult to monitor, and typically difficult to identify clearly as they will often be strongly influenced by other stressors and systems and might only appear with a severe delay, or hysteresis. According to Davidson Hunt & Berkes

[398] Fraser, E.D.G. et al. (2012) "'Vulnerability Hotspots': Integrating Socioeconomic and Hydrological Models to Identify Where Cereal Production May Decline Due to Climate Change Induced Drought" Working Paper No. 83, Centre for Climate Change Economics and Policy, University of Leeds, Leeds cccep.ac.uk/Publications/Working-papers/Papers/80-89/WP83_cereal-production-climate-change.pdf

[399] Radeloff, V.C. et al. (2012) "Economic-Based Projections of Future Land Use in the Conterminous United States under Alternative Policy Scenarios" Ecological Applications, 22 (3) pp. 1036-1049

[400] Econometric land-use models are based on the relationship between land-use and land productivity defined by biophysical features, returns to land improvement, society's preferences for various goods, and policies that manipulate economic returns. The models can therefore be used to simulate future land-use changes.

(2003)[401], when faced with environmental change, social groups mobilize pre-existing knowledge, which is inscribed and (re)produced in complex networks of biophysical, social and cultural relationships. Social memory therefore includes the remembrance, creativity, and learning of social groups facing environmental change and continuity, as well as the palette of perceptions, memories, knowledge, and technologies available at a given time. To understand the impact of policies and practices these aspects are critical to understand.

As socio-economic assessments of dryland and drought risk management policies and practices are therefore challenging undertakings covering a wide range of sectors such as local economies and infrastructure, practices, traditional and local knowledge, culture and traditions, beliefs and perceptions, political and institutional frameworks, and their consequences for the well-being of people, communities and organizations. Further, following Bunce et al. (2000)[402] one can distinguish between two broad types of socio-economic assessments: 1/ those which are participatory or extractive in nature, and 2/ those being rather product- or process-oriented.

## Economic Valuations Based on the Ecosystem Service Approach

### 1. Soil Ecosystem Services

Asserting that most existing frameworks for valuation of ecosystem services do not consider soil appropriately, Dominati et al. (2010)[403] suggest a framework to classify and quantify soil natural capital and ecosystem services. The framework consists of five interconnected components: 1/soils as natural capital, 2/natural capital formation, maintenance and degradation, 3/ the drivers of soil processes, 4/provisioning, regulating and cultural soil ecosystem services; and 5/human needs satisfied by soil ecosystem services. The framework was applied in a valuation of soil ecosystem services in a dairy farm in New Zealand[404]. Proxies were used for each soil ecosystem service to quantify the service based on one or more soil properties. The so-called SPASMO: soil, plant, atmosphere, system model was used. SPASMO describes soil processes, plant growth, and aspects of farm management. To model a dairy farm and gather all needed data for all ecosystem services extra-functionality was added to the SPASMO, including impact of soil water content on pasture utilization and the pasture growth rate. The study showed that regulating services have a much greater economic value than provisioning services. Of these services, the filtering of nitrogen and flood mitigation services have the highest value. Based on the analysis, the author concludes that farmland is greatly undervalued.

[401] Davidson-Hunt, I. & F. Berkes (2003) "Learning as You Journey: Anishinaabe Perception of Social-Ecological Environments And Adaptive Learning" Conservation Ecology 8(1): 5 consecol.org/vol8/iss1/art5/

[402] Bunce, L. et al. (2000) “Socioeconomic Manual for Coral Reef Management” Australian Institute of Marine Science, Townsville

[403] Dominati, E. et al. (2010) “A Framework for Classifying and Quantifying the Natural Capital and Ecosystem Services of Soils” Ecological Economics 69 pp.1858–1868

[404] Dominati, E. et al. (2011) “The Value of Soil Services for Nutrient Management” Paper presented at the 24th Annual Fertilizer and Lime Research Centre Workshop, Massey University, February 2011 massey.ac.nz/~flrc/workshops/11/paperlist11.htm

# VALUATION OF SCHEMES FOR PAYMENT FOR ECOSYSTEM SERVICES

## 1. SOUTH-EAST ASIA

In South-East Asia, schemes for payment for ecosystem services have been implemented for a couple of decades. China established the Grain to Green Program[405] in 1999 after a severe drought in 1997 in the Yellow River area and massive floods in 1998. Most of the country's soil erosion and desertification is concentrated in the area. The objective of the program was defined in terms of reducing soil and water degradation and the physical target was to convert 15 million ha cropland on steep slopes to forests and grasslands and afforest around 15 million wasteland by 2010[406]. Grain oversupply in the late 1990s and China's increasing financial capacity allowed the Government to implement this large-scale payment for ecosystem services program.[407] It was estimated that 40 to 60 million rural households would be affected by the program.

The program had a secondary objective of poverty alleviation. This led to some conflicts with the environmental objective, as local leaders responsible for managing the program could not implement sanctions when the environmental goals were not met because of pressure to ensure that the poverty goal would be achieved. Opportunity costs were not calculated before the program but according to Uchida et al. (2005),[408] 40 to 84% of the program areas had opportunity costs well below the compensation offered. The study estimated the opportunity costs based on data from a household survey of net revenue of a plot before the program as an indicator for the opportunity cost and the steepness as an indicator for the environmental benefit. The authors conclude that the farmers are being over compensated. On the other hand, Liu et al. (2008)[409] estimate that the total value of the ecosystem services from the converted land is 11 times higher the value before the program. The value after the program includes ecosystem productivity, tourism, biodiversity, water and soil conservation, and pollution reduction. The authors note, though, that the valuation methods are controversial.

Another criticism is about the top-down approach, e.g., many farmers have indicated that they did not feel that their participation was voluntary complicating the assessment of the economic interests in this approach over others more traditional central policies. It can even be questioned if the program can be characterized as a payment for ecosystem services or if it should be classified as a social protection program.

In a 2010 study of the assessments of the most important environmental restoration programs in China over the last decades, particularly the Grain to Green Program and the Natural Forest Protection Pro-

[405] Also referred to as the Sloping Land Conversion Program and the Farm to Forest Program

[406] Bennett, M. & Jintao Xu (2005) Paper presented at the Workshop on "Payments for Environmental Services (PES) – Methods and Design in Developing and Developed Countries." June 15-18, 2005 in Titisee, Germany , organized by Center for Development Research (ZEF), University of Bonn Center for International Forestry Research (CIFOR), Bogor http://www.cifor.org/pes/publications/pdf_files/China_paper.pdf

[407] Liu, J. et al. (2008) "Ecological and Socioeconomic Effects of China's Policies for Ecosystem Services" Proceedings of the National Academy of Sciences 105 (28) pp. 9477-9482

[408] Uchida, E. et al. (2005) "Grain for Green: Cost-effectiveness and Sustainability of China's Conservation Set-aside Program" Land Economics 81(2) pp. 247-264

[409] Liu, J. et al. (2008) "Ecological and Socioeconomic Effects of China's Policies for Ecosystem Services" Proceedings of the National Academy of Sciences 105 (28) pp. 9477-9482

gram[410], Yin et al.[411] assert that while many studies show that the programs have been successful in restoring degraded land, the assessments do not include comprehensive analysis of the cost effectiveness of the programs. For instance, externalities have not been included in the assessments although there have been great debate among researchers and officials about the real costs of the programs. E.g., according to Xu et al. (2006)[412] rapidly rising domestic grain prices in 2003 was identified as a cost by many while others argued that setting aside marginal land would only have marginal impact on the price of grains. Similar discussions followed conversion programs in the United States, where partial equilibrium models[413] showed an impact on food prices of 12-15% while a general equilibrium model[414] showed price impacts of less than 1%[415]. Using the Centre for China's Agricultural Policy's Agricultural Policy Simulation and Projection Model (CAPSiM), Xu et al. (2006)[416] showed that less than 1% of the reduction on total crop production could be assigned to the Green to Grain Program. The CAPSiM covers 12 crops that make up more than 90% of China's crop area and 7 animal products.

Zhang et al. (2010)[417] analyze the development of the values of ecosystem services in the Guangxi province in southwestern China from 1985 to 2005. The area is a karstic landscape[418] and highly susceptible to land degradation with very slow soil formation. Nine different land use/land cover (LULC) systems were identified in the study area including drylands, woodlands, and grasslands, and the total value of ecosystem services[419] were estimated for each LULC area and actual and potential soil erosion were identified. During the study period, a substantial change in LULC could be observed as a result of the reforestation policy and relocation of farmers. Still, the analysis of the total value of ecosystem services decreased with around 3% over the 20 years.

## 2. AFRICA

In Africa, there has been a rapid increase in the number of schemes for payment for ecosystem services but mostly introduced as part of overall development cooperation programs. As a consequence, most empirical studies of the schemes are carried out as project evaluations with limited use of rigorous economic valuation frameworks and hence limited information on a number of economic decision-making information, such as option values and indirect costs for landowners to participate in such schemes. Likewise, one of the key arguments for introducing payment for ecosystem services to landowners in

[410] The Natural Forest Program is implemented through logging bans and economic incentives to forest enterprises.
[411] Yin, R. et al. (2010) "Assessing China's Ecological Restoration Programs: What's Been Done and What Remains to Be Done?" Environmental Management 45(3) pp. 442-453
[412] Xu. Z. et al. (2006) "Grain for Green versus Grain: Conflict between Food Security and Conservation Set-Aside in China" World Development 34 (1) pp. 130–148
[413] Only part of the markets are taken into account, for instance inputs for agricultural production are not included.
[414] Includes secondary impacts.
[415] Xu. Z. et al. (2006) "Grain for Green versus Grain: Conflict between Food Security and Conservation Set-Aside in China" World Development 34 (1) pp. 130–148
[416] Xu. Z. et al. (2006) "Grain for Green versus Grain: Conflict between Food Security and Conservation Set-Aside in China" World Development 34 (1) pp. 130–148
[417] Zhang, M. et al. (2010) "Spatiotemporal Variation of Karst Ecosystem Service Values and Its Correlation with Environmental Factors in Northwest Guangxi, China" Environmental Management 48(5) pp. 933-944
[418] Karst landscapes are formed on rocks, which can be dissolved, by surface water or ground water. Karst landscapes constitute 10% of the land area of the Earth and exist in both dry and humid areas.
[419] Net primary productivity (NPP), gas regulation, water conservation, soil reservation, organic production, nutrient cycling, soil information, biodiversity, recreation, and culture.

development contexts is to allow cash-strapped landowners investing in sustainable land management. However, little is known about the actual impact on land management.

60. One example, of a development project piloting payment for water services in African drylands is from the Uluguru Mountains in Tanzania, which part of the Eastern Arc Mountains[420]. The area includes forests, grasslands and some farmland and includes a number of biodiversity reserves. Deforestation combined with increased agricultural and urban off-take has resulted in a marked decrease in dryland water flow in spite of stable rainfall. A payment for ecosystem services scheme was established between four communities and two larger downstream water users from 2008 to 2012. Payment recipients commit to implement some specific soil conservation measures. The payments were based on Discussions with the communities led to identification of opportunity costs, which were used to determine the amount to be paid to participating farmers. The identified opportunity costs were based on labor costs, areas covered by conservation measures, and loss of income in the short term. While the there was an important increase in the number of participating farmers over the four years of the project, the environmental impact has not been evaluated and link between land-use changes and water quality has not yet been established[421]. Whether or not such projects should be considered as payment for ecosystem services, direct conservation payment, or social safety nets can be discussed. It is noted, for instance, that the water corporations use corporate social responsibility funds for the project.[422] Likewise, the motivation for the farmers to adhere to the program is the financial initiative and increased productivity, which might be more linked to the technical support offered by the project.

## ECONOMIC VALUATION OF DROUGHT RISK MANAGEMENT

Despite the prevalent view of the high sensitivity of climate change in African countries there are relatively few attempts to quantify the economic impacts[423]. It is only recently that non-equilibrium approaches to economic assessments are being developed, allowing for instance to take into account rainfall variability and droughts caused by climate change.

### 1. INSURANCE DATA

Insurance data have been used in various cost-benefit studies of natural disaster risk management to estimate the costs of natural disasters, including droughts. However, most insurance reports focus on impacts on produced capital and economic activity while impacts on the natural environment and socio-economic impacts are not considered in the monetary assessments[424]. Furthermore, the sophisticated models to predict and estimate the costs of disasters that have been developed by the insurance indus-

[420] Dosteus L. et al. (2012) "Towards Operational Payments for Water Ecosystem Services in Tanzania: A Case Study from the Uluguru Mountains" Oryx, 46 , pp. 34-44
[421] Ibid.
[422] Ibid.
[423] Conway, D. & L. Schipper (2011) "Adaptation to Climate Change in Africa: Challenges and Opportunities Indentified in Ethiopia" Global Environmental Change 21 pp. 227-237
[424] Handmer, J. et al. (2012) "Changes in Impacts of Climate Extremes: Human Systems and Ecosystems" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 231-290

try are of little value for low-income countries where insurance cover is almost non-existent[425]. Over the last years various forms of index-based weather insurances have been offered to farmers in many African countries. Index based weather insurance schemes such as drought index insurance is designed so indemnification is triggered when predefined drought indicator thresholds such as rainfall are passed. The payout is thus not related to observed output damage. Rather, all policyholders in the same area will be compensated equally in case droughts. While the drought index insurance can be used as a proxy for the costs of drought it typically only focuses on short term output losses and not on losses, for instance in form of land degradation induced by the drought.

## 2. HYDROLOGICAL MODELS

While there have been limited attempts for economic valuation of drought risk management, the last years have seen several general studies showing the overall costs of droughts based on hydrological models. Pauw et al. (2010) carried out a study of the drought and flood related production losses in Malawi[426]. The study is based "on a stochastic risk model developed by the Risk Management Solution International[427] calculating the probability of future droughts and risks in the light of climate change. The economic assessments of the losses was based on a general equilibrium model where prices are determined by simple supply and demand; i.e. the study considers both impact on loss incomes for farmers and increased expenses for consumers for major crops. According to the analysis droughts result on average in a GDP decrease of 0.97%. The analysis takes into account farmers' adaptation through shifting to more drought resistant varieties when droughts are predicted but do not consider other management adaptation effects such as diversification. Likewise, the study only considers direct losses in terms of reduced production and land taken out of production due to drought and floods while longer term costs in terms of soil degradation is not accounted for. It can thus be argued that the cost calculation is based on both underestimated and overestimated costs. Still, the analysis provided some basic information for future drought risk management policy making.

## 3. CROP-LOSS MODELS

In an evaluation of drought coping[428] mechanisms applied by farmers in Eastern India, Bhandari et al. (2007)[429] use district level temporal data for 1970-2003[430] for monthly rainfall combined with household surveys and statistical data for agricultural production as well as socio-economic data such as poverty and income levels. The crop loss due to drought was estimated using crop loss models and used for the calculation of the total costs of droughts, which included 1/the value of production losses during

[425] Freeman, P. & K. Warner (2001) "Vulnerability of Infrastructure to Climate Variability: How Does This Affect Infrastructure Lending Policies?" Disaster Management Facility of the World Bank and the ProVention Consortium proventionconsortium.org/files/vulnerabilityofinfrastructure.pdf

[426] Pauw, K. et al. (2010) "Droughts and Floods in Malawi Assessing the Economywide Effects" International Food Policy Research Institute", Washington D.C.

[427] rmsi.com/ri/index.asp

[428] The study includes adaptation measures under coping mechanisms.

[429] Bhandari, H. et al. (2007)" Economic Costs of Drought and Rice Farmers' Drought-Coping Mechanisms in Eastern India" in Pandey, S. et al. (Eds.) (2007) "Economic Costs of Drought and Rice Farmers' Coping Mechanisms: A Cross-Country Comparative Analysis" International Rice Research Institute, Manila, books.irri.org/9789712202124_content.pdf pp. 43-112

[430] The Government declared drought in 25 of the 32 years (1970-2002) while the meteorological drought was declared in 18 of the years.

drought years, 2/cost of adapting drought risk management strategies, 3/cost of drought relief, and 4/cost of mitigation programs. As can be seen, the total cost includes both public spending and farmer spending. The authors recognize that indirect and long-term costs are not included and that the calculated cost is underestimated. However, possible offset benefits are not included either. Likewise, government costs for drought management measures such as early warning systems are not included. The identified drought-coping strategies applied by farmers include non-farm work, reduced consumption, and credits. Because droughts occur late in the season, farmers have little farm management flexibility. Moreover, farmers do not have access to drought tolerant varieties. Rather, the farmers adapt conservative management and the potential opportunity costs are calculated as the cost of irrigation. The cost of adapting drought risk management strategies, i.e., cost low risk behavior, is the biggest contributor to the total costs of droughts, while the government costs of relief and mitigation (watershed management) are relatively small. Overall, the cost of droughts in Eastern India is 7% of average value of the production. The study shows, furthermore, the great negative socio-economic impacts from drought, including an increase in the poverty. The study indicates the need for institutional support to drought risk management, including research, extension and information systems, and introduction of drought tolerant crops. Similar studies were carried out in Northeast Thailand[431] and Southern China[432] based on the same methodology. Those studies showed that the total costs of drought only constituted around 1% of total production value due to lower drought probabilities and different drought management policies. In China and Thailand, for instance, governments provide a number of drought adaptation measures including water development while official response in India is mainly relief.

## 4. Cost-Benefit Analysis

A cost-benefit analysis of two alternative drought risk management strategies among small-scale farmers in Uttar Pradesh, India[433] analyzes two forms of benefits: risk reduction through groundwater irrigation and risk transfer through crop insurance. The study is based on modeling using historical rainfall data taking into account climate change predictions. The economic factors that are analyzed include debt, investment, savings, and income relations. Both the irrigation and the insurance options are based on cost-sharing models with government subsidizes. Data limitations prohibited taking into account important factors such as soil conditions, cropping patterns, etc. The findings show that all interventions are economically efficient and that irrigation benefits increase with climate change as a result of increased rainfall while insurance benefits reduce volatility. In conclusion, the analysis shows that integrated packages deliver similar benefits at lower costs. The authors thus offer a clear advice for farm management. However, there might be critical secondary impacts that are not accounted for because of

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[431] Prapertchob, P. et al. (2007) " Economic Costs of Drought and Rice Farmers' Drought-Coping Mechanisms in Northeast Thailand" in Pandey, S. et al. (Eds.) (2007) "Economic Costs of Drought and Rice Farmers' Coping Mechanisms: A Cross-Country Comparative Analysis" International Rice Research Institute, Manila, books.irri.org/9789712202124_content.pdf pp. 113-148

[432] Ding, S. et al. (2007) "Economic Costs of Drought and Rice Farmers' Drought-Coping Mechanisms in Southern China" in Pandey, S. et al. (Eds.) (2007) "Economic Costs of Drought and Rice Farmers' Coping Mechanisms: A Cross-Country Comparative Analysis" International Rice Research Institute, Manila, books.irri.org/9789712202124_content.pdf pp. 149-184

[433] Mechler, R et al. (2008) "Uttar Pradesh Drought Cost-Benefit Analysis" From Risk to Resilience Working Paper No. 5, Institute for Social and Environmental Transition, Kathmandu and Provention, Geneva

data limitations. For instance, the analysis of the irrigation option does not address the overall impact of water extraction.

# ANNEXES

# 1. Definitions Used in the White Paper for Specific Concepts and Terms

Technical terms and concepts are typically defined contextually, e.g., for a specific scientific field. The same term might therefore have different meanings to different sectors. 'Mitigation', for instance, is defined as "the lessening or limitation of the adverse impacts of hazards and related disasters" by United Nations Office for Disaster Risk Reduction (UNISDR) in the 2009 Terminology on Disaster Risk Reduction[434], and as such with a focus on impact reduction. On the other hand, the UN Framework Convention on Climate Change (UNFCCC) defines 'mitigation' as "a human intervention to reduce the sources or enhance the sinks of greenhouse gases", i.e. focus on the drivers or causes while impact reduction is defined through 'adaptation' as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[435].

Even for definitions that in principle have been written into national legislations through ratification of international conventions such as the UNCCD there is still a continuing debate about the meaning of terms such as land degradation and desertification. Part of this is of course linked to the dynamic aspect of the knowledge system. As times go by we might therefore need to adapt our definitions of concepts and terms to make them more useful of the new understanding. As has been explained in the text of this White Paper, this is the case of the concept of resilience where definitions continue to evolve even within the same sector. Important publications can also include several and even contradictory definitions of the same concept as pointed out for instance by Brooks et al. (2005)[436] showing that the Third Assessment Report of the International Panel on Climate Change defines vulnerability both as the coping capacity vis-à-vis climate change and as the sensitivity to climate change.

Because of the multi-stakeholder and multi-sector nature of dryland development, it is critical to agree on common definitions for terms used. For this white paper, we suggest the following definitions while still recognizing that other definitions might be valid for other contexts.

**Table 3:** Definitions Used in the White Paper

| | |
|---|---|
| Activity | Actions taken or work performed through which inputs, such as funds, technical assistance and other types of resources are mobilized to produce specific outputs. |
| Adaptive Capacity | The ability of individuals and groups to adapt to changing conditions through learning, planning, and reorganization (WRI – World Resource Institute). |
| Adaptive Management | Management based on constant monitoring of internal and external changes to the dryland ecosystem and with rolling planning. Adaptive management requires that scientific data are collected through monitoring and studies and that those data are effectively communicated to all stakeholders. |
| Advocacy | Any attempt by one stakeholder group to persuade another to agree to one's vision, demands, and requirements: e.g. dryland practitioners' research and development activities to draw political decision-makers' attention to invest in sustainable dryland development. |

434 unisdr.org/we/inform/terminology#letter-m
435 unfccc.int/essential_background/glossary/items/3666.php#M
436 Brooks, N. et al. (2005)"The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation" Global Environmental Change 15 pp. 151–163

| | |
|---|---|
| Baseline | The reference situation against which changes can be assessed such as changes and impact resulting from new policies or management changes. |
| Capacity Development / Building / Strength-ening | The process by which individuals, groups, organizations, institutions and countries develop, enhance and organize their systems, resources and knowledge, all reflected in their abilities, individually and collectively, to per-form functions, solve problems and achieve objectives. |
| Communication | The process of transmitting information in a way that will be understood. Thus communication goes beyond simple information dissemination. To en-sure that the information will be understood any communication should be based on a good knowledge of the context of the target group, in terms of values, priorities, resources, capacities, etc. Communication becomes even more important, and takes on added dimensions when it involves inter-cultural, inter-disciplinary, or inter-organizational communication, which is the context for sustainable dryland and drought risk management. |
| Complex systems | Systems with a high degree of parts, connections, inhomogeneity, number of scales, number of subsystems, and dynamism and characterized by 1/the parts and structure are constantly changing, 2/feedbacks determine the sys-tem's dynamic behavior, 3/non-linearity where effects are rarely proportional with causes, and 4/systems self-organize in response to external and internal changes. |
| Consultation | A process that finds out what targeted stakeholders think about specific poli-cies, activities, projects, approaches, etc. Focus groups, questionnaires, and interviews are common consultation techniques. |
| Coordination | The process of systematically analyzing a situation, developing relevant in-formation, and informing appropriate command authority of viable alterna-tives for selection of the most effective combination of available resources to meet specific objectives |
| Critical Natural Capital | The natural capital that cannot be substituted by human-made capital. |
| Disaster | A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which ex-ceed the ability of the affected community or society to cope using its own resources. (www.UNISDR.org)<br>Disasters are mainly social constructs as they are a result of how we manage risks. Generally, the more assets people have the less vulnerable they are as they can engage in greater diversity. |
| Drivers | Driving forces of processes in a system. The drivers might be internal or ex-ternal. The use of the concept of drivers does not indicate any causality; i.e. drivers are different from causes |
| Drought | The naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological im-balances that adversely affect land resource production systems (UNCCD). Drought is not a disaster per se but a hazard that can evolve into a disaster if the drought risk is not managed well. |

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| Drought Risk Reduction | Framework of elements to minimize drought impact risks:<br>to avoid (prevention)<br>to limit (mitigation and preparedness) |
| Drought Response Management | Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of drought risk, foster disaster risk reduction and transfer, and promote continuous improvement in drought preparedness, response, and recovery practices, with the explicit purpose of increasing human well-being, quality of life, resilience, and sustainable development (adapted from Field, C.B. et al. (eds.) (2012))[437] |
| Drought Risk Management | Systematic process using administrative decisions, organization, operational skills and capacities to implement Drought Risk Reduction and Drought Response Management effectively and efficiently to reduce risk to an acceptable level and with coping capacities to limit the consequences of hazards. Effective and efficient Drought Risk Management will ensure that risk reduction and direct response activities take place at all levels and simultaneously in a harmonized and coordinated manner where response capacity will be maintained even in periods of non-drought. |
| Drylands | The areas covered by the UNCCD: Arid, semi-arid and dry sub-humid areas, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65; i.e. evapotranspiration from the land is at least 1.5 times higher than the precipitation. |
| Ecosystems | Areas containing a dynamic complex of biotic communities (for example, plants, animals and micro-organisms) and their non-living environment interacting as a functional unit to provide environmental structures, processes, and functions (www.unstats.un.org). Humans are an integral part of ecosystems (Millennium Ecosystem Assessment, 2005). |
| Ecosystem Approach | A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems (Millennium Ecosystem Assessment, 2005). |
| Ecosystem Assessment | A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers. (Millennium Ecosystem Assessment, 2005). |
| Ecosystem Function | Subset of the interactions between ecosystem structure and processes that underpin the capacity of an ecosystem to provide goods and services (The Economics of Ecosystems and Biodiversity, 2010). See Ecosystem Process. |

[437] Field, C.B. et al. (Eds.) (2012) "Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, pp. 3-21.

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|---|---|
| Ecosystem Process | An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy (Millennium Ecosystem Assessment, 2005). Ecosystem functions and processes are used as synonyms. |
| Ecosystem Services | Benefits supplied by the functions of ecosystems and received by humanity (Millennium Ecosystem Assessment, 2005). |
| Effectiveness | The extent to which the intervention's planned outputs and outcomes were achieved. Measuring effectiveness means taking the perspectives of the target groups into account. Use of qualitative indicators is critical, as they are closer to a number of the changes aimed for, including complex conditions such as food security and livelihood improvements. Moreover, qualitative indicators are closer to the vision of the target groups. |
| Efficiency | A measure of how economically resources / inputs (funds, expertise, time, etc.) are converted into outputs and results. Quantitative indicators are appropriate for most efficiency measures. |
| Externality | An unintended positive or negative effect from a specific activity / process; e.g., impacts from ecosystem management decision beyond the specific ecosystem. Externalities are typically borne by people who are not direct stakeholders to the activities / processes that create them and are therefore also referred to as social benefits and costs. |
| Feedbacks | Output from one part of a system will eventually influence input to that same part through different interactions with other parts of the system. Feedbacks can either be negative, i.e. having a damping impact on the initial response to a given stressor, or positive; i.e. having an enhancing impact. |
| Harmonization | The process through which two or more parties apply consistency in their procedures, rules, and regulations for specific activities. |
| Impact | Positive and negative, primary and secondary long-term effects produced by an intervention, directly or indirectly, intended or unintended. These effects can be economic, socio-cultural, institutional, organizational, political, environmental, technical, or of other types. |
| Institutional Learning | Improved knowledge and understanding of what works based on assessments, evaluations, and reflections on activities and results; i.e. the general learning process that leads to identification of good practices. |
| Land | Terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system (UNCCD). |

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| Land Degradation | Reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns (UNCCD). |
| Learning | Process in which changes in knowledge take place inside an individual or community[438]. |
| Livelihood | Combination of the resources used and the activities undertaken in order to live. The resources might consist of individual skills and abilities (human capital), land, savings and equipment (natural, financial and physical capital, respectively) and formal support groups or informal networks that assist in the activities being undertaken. |
| Macroeconomic | Study of economic interactions in society as a whole to understand the empirical regularities in the behavior of aggregate economic variables such as investment, price levels, and interest rates. |
| Objective | Precise and concrete target of an intervention such as a specific activity, a project, a Programme, or a policy. |
| Outcome | The likely benefits of outputs. |
| Output | The goods and services resulting from activities such as ecosystem processes or a production line. |
| Participation | Participation is about including targeted stakeholders in decision-making processes, including identification of needs and solutions and actively involvement in design, implementation, and monitoring and evaluation of instruments such as policies, programs, and projects. Common participatory techniques include facilitated community meetings and workshops often in combination with various empowerment tools, including capacity development. |
| Payment for Ecosystem Services | Voluntary transactions through which landowners or land managers are compensated for the delivery of well-defined ecosystem services or land uses |
| Resilience | A set of capacities of an individual, communities, and systems to survive, adapt, and follow a positive trajectory in the face of external and/or internal changes, even catastrophic incidents and rebound strengthened and more resourceful. The resilience capacity is a continuous and dynamic process including both proactive and reactive abilities vis-à-vis change. The capacities can be fostered through interventions and policies. A resilient system is a system that can predict and foresee and has the capacity for long term planning with inbuilt flexibility. |

[438] Jensen, P.E. (2005) "A Contextual Theory of Learning and the Learning Organization" Knowledge and Process Management 12 (1) pp. 53–64

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|---|---|
| Revealed Preference | Approach used in valuations where the value of environmental goods and services is estimated using economic values in related markets. |
| Risk | The combination of the probability of an event and its negative consequences (www.UNISDR.org). |
| Social-Ecological Systems | Integrated systems of ecosystems and human society with reciprocal feedback and interdependence. |
| Self-organization | When a group of system components follow a simple rule collectively in a pattern that is not centrally planned. A widely cited example is flocking birds where the movements of each bird become synchronized to follow the same trajectory and pattern based on individual actions and interactions. |
| Social-Ecological Systems | Systems where social systems are intimately tied to and dependent on environmental resources and conditions[439] |
| Social values | The value society as a whole ascribes to goods and services. Social values reflect the cultural norms, belief systems, and general institutions of the society. As these are dynamic, social values change over time. |
| Stakeholders | Agencies, organizations, groups, or individuals who have a direct or indirect role and interest in the objectives and implementation of a specific process, program, etc. For environmental goods and services, stakeholders are any agency, organization, group, or individual who can affect or is affected by the environmental goods or services. |
| Stated Preference | Approach used in valuations where people are asked directly how much they would be willing to pay for a change in an environmental good or service. |
| Stress | A continuous or slowly increasing pressure |
| Stressors | The source of stress. |
| Strong Sustainability | Natural capital, including natural resources and ecosystem services can only be substituted by human-made capital until a certain level, which is referred to as the critical natural capital level. |
| Sustainability | Maintenance of stock of capital for future generations whether produced, financial, natural, human, or social capital. |

[439] Lavell, A. et al. (2012) "Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience" in Field, C.B et al. (Eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge pp. 25-64

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| Total Economic Value | In environmental economics Total Economic Value refers to the sum of values of present and future flows of ecosystem services whether categorized as use (e.g. food, recreational values, and spiritual values) and non-use values (e.g. value of saving for future generations or bequest value, and value from knowledge of continued existence of existence values). |
| Transaction Costs | The cost of negotiating, securing, and completing transactions in a market economy. Transaction costs can also be seen as the factors that prevent markets from operating efficiently (Solomon, B.D. (1999)[440] ) |
| Utility | Degree of satisfaction a good or service brings a person. |
| Value | The usefulness of an action/service or an object/good. In economics the term value is to explain the price of goods and services. |
| Valuation | The process of assigning or identifying value of an entity or process, whether measured in monetary or other societal terms. |
| Vulnerability | The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (www.UNISDR.org). Vulnerability can also be seen as the social construct of risk. |
| Weak Sustainability | Natural and human-made capital can be substituted within specific production processes. |

[440] Solomon, B.D. (1999) "New Directions in Emissions Trading: The Potential Contribution of New Institutional Economics" Ecological Economics 30 pp. 371-387

# 2. Examples of Resilience Definitions

Deveson, A. (2003) “Resilience” Allen & Unwin, Crows Nest

> *“Nowadays, ‘resilience’ has become to mean the ability to confront adversity and still find hope and meaning in life. George Vailant, a Harvard psychologist who has written widely on the subject, declares, “We all know perfectly well what resilience means until we try to define it””*

### *Dictionary Definition*

Merriam-Webster.com (2011) merriam-webster.com

> *An ability to recover from or adjust easily to misfortune or change.*

### *Definitions from Social-Ecological Studies*

Holling, C.S. (1973) “Resilience and Stability of Ecological Systems” Annual Review of Ecology and Systematics 4 pp.1-23.

> *The persistence of relationships within a system and is a measure of the ability of these systems to absorb change of state variable, driving variables, and parameters, and still persist.*

Adger, N.W. et al. (2002) ”Migration, Remittances, Livelihood Trajectories, and Social Resilience” Ambio 31(4) pp. 358 – 386

> *[T]he ability of communities to absorb external changes and stresses while maintaining the sustainability of their livelihoods. We recognize that degradation of the natural resource base will undermine social resilience.*

Folke, C. et al. (2002) “Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations” Ambio, 31(5) pp. 437- 440.

> *….resilience for social-ecological systems is often referred to as related to three different characteristics: (a) the magnitude of shock that the system can absorb and remain in within a given state; (b) the degree to which the system is capable of self-organization, and (c) the degree to which the system can build capacity for learning and adaptation.*

Walker, B.H. et al. (2004) “Resilience, Adaptability, and Transformability in Social-Ecological Systems” Ecology and Society 9(2):5

> *[T]he capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks.*

Resilience Alliance, resalliance.org

*Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems (SES). "Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:*

*• The amount of change the system can undergo and still retain the same controls on function and structure*

*• The degree to which the system is capable of self-organization*

*• The ability to build and increase the capacity for learning and adaptation*

Millennium Ecosystem Assessment (2005) "Ecosystems and Human Well-being: Policy Responses, Volume 3" www.millenniumassessment.org

*The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.*

Berkes, F. (2007) "Understanding Uncertainty and Reducing Vulnerability: Lessons from Resilience Thinking" Natural Hazards, 41 pp. 283-295

*The capacity of a system to absorb recurrent disturbances, such as natural disasters, so as to retain essential structures, processes, and feedbacks.*

WRI et al. (2008) "World Resources: Roots of Resilience – Growing the Wealth of the Poor" World Resource Institute, Washington D.C.

*[T]he capacity to adapt and to thrive in the face of challenge.*

Rockstrom, J. et al. (2009) "Planetary Boundaries: Exploring the Safe Operating Space for Humanity" Ecology and Society 14(2):32 ecologyandsociety.org/vol14/iss2/art32/

*[T]he combined capacity of a system to persist (absorb and resist shocks), adapt, and transform in the face of natural and human-induced disturbances.*

Vetter, S. (2009) "Drought, Change and Resilience in South Africa's Arid and Semi-Arid Rangelands" South African Journal of Science 105 (1-2) pp. 29-33

> *[T]he amount of perturbation a social or ecological system can absorb without shifting to a qualitatively different state.*

Miller, F. et al. (2010) "Resilience and Vulnerability: Complementary or Conflicting Concepts?" Ecology and Society 15 (3) ecologyandsociety.org/vol15/iss3/art11/

> *[T]he capacity of a system to absorb disturbance and reorganize while undergoing change, so as to still retain essentially the same function, structure, identify, and feedbacks.*

Adger, W.N. et al. (2011) "Resilience Implications of Policy Responses to Climate Change" WIRE's Climate Change 2(5) pp. 757-766

> *….resilience is characterized by the ability to absorb perturbations without changing overall system function, the ability to adapt within the resources of the system itself, and the ability to learn, innovate, and change….. A resilience framework focuses on understanding processes of change.*

Biggs, R. et al (2012) "Toward Principles for Enhancing the Resilience of Ecosystem Services" Annual Review of Environment and Resources, 37 pp. 421-448

> *[T]he capacity of [a social-ecological] system …to sustain a desired set of [ecosystem services] .. in the face of disturbance and ongoing evolution and change*

Glaser, M. et al. (2012) "New Approaches to the Analysis of Human-Nature Relations" in Glaser, M. et al. (eds.) (2012) "Human-Nature Interactions in the Anthropocene – Potential of Social-Ecological Systems Analysis" Routledge, New York pp. 3-12

> *[T]he capacity of a system to handle whatever the future brings without being altered in undesirable ways. Resilience is necessary for a sustainable future and is rooted in self-enforcing dynamics of natural systems that prevent shifts into undesirable directions.*

### *DEFINITIONS FROM CLIMATE CHANGE LITERATURE*

Pachauri, R.K. & A. Reisinger, A. (eds.) (2007) "Climate Change 2007: Synthesis Report" Cambridge University Press, Cambridge ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

> [T]*he ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.*

Field, C.B. et al. (eds.) (2012) "Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" in Field, C.B et al. (eds.) (2012) "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, pp. 3-21.

> *The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.*

The Climate Change Convention does not define resilience per se and interestingly enough the glossary[441] on climate change acronyms presented at the UNFCCC website does not include 'resilience' either in contrast to related terms such as 'vulnerability' and 'adaptation'.

In spite of the resilience definition in the Fourth Assessment, the report makes limited reference to resilience and states that so far little attention has been given to mainstreaming climate resilience in development efforts and to measuring and valuation adaptation[442]. It is expected that the Fifth Assessment Report, scheduled to be released in 2014 will discuss 'resilience' more prominently.

## *Definitions from Economic Science*

Duval, R. & L. Vogel (2008) "Economic Resilience to Shocks: The Role of Structural Policies" OECD Economic Studies 1 oecd.org/eco/42504164.pdf

> *Economic resilience may be loosely defined as the ability to maintain output close to potential in the aftermath of shocks. Hence, it comprises at least two dimensions: the extent to which shocks are dampened and the speed with which economies revert to normal following a shock.*

## *Definitions from Psychology and Social Science*

Coutu, D.L. (2002) "How resilience works" Harvard Business Review May 80(5) pp. 46-50

> *True resilience requires the three following characteristics of resilient people and / or organizations: capacity to accept and face down reality, value systems that remain constant even during stress; i.e. always finding a meaning, and ability to improvise.*

Deveson, A. (2003) "Resilience" Allen & Unwin, Crows Nest

> *Street definitions of Resilience: "rising above the shit" (overburdened mother) – "transforming adversity into wisdom, insight, and compassion" (Buddhist) – "evolution and survival, the capacity of all life-forms to endure" (biologist).*

[441] unfccc.int/essential_background/glossary/items/3666.php

[442] Parry, M.L, et al. (Eds.) (2007) "Climate Change 2007: Impacts, Adaptation and Vulnerability" Cambridge University Press, Cambridge

Norris, F.H. et al. (2008) "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness" American Journal of Community Psychology, 41 pp. 127-150

> *[A process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance.*

Tousignant, M. & N. Sioui (2009) "Resilience and Aboriginal Communities." Journal of Aboriginal Health, November pp. 43-61

> *[A] long process of interactions between an individual and his or her environment to face adversity, and lead to the emergence of moral strength and a sense of optimism.*

McAlpine, K. (2009) "Enhancing Resilience in Tanzanian Children and Youth that are Separated from their Families" Mkombozi Research Report January 2009, Mkombozi, Moshi
mkombozi.org/publications/research_report/2009_11_01_research_report_resilience_ENG.pdf

> *[T]he ability to recover from stresses and shocks and to maintain or enhance personal capabilities and assets….the resilience framework considers not only deficits but considers strengths.*

## DEFINITIONS FROM DEVELOPMENT LITERATURE

ICRC (2004) "World Disasters Report 2004 – Focus on Community Resilience" International Federation of Red Cross and Red Crescent Societies, Geneva

> [C]*apacity to mitigate, prepare for, respond to and recover from the impacts of disaster – in a way which leaves communities less at risk than before.*

Béné, C. et al. (2012) "Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes" IDS Working Paper 405, Institute of Development Studies, Brighton

> *Good Resilience is the ability of a system to accommodate positively adverse changes and shocks, simultaneously at different scales and with consideration of all the different components and agents of the system, through the complementarities of its absorptive, adaptive and transformative capacities.*

## DEFINITIONS FROM DISASTER RISK MANAGEMENT LITERATURE

Wildavsky, A. (1988) "Searching for Safety" Transaction Publishers, Edison

> *[R]esilience is the capacity to cope with the unanticipated dangers after they have become manifest, learning to bounce back. [While] anticipation attempts to avoid hypothesized hazards; resilience is concerned with those that have been realized.*

Bruneau, M. et al. (2003) "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities" Earthquake Spectra 19(4) pp. 733–752

> *[C]ommunity seismic resilience is defined as the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes.*

Subcommittee on Disaster Reduction (2005) "Grand Challenges for Disaster Reduction" National Science and Technology council, Committee on Environment and Natural Resources, Washington, D.C.

> *[T]he capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.*

Paton, D. & D. Johnston (eds.) (2006) "Disaster Resilience: An integrated Approach" Charles C. Thomas, Springfield

> *Firstly, communities, their members, business and societal institutions must possess the resources (e.g., household emergency plans, business continuity plans) required to ensure, as far as possible, their safety and the continuity of core functions in a context defined by hazard consequences (e.g., ground shaking, volcanic ash fall, flood inundation) that can disrupt societal functions. Secondly, they must possess the competencies (e.g., self-efficacy, community competence, trained staff, disaster management procedures) required to mobilize, organize and use these resources to confront problems encountered and adapt to the reality created by hazard activity. Thirdly, the planning and development strategies used to facilitate resilience must include mechanisms designed to integrate the resources available at each level to ensure the existence of a coherent societal capacity, and one capable of realizing the potential to capitalize on the opportunities for change, growth and the enhancement of quality of life. Finally, strategies adopted must be designed to ensure the sustained availability of these resources and the competencies required to use them over time and against a background of hazard quiescence and changing community membership, needs, goals, and functions.*

Cutter, S.L., et al. (2008) "Community and Regional Resilience: Perspectives from Hazards, Disasters, and Emergency Management" CARRI Research Report 1, Community and Regional Resilience Initiative, Oakland Ridge resilientus.org/library/FINAL_CUTTER_9-25-08_1223482309.pdf

> *Resilience refers to the ability of a human system to respond and recover. It includes those inherent conditions that allow the system to absorb impacts and cope with the event, as well as postevent adaptive processes that facilitate the ability of the system to reorganize, change, and learn in response to the event (Cutter et al. 2008). Resilience is also dynamic, but for measurement purposes, it is viewed as a static property.*

Tulane Disaster Resilience Leadership Academy (2010) “Resilience Framework: Deep W Water Horizon Oil Spill Impact Assessment - Phase I” Tulane University, Tulane

> *[T]he capacity of an affected community or system to maintain services and livelihoods following a critical incident or shock….Resilience thus, reflects the capacity of the affected community to self-organize and to learn from and adapt.*

Almedon, A.M. (2011) “Capturing Complex Realities in One Word” The Fletcher Forum of World Affairs Journal 35 (1), pp. 145-155

> *[T]he capacity of individuals, families, communities, systems, and institutions to anticipate, with-stand and/or judiciously engage with catastrophic events and/or experiences, actively making meaning out of adversity with the goal of maintaining ‘normal’ function without fundamental loss of identity.*

Tulane University’s Disaster Resilience Leader Leadership Academy & Université d’Etat d’Haiti (2012) “Evaluation de l’Aide Humanitaire en Haïti sous l’Angle de la Résilience“ Tulane University, New Orleans

> *[T]he capacity of the affected community to self-organize, learn from and vigorously recover from adverse situations stronger than it was before.*

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