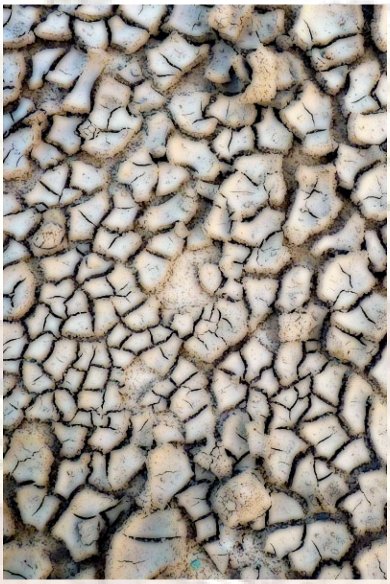
DESIRE REPORT series



A methodological approach and modelling tool to evaluate desertification remediation options

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DESIRE

DESERTIFICATION MITIGATION AND REMEDIATION OF LAND – A GLOBAL APPROACH FOR LOCAL SOLUTIONS

Deliverable 5.4.2

A methodological approach and modelling tool to evaluate desertification remediation options[1]

[1] This report is adapted from the following paper: Reed MS, Buenemann, M, Atlhopheng J, Akhtar-Schuster M, Bachmann F, Bastin G, Bigas H, Chanda R, Dougill AJ, Essahli W, Evely AC, Fleskens L, Geeson N, Glass JH, Hessel R, Holden J, Ioris A, Kruger B, Liniger HP, Mphinyane W, Nainggolan D, Perkins J, Raymond CM, Ritsema CJ, Schwilch G, Sebego R, Seely M, Stringer LC, Thomas R, Twomlow S, Verzandvoort S (2011) Cross-scale monitoring and assessment of land degradation and sustainable land management: a methodological framework for knowledge management. *Land Degradation & Development* 22: 261-271. An earlier version of the report was originally published as part of the Dryland Science for Development Consortium's Working Group 3, presented at the first UNCCD CST Scientific Conference at COP-9, 22-24 September 2009 in Buenos Aires, Argentina

Summary

For land degradation monitoring and assessment to be accurate and for sustainable land management (SLM) to be effective, it is necessary to incorporate multiple knowledges using a variety of methods and scales, and this must include the (potentially conflicting) perspectives of those who use the land. This report presents a hybrid methodological framework that builds primarily upon the DESIRE project. To ensure that the approach is as widely applicable as possible beyond this original context, this report describes how the DESIRE methodological framework has been combined with approaches developed by UN Food & Agriculture Organisation's Land Degradation Assessment in Drylands (LADA), the World Overview of Conservation Approaches and Technologies (WOCAT) programme and the Dryland Development Paradigm (DDP). This was done as part of a process facilitated by the UNCCD's Committee on Science & Technology and has informed discussion on knowledge management within the Convention. The framework suggests that monitoring and assessment should determine the progress of SLM towards meeting sustainability goals, with results continually and iteratively enhancing SLM decisions. The framework is divided into four generic themes: i) establishing land degradation and SLM context and sustainability goals; ii) identifying, evaluating and selecting SLM strategies; iii) selecting land degradation and SLM indicators; and iv) applying SLM options and monitoring land degradation and progress towards sustainability goals. This approach incorporates multiple knowledge sources and types (including land manager perspectives) from local to national and international scales. In doing so, it aims to provide outputs for policy-makers and land managers that have the potential to enhance the sustainability of land management in drylands, from the field scale to the region, and to national and international levels. The paper draws on operational experience from across the DESIRE project to break the four themes into a series of methodological steps, and provides examples of the range of tools and methods that can be used to operationalise each of these steps. It describes in particular how process-based biophysical and economic models were used in combination with stakeholder participation to scale up potential remediation options from local to regional scales and prioritise the most appropriate options for wider dissemination.

1 Introduction

1.1 Why do we need a new framework for land degradation monitoring & sustainable land management?

Managing land degradation effectively is an information-intensive endeavor requiring an in-depth understanding of human-environment interactions. As a result it is practically impossible for a small number of people to possess the depth and breadth of knowledge required for effective monitoring and assessment. For land degradation monitoring and assessment (M&A) to provide accurate information and for sustainable land management (SLM) to be effective, it is therefore necessary to incorporate multiple knowledge sources and types using a variety of methods operating at different temporal and spatial scales. Methods must capture both biophysical and socio-economic aspects of land degradation processes over very different spatial and temporal scales, and consider the (potentially conflicting) perspectives of land managers. This may involve those who benefit from ecosystem services, but who live far away from the land in question. In short, approaches to land degradation M&A that are multi-stakeholder, multi-method and multi-scale are necessary.

There have been many attempts to address this complex methodological challenge, each with its own strengths and limitations. These range from qualitative approaches based on local knowledge at relatively fine spatial scales or "expert" knowledge at coarser spatial scales, to quantitative approaches using field-based and remotely sensed data, analysed and interpreted using models and Geographical Information Systems.

Attempts are also being made to link land degradation M&A to SLM options from local to international scales. A growing number of decision-support systems do this at local scales (e.g. Reed and Dougill, 2010). At the international scale, the Millennium Ecosystem Assessment reviewed SLM options available to dryland communities (MA, 2005) and the World Overview of Conservation Approaches and Technologies (WOCAT) group are documenting and evaluating SLM options, building on and sharing local knowledge between comparable contexts around the world (WOCAT, 2007; Schwilch *et al.*, 2009; Schwilch *et al*., 2011). Despite this, there has been limited dissemination of results to the majority of affected land managers. Evaluation of SLM options has tended to take place at the field scale and has been unable to investigate likely effects of remediation, or the factors influencing uptake of remediation options at a regional scale. The majority of integrated approaches at the global scale still rely predominantly on indicators selected by the scientific community. For example, the United Nations Convention to Combat Desertification (UNCCD) recently developed a global minimum set of scientific indicators to monitor the implementation of its 10 year strategy plan. This approach facilitates comparability across temporal and spatial scales. However, to actually help people on the ground make more sustainable land management decisions, any minimum list must be supplemented with locally relevant indicators that land managers can monitor and act upon themselves.

This report proposes an approach for integrated M&A of land degradation and SLM that incorporates and builds on the strengths of previous approaches, notably the

DESIRE project, the Dryland Development Paradigm (DDP), the UN Food & Agriculture Organisation's UNEP/GEF-funded Land Degradation Assessment in Drylands (LADA) and WOCAT. It then describes in more detail how process-based biophysical and economic models are being used in the DESIRE project to scale up from local to regional remediation strategies, and to prioritise options for national policy-makers.

1.2 Approaches to land degradation and SLM monitoring and assessment

Global land degradation and SLM M&A have, to date, used a range of approaches. Each covers different spatial and temporal scales and has different strengths and limitations. To effectively integrate land degradation monitoring and assessment approaches and manage the knowledge they generate, their strengths and limitations must first be understood. To incorporate context-specific, local knowledge and fine-scale measurements into assessments at broader scales, we then need to understand how local data may be scaled-up and/or integrated with data and information from coarser spatial scales. The following text briefly evaluates some of the most notable approaches:

Coarse-scale Expert Knowledge: Early attempts to assess land degradation at international scales focussed on expert knowledge to achieve global coverage rapidly and cost-effectively (e.g. UNEP, 1987; UNEP, 1997). However, such assessments were subjective and difficult to replicate, and rarely incorporated the expertise of land managers (van Lynden and Kuhlmann, 2002). More recently, WOCAT, LADA and DESIRE jointly developed a mapping tool for a participatory expert assessment (WOCAT/LADA/DESIRE, 2008; LADA 2009a, b). Using this tool, experts including local land managers estimate current area coverage, type and trends of land degradation as well as presence and effectiveness of SLM, based on predefined land use system units. This method is currently applied in 18 countries as part of the LADA and DESIRE projects (see also Schwilch *et al.* 2011).

Fine-scale Local Knowledge: Growing numbers of local-scale assessments are based on the expertise of land managers, analysing and often mapping perceptions of land degradation status and trends, for example using interviews, oral histories and participatory mapping (e.g. Thomas and Twyman, 2004; Reed *et al.*, 2008). There is also a WOCAT methodology for documentation, evaluation and dissemination of SLM technologies and approaches (case study level) combining knowledge of local land managers, experts and scientists and including reports (WOCAT, 2007; WOCAT 2008a,b). LADA has developed field manuals for local level land degradation assessment in drylands (LADA 2009a,b), which include a large number of assessment methods applied in collaboration with local land managers and also entail the WOCAT case study level to capture SLM achievements (see also Schwilch *et al.*, 2011).

Agricultural productivity trends: Although changes in agricultural productivity have been used to assess land degradation (e.g. Dean and MacDonald, 1994; Perrings and Stern, 2000), such data must be used with great care, as different degradation processes have different effects on productivity, and results can be biased by pests, diseases, rainfall and extreme climatic events. A further pitfall may occur if policy-makers use indicators of practice (e.g. reduced tillage) rather than goals (e.g. lower soil erosion rates) in formulating policies, as this may hamper the search for alternative mitigation methods (Van der Werf and Petit, 2002). Instead, technologies and interventions must be matched not only to the crop or livestock enterprise and the biophysical environment, but also with the market and investment environment, including input supply systems and policy context (Twomlow *et al.*, 2008).

Fine-scale field-based and modelling techniques: Most recent work has focussed on empirical measurements of land degradation using indicators[2]. Soil-based studies were long favoured by non-equilibrium ecologists, who argued that given the rapid response of vegetation to stochastic rainfall events, only physical and chemical changes in the soil could reliably detect long-term, effectively irreversible trends from which degradation could be inferred (e.g. Biot, 1993; Dougill *et al.*, 1999). However, evidence from field research and fine-scale modelling studies suggest that equilibrium and non-equilibrium dynamics operate at different speeds in semi-arid environments (e.g. Derry and Boone, 2009). Consequently, vegetation dynamics are increasingly recognised in the assessment of land degradation (e.g. thorny bush encroachment). This reflects the perceptions of local land managers when they are involved in land degradation assessment (Reed *et al.*, 2008).

Geospatial techniques: Remote sensing can facilitate assessment of the status of multiple land degradation and SLM indicators over much larger areas than is possible with field-based techniques. For example, the Pan European Soil Erosion Assessment (PESERA) modelled soil erosion rates across Europe (Kirkby *et al.*, 2008) and the Global Assessment of Land Degradation and Improvement (GLADA; Bai *et al.*, 2008) identified “hot spots” of land degradation and “bright spots” of land improvement worldwide. Nevertheless, such continental- to global-scale assessments have often been criticized, especially for insufficient calibration and validation. The coarse spatial resolution of mapping products (e.g., a pixel may represent an area of 1 km^2, which is larger than the average land management unit) limits their utility for land managers. Consequently, efforts are now underway to model land degradation and SLM from local to national scales. Often integrating remote sensing and geographic information systems, many of these efforts also extend the potential of remote sensing to provide information beyond the biophysical realm to capture socio-economic dimensions of land degradation and SLM. Aspects of human well-being may be assessed by linking biophysical patterns observed in remotely sensed imagery to human processes on the ground (“socializing the pixel”) and vice versa (“pixelizing the social”) (Geoghehan *et al.* 1998). In this way, remote sensing data have been used to derive population estimates, monitor human health and disease, predict socio-demographic conditions, evaluate social vulnerability, and aid identification of human (and environmental) driving forces of land change from local to regional scales (Buenemann *et al.*, 2011).

[2] We define indicators as variables that can characterise environmental, social and economic system structure and function over time

Current approaches to assessing land degradation and SLM increasingly attempt to integrate data and information from many different knowledge sources. For example, after mapping “hotspots” and “brightspots” at a global scale, LADA uses indicators at local and national scales to further assess land degradation and SLM in collaboration with stakeholders. The DESERTLINKS project[3] used a similarly wide range of indicators to assess land degradation in the Mediterranean. The Dryland Development Paradigm advocates the use of multiple methods including local knowledge as a means to monitor variables that change slowly over time, reflecting the nested hierarchical nature of human environmental systems and thresholds to be used where possible to interpret measurements (Reynolds *et al.*, 2007). However, to date the Dryland Development Paradigm has focussed on land degradation M&A without reference to SLM, and further work is needed to develop a methodological framework to fully operationalise this approach. The next chapter therefore develops an integrated methodological framework for cross-scale land degradation and SLM monitoring and assessment to operationalise the Dryland Development Paradigm, and builds on the strengths of each of the methodological approaches that have been discussed previously.

[3] http://www.kcl.ac.uk/projects/desertlinks/

2 The DESIRE integrated methodological framework for global land degradation and SLM monitoring and assessment

2.1 Introduction

Four broad themes are recurrent in the methodological approaches described above. These form the core of the methodological framework for knowledge management proposed in this paper for land degradation and M&A of SLM (the central circle in Figure 1):

i) Establishing land degradation and SLM context and sustainability goals;
ii) Identifying, evaluating and selecting SLM strategies;
iii) Selecting land degradation and SLM indicators; and
iv) Applying SLM options and monitoring land degradation and progress towards sustainability goals.

Although these themes are applicable across a range of contexts, the way in which they are operationalised may need to be adapted to different situations. Drawing predominantly on experience from the DESIRE project, Figure 1 illustrates one way of translating these themes into methodological steps (steps 1-11 in Figure 1, explained below in detail). These may be operationalised using a range of methods and are described fully in the text that follows, in addition to descriptions of alternative methods that could be used in different contexts.

Figure 1 is based on the methodological framework of the DESIRE project, incorporating elements of other frameworks proposed by Reed *et al.* (2006), WOCAT, LADA and the Dryland Development Paradigm (Reynolds *et al.*, 2007). Figure 1 incorporates multiple knowledges (including land manager perspectives) from multiple scales. In doing so, it aims to provide outputs for policy-makers and land managers that have the potential to enhance the sustainability of land management, from the local scale to the regional, and to national and international scales. The framework could be used in a relatively top-down manner, to collect and feed data into a Global Drylands Observing System, as proposed by Verstraete *et al.* (2011). Equally, the framework can be used in a more bottom-up manner, identifying system boundaries and sustainability goals with local stakeholders from the outset, and engaging with stakeholders at local, district, national and international levels throughout the process.

If the purpose of monitoring and assessing land degradation and SLM is to help enhance the sustainability of land management, then M&A must take place in the context of a broader process that aims to first negotiate and achieve sustainability goals. It is critical that this is informed by an exploration and understanding of sustainability perceptions, as they differ between stakeholders (Rasul and Thapa, 2003). This may for example be through participation in the development and implementation of National

Action Plans, or in dedicated processes like the DESIRE project, or the "scoping" phase of Reynold *et al.*'s (2007) integrated assessment model. SLM then becomes a strategy to meet sustainability goals, while M&A becomes a way to monitor progress towards these goals, as well as monitoring land degradation. Evidence from southern Africa suggests that providing tangible benefits to land managers in this way may act as an incentive for the collection and reporting of data (section 3.2; Klintenberg *et al.*, 2008).

The remainder of this section describes how the framework in Figure 1 attempts to achieve integration of data and information from local to national and international scales to generate knowledge of land degradation processes, its severity and extent, as well as possible SLM options. Despite describing this as a step-by-step procedure, this is intended to be a cyclical process designed to engage relevant stakeholders and to provide space for reflection, learning and innovation. Perkins *et al.* (in press) show how this framework is being operationalised through the DESIRE project internationally, using Botswana as a case study.

2.2 Establishing the land degradation and SLM context and sustainability goals

First it is necessary to determine the biophysical, socio-economic and policy context within which M&A is being conducted. This is established through three components:

- <u>Identifying system boundaries, stakeholders and their goals (Figure 1, step 1):</u> Before stakeholders can be identified, it is necessary to establish the boundaries of the system that is to be monitored. Often these are administrative boundaries (e.g. a district), but boundaries may also be based on biophysical criteria, such as landscape homogeneity, water catchments, agro-ecological zones or altitude (e.g. plateau land). To avoid creating or exacerbating conflict, and ensure adequate representation of land manager perspectives, a systematic and pragmatic approach towards the identification and inclusion of stakeholders is an important, but often neglected, first step (Reed *et al.*, 2006). A number of methods exist for identifying, categorising and understanding relationships between stakeholders, which can be grouped under the term, "stakeholder analysis" (Reed *et al.*, 2009). Stakeholder analysis has been used successfully to select stakeholders for inclusion in participatory land degradation M&A. Stakeholders involved in the M&A of any given piece of land may source information from a variety of spatial scales, from local land managers and their representative organisations to district extension services, to national government departments/ministries, UNCCD focal points and members of the international policy community, who operate at coarser spatial scales but continue to have a direct interest and influence over local land management. Once stakeholders have been identified, they can be consulted to develop sustainability goals for the system. Different stakeholders are likely to have different goals which may not always be compatible with each other. Therefore a range of tools have been developed to negotiate and explore these differences. For example, participatory scenario development can be used to identify a range of sustainability goals, grouping compatible goals into different scenarios, and using backcasting techniques to identify which strategies could help to achieve the goals in each scenario (Reed *et al.*, in press). Similarly, Participatory Impact Pathways Analysis (PIPA) can be used to define desired goals and understand the logic and assumptions behind activities that could be used to reach these goals (Douthwaite *et al*., 2008). Alternatively, Multi-Criteria Evaluation can be used to evaluate a range of goals against negotiated (and possibly weighted) criteria (e.g. Mendoza and Prahbu, 2004; Reed *et al.*, 2008). In DESIRE, this was done in WB1;

- <u>Describing the socio-cultural, economic, technological, political and environmental context and identifying key drivers of change (Figure 1, step 2):</u> Once relevant stakeholders have been identified and selected, it is possible to start describing and analysing the system that is to be monitored/assessed. In addition to understanding the socio-cultural, economic and environmental context, it is important to understand constraints that may prevent land managers from adopting more sustainable practices (e.g. financial, institutional capacity and knowledge constraints at local, national and supra-national levels) (Douthwaite *et al*., 2007). Through identifying constraints it is possible to make more informed decisions about the sorts of monitoring systems and SLM options likely to be viable and sustainable in the long term. Methods and tools which may help in identifying constraints at different scales include PIPA (Douthwaite *et al*., 2007), conceptual or mediated modelling (van den Belt, 2004), participatory scenario development (Reed *et al.*, in press) and literature/policy reviews (e.g. Baartman *et al.*, 2007). In DESIRE, this was done in WB1;

- <u>Determining current land degradation status, future land degradation risk and existing SLM measures using existing indicators (Figure 1, step 3):</u> Next, it is necessary to establish a baseline of land degradation status against which future progress can be monitored. Although this can be done through empirical research (e.g. measuring biological indicators of soil biodiversity), field-based methods are expensive and time-consuming over large areas. In the DESIRE project (WB2), preliminary assessments are being undertaken using core sets of existing land degradation indicators developed through previous research (Kosmas *et al.*, 2003). Using methods developed in the DESERTLINKS project, indicators relevant to each desertification process are selected from a core list of scientific indicators to assess desertification risk[4]. This is done for different land uses separately. By identifying areas at greatest risk of future land degradation and areas where successful SLM measures have already been put in place, it is possible to prioritise areas for action in the next step of the framework. Apart from land degradation risk, it is also important to know the current status of land degradation, as the areas at highest risk of degradation and those currently with highest current degradation might be different. Those areas that are highly degraded might not be susceptible to further degradation, while non-degraded areas might be highly vulnerable. This approach can help prioritise the locations

[4] Calculated using multi-factor statistical analysis on sets of indicators, for each land use type, according to the methodology to classify environmentally sensitive areas developed in the MEDALUS and DESERTLINKS projects.

and types of SLM that might be most appropriate in step 4. Current status, as well as the current SLM measures can then be mapped using the WOCAT/LADA/DESIRE approach. This methodology creates maps identifying land degradation hot spots and bright spots of good land management practices, enabling decision-makers to be informed about likely degradation impacts and where to invest.

The core set of scientific indicators used during step 3 to establish a baseline for land degradation risk and status can be supplemented in step 8 with indicators used by local communities (collected in the DESIRE project in WB3), ensuring that land managers are able to use the indicators themselves and feed their monitoring results into SLM decisions. At national and international scales, a group of indicators such as those proposed in the UNCCD's global minimum set of indicators[5] or by the GEF-funded project on 'Ensuring impacts from SLM' (Schuster *et al*., in press) can ensure comparability across spatial and temporal scales. At local scales however, stakeholders need to be able to choose the most relevant scientific indicators from a larger core set, and supplement these with indicators that are currently used by land managers in the local area (Figure 1, step 8). In this way, it is possible to achieve comparability as well as relevance and accessibility to land managers.

2.3 Identifying, evaluating and selecting SLM strategies

Once the SLM context has been established, it is possible to start identifying, evaluating and selecting SLM options for implementation. Three steps are involved:

- Identifying, assessing and prioritising possible SLM options (Figure 1, steps 4 and 5): The methodology used in the DESIRE project combines a collective learning and decision approach using evaluated global best practices (Schwilch *et al.*, 2009). It takes place in three parts: i) identifying land degradation problems and locally applied solutions in a stakeholder workshop based on the Learning for Sustainability approach (Gabathuler *et al.*, 2009); ii) assessing local solutions with a standardised evaluation tool (WOCAT 2008a,b); and iii) jointly selecting promising strategies for trial implementation with the help of a decision-support tool (for more information, see: Schwilch *et al.*, 2009 and Schwilch *et al.*, 2011). In DESIRE, this was done in WB3;

- Trial SLM options at field scale (Figure 1, step 6): Field trials may be conducted to test the effectiveness of selected SLM options. These trials may be monitored using a range of biophysical (many of which may have been already used in step 3 above) and economic indicators (principally via Cost-Benefit Analysis), in collaboration with local land managers. Given climatic variability in drylands, data may need to be collected over many seasons to detect trends. However, where good evidence exists for the benefits of SLM options in comparable contexts, more limited field trials focussed on adapting technologies to local

[5] http://www.unccd.int/cop/officialdocs/cop9/pdf/cst4eng.pdf

contexts may be tenable. By documenting SLM options and the contexts in which they are applied in detail, the WOCAT database may help support this sort of adaptation. In DESIRE, this was done in WB4;

- Up-scale/aggregate biophysical and socio-economic effects of SLM from field to regional and national scales to further prioritise SLM options (Figure 1, step 7): To evaluate the likely effects of SLM strategies at a regional scale and make policy and extension recommendations, it is necessary to scale up results from field trials (step 5) and use secondary data to evaluate the regional implications of SLM strategies. This may be done through the aggregation of comparable local data to district and national scales or via biophysical and socio-economic modelling. In DESIRE, this was done via WB5. This is described fully in the next chapter.

2.4 Selecting land degradation and SLM indicators

Once SLM strategies and policies have been implemented, it is necessary to monitor the extent to which they achieve the sustainability goals for which they were developed and the extent to which they help tackle land degradation. This monitoring may be done using existing indicators (step 3), but some of these indicators are likely to be more relevant than others. It may be necessary to develop new indicators to enable land managers to monitor the effects of SLM strategies on land degradation at relevant scales:

- Finalise selection of indicators (in collaboration with likely users) to represent relevant system components for ongoing monitoring by land managers (Figure 1, step 8): Changes in degradation status can be measured in relation to the baseline established in step 3. Many of these indicators may match scientific indicators. However, additional, locally-relevant indicators may need to be identified in consultation with local stakeholders, to ensure monitoring adequately reflects the unique characteristics of the local system and the SLM strategies that have been selected for implementation (Reed *et al.*, 2006). In the DESIRE project, some of these local indicators are already discussed during steps 4 and 5 (WB3). Indicators based on both local and scientific knowledge may then be evaluated together and prioritized using techniques such as multi-criteria evaluation, for example, to make certain that the indicators are both accurate and easy for land managers to apply. To ensure that the proposed indicators are sufficiently comprehensive to represent all key system components, a number of indicator classification frameworks exist. The most widely used of these is the Driving Force-Pressure-State-Impact-Response (DPSIR) framework (OECD, 2001), but many alternatives exist. It may be sufficient to simply check that there are indicators to represent changes in environmental, social and economic components of the system. The accuracy, sensitivity and reliability of local indicators that are new to science may then be evaluated further through empirical research (Reed *et al.*, 2006; 2008). However, it is important not to use this as a validation exercise, but rather to evaluate local knowledge and to provide opportunities for local stakeholders to evaluate the results of empirical research. This approach leads to an iterative process through which local and scientific knowledges are combined to select the indicators perceived to be most appropriate for the local context.

2.5 Applying remediation options and monitoring land degradation and progress towards sustainability goals

The final three steps to complete the framework comprise dissemination, application, and review of strategies:

- Disseminate strategies and indicators for extension and national and international policy (Figure 1, step 9): It is necessary to consider how land degradation and SLM can be discussed, further refined and disseminated for use among local land managers, extension workers at district scales, and to the national and international policy community. Dissemination may include providing information that could lead to the revision of National Action Plans under the UNCCD so that they can reflect ideas that emerge from the process. Targeting such a wide audience is a major challenge, as information needs to be provided at different levels of complexity in different formats, including, for example: scientific papers, policy briefs, leaflets for land managers, and pictorial posters or videos for school children. This information may be made available via an online knowledge platform to act as a knowledge repository and facilitate knowledge exchange based on data and information emerging from knowledge management systems at national and international levels. However, care must be taken to ensure information is available to those without internet access. In DESIRE, this was done via WB6.

- Apply SLM strategies, monitor degradation and progress towards SLM goals, up-scaling or aggregating to district and national levels (Figure 1, step 10): In this context, SLM strategies and policies are applied, and land degradation is monitored at local levels, up-scaling or aggregating (step 7) to district and national levels using the indicators developed in step 8. Although land managers may already be monitoring SLM informally, this step emphasises the need to record these measurements so that they can be up-scaled or aggregated.

- Adjust strategies to ensure goals are met (Figure 1, step 11): As goals are met and contexts change, it may be necessary to develop or prioritise new SLM strategies and indicators with the stakeholders identified in step 1. Consequently, this framework is iterative, represented by the dashed arrow between steps 11 and 4.

In DESIRE, the previous two steps described in this section occur after the end of the research project.

3 Up-scaling local solutions & prioritising regional remediation strategies

3.1 Introduction

When local stakeholders have selected promising soil and water conservation technologies for their area, and these technologies have been tested in field experiments, it may still be difficult to formulate recommendations for their use. For example:

- The experimental conditions for which selected technologies were tested are limited and do not reflect the variable conditions within a region. Rains may have been plentiful so that water conservation did not boost yields, or a terracing experiment was set up on a slight slope so that it remains uncertain how terraces would perform on steeper slopes;
- The time it takes for technologies to develop full effectiveness and benefits is longer than technologies can be tested during a five year research project. Build up of soil organic matter after changing tillage methods or crop rotations is a slow process, and long-term yield increases will not have been observed; and/or
- Policymakers and extension services would like to know whether a technology performs across a range of conditions before committing to stimulating adoption. Apart from differences in environmental conditions and the time it takes to develop full benefits, the investment costs and access to markets are important factors influencing the viability of a technology.

Modelling offers a complementary approach to evaluate the likely biophysical effects of adopting different remediation strategies at a regional scale and their financial viability.

Several previous attempts have been made to aggregate local data to regional and national levels. For example, the Australian Collaborative Rangeland Information System (ACRIS) is a partnership between federal and state governments that uses meta-analysis of monitoring data collected at regional scales to develop a more complete understanding of environmental change at the national scale. Analysis and interpretation of results may be complicated by regions collecting data on different drivers, impacts and responses (or data in different formats), but provides a “reasonable first-pass” and a basis for more effective future collaboration (Bastin *et al.*, 2009). A more bottom-up approach to aggregating data from local to regional scales has been developed in Namibia. Communal farmers record indicator measurements themselves in a field guide (Klintenberg *et al.*, 2008). These data can inform land management decisions over time, as well as feeding into farmer-led community Forums for Integrated Resource Management (FIRMs) (Kruger *et al.*, 2008). These FIRMs collect data from different farming communities and provide a forum for farmers to discuss results and facilitate joint decision-making at this scale (Kruger *et al.*, 2008). By comparing results from a national land degradation monitoring system (Klintenberg and Seely, 2004) with local perceptions of environmental change, Klintenberg *et al.* (2008) showed that local perceptions, as recorded by FIRMs, corresponded with environmental changes identified by national monitoring. Information given by local farmers revealed a more complex picture of causes and effects of environmental changes compared to the variables that were used for national level monitoring.

The DESIRE project uses a biophysical model that builds on and extends the PESERA model (Kirkby *et al.*, 2008). This model was adapted to each study area to closely reflect indicators and land degradation drivers identified in steps 2 and 3 (Figure 1). Model outputs were then used to look at the likely regional biophysical effects of different SLM options that had previously been trialed in study areas at a local (usually field) scale, to help formulate extension and policy recommendations. In this context, modelling may also provide a more cost-effective and less time-consuming alternative to field trials (step 5; Figure 1). Models can be used to establish a link between the application of SLM strategies and their effects on water and nutrient cycles and, ultimately field productivity, and potentially also other ecosystem services (Baartman *et al.*, 2007). The links that the model identifies can in turn be priced. In the DESIRE project, cost-benefit analysis was applied with cost information stemming from combined expert and land manager knowledge, and benefits were calculated based on biophysical effects as determined by the PESERA model. This combined approach makes it possible to determine the field conditions in which different remediation strategies are likely to be most cost-effective and adoptable. Model outputs were presented during a workshop in each study site, where results from models and field trials were presented and discussed together, to prioritise SLM options using Multi-Criteria Evaluation. This sort of approach is important because farmers/land managers do not necessarily make adoption decisions based on soil conservation, agronomic or economic considerations alone (Ncube *et al.*, 2007).

3.2 Modelling the biophysical impact of soil and water conservation technologies

The biophysical impact of technologies was simulated in DESIRE with an extended version of the PESERA model (Kirkby et al, 2008), originally developed for Pan-European Soil Erosion Assessment within a dedicated EU (FP5) project. As PESERA originally addressed water erosion only, it was extended to capture the processes of grazing, fire and wind erosion as well. The model was also adapted to represent particular management strategies such as mulching, irrigation, terracing, and crop rotations. The model is being adapted to each study area to reflect indicators and land degradation drivers identified as closely as possible. The model can be applied at 100 m to 1 km resolution scales, with sub-grid routines being used to simulate some of the fine-scale effects. The model is described in detail in Deliverable 5.1.1 (section 2).

The model has been extended to capture the role of specific biophysical processes that are found in the DESIRE study sites. These include grazing, fire and wind erosion. The model has also been extended for a number of particular mitigation and remediation measures that have been proposed by the study sites, including:

- Mulching and/or maintaining ground cover vegetation within tree crops;
- Retention of crop residues as litter layer at harvesting of arable and other crops;
- Irrigation and water harvesting for croplands;
- Invasion and clearance of unpalatable species;

- Terracing and strip cropping; and
- Nitrogen budgeting and rotations.

Finally, the expertise of other DESIRE partners has allowed extension in areas of mass movements and data collection calibration against reservoir data. These model extensions are described in detail in Deliverable 5.1.2 "Improved Process Descriptions in the PESERA Model".

3.3 Modeling the financial viability of soil and water conservation technologies

The Desertification Mitigation Cost Effectiveness (DESMICE) model has been developed within the DESIRE project to scale up the financial assessment of mitigation strategies from field to regional scale using a spatially-explicit cost-benefit analysis. Taking the assessments of mitigation strategies selected in stakeholder workshops in each study site as a starting point, DESMICE establishes how investment costs of those strategies change based on environmental conditions and distance to markets or source areas. An example of the importance to consider environmental conditions is the case of terracing: investment cost increases with slope gradient, as terraces need to be more closely spaced on steeper slopes. Distance to markets matters as changing crops or higher yields may mean more produce needs to be transported, implying additional costs. Moreover, some of the technologies themselves require specific inputs. Where e.g. stones are not locally available on the field to construct stone bunds, it may be infeasible to source them from elsewhere. The benefits of soil and water conservation technologies need to be assessed in a similar fashion. DESMICE interacts with PESERA to put a value on the biomass output from the latter. We always need to consider investment options against a without case. DESMICE output can be tailored to stakeholder needs: from a land manager's perspective, it presents a spatial configuration of where which promising technology is likely to perform well; from a policymakers' perspective, analyses can be made to see how policies affect the viability of different technologies across a region or where environmental targets can be satisfied at what cost (using cost-effectiveness analysis).

Using a case study in one site (Guadalentin, Spain), we have also investigated the regional economic effects of adopting different remediation strategies (using input-output modelling), and determining what factors influence the decisions of land managers to adopt different remediation strategies and change land use under different future scenarios (using Agent-Based Modelling). By investigating the effects of different policy scenarios on these decisions, it will be possible to evaluate how different policy options may affect adoption of different remediation strategies and land uses across landscapes, and evaluate the biophysical consequences of such changes.

This modeling approach contains a number of important novelties. For example:

- The approach overcomes a number of challenges to incorporate inputs from multiple stakeholders in very different contexts into the modeling process, in order to enhance both the realism and relevance of outputs for policy and practice;
- A number of modeling approaches have been applied to the mitigation of land degradation for the first time to provide novel insights. For example, site-selection

modeling is being applied to land degradation mitigation to enable landscape-scale assessments of the most economically optimal way to attain of environmental targets;

- There have been few attempts to use Cost-Benefit Analysis to investigate the spatial variability of the profitability of SWC measures, which may have important implications for the adoption of measures across landscapes and their consequent environmental effects;
- For the first time, regional (input-output) economic models have also been used to consider the effects of land degradation mitigation on the regional economy;
- By linking (Agent-Based) models of human behaviour to models that describe the wider regional economic and biophysical implications of people's actions, it may be possible to better understand how people are likely to respond to environmental change, and how their responses in turn are likely to influence their environment. Such models may offer us the opportunity to explore how land managers might react to different future policy options and provide ways to make refinements to policy design that can more effectively achieve environmental sustainability goals.

PESERA-DESMICE model outputs for all study sites are described in Deliverable 5.4.1.

3.4 Evaluating model outputs with stakeholders to prioritise remediation options

Model outputs and field trial results were fed back to stakeholders in each site through workshops with agricultural extensionists and other stakeholders (and in some cases members of the policy community), to evaluate and short-list strategies for further dissemination. Building on the relationships developed through work with stakeholders in previous WBs, these focus groups were facilitated by in-country staff employed on the project to ensure sensitivity to local context, and avoid language and cultural barriers to effective communication. The workshops will combine presentations of results with participatory methods to engage participants in evaluating trial results and model outputs, and formulating recommendations for policy and practice. As such, they represent an opportunity to both disseminate findings and collect new information on model output evaluation and policy recommendations. The workshops focused on:

- Sharing and evaluating results from WB4 trials of remediation options that were prioritised during the previous WB3 workshop;
- Sharing and evaluating results from WB5 models which show how the remediation options can be applied throughout the local area, taking into account the physical limitations and socio-economic assessment criteria; and
- Selecting and/or prioritising (using Multi-Criteria Evaluation) remediation options for wider dissemination/application and making lists of recommendations relevant to stakeholders at local, up to national scales, that can facilitate their widespread adoption.

Workshop outcomes are described in detail in Deliverable 5.4.1. Workshop reports have been disseminated to all participants. In addition to local workshops in study sites, to ensure that members of the policy community were engaged in each study site, policy briefs were developed in collaboration with NGOs for each site, and meetings scheduled to discuss key findings with relevant policy-makers.

4 Conclusions

The proposed framework attempts to overcome the trade-off between the relevance of monitoring locally significant processes, and the comparability of monitoring results across wider spatial scales. Each study site selects indicators from the same minimum set of indicators to ensure comparability (step 3; Figure 1). These core indicators are then supplemented with indicators elicited from local stakeholders to ensure relevance and to facilitate links to SLM, whilst supporting comparisons between sites on the basis of shared indicators from the minimum set of indicators (step 8; Figure 1). We recognise that there have been increasing calls for the standardization of local indicators and monitoring procedures in order to facilitate comparison and communication at coarser spatial scales (e.g. Adeel *et al.*, 2006). However, alongside standardization of indicators we must also retain context-specific local knowledge to enable us to interpret whether environmental change represents land degradation, is benign, or even positive and to retain the flexibility required to ensure local relevance and to reflect environmental change. Such an approach makes it possible to capture the complexities of land degradation, provide outputs that are relevant to land managers, and can enhance the sustainability of their land management through improved knowledge management. Thus, there is no need to choose between a top-down approach to M&A based around a minimum set of core indicators and a more bottom-up approach that is sensitive to local contexts. Instead, the DESIRE framework enables a combination of top-down and bottom-up M&A approaches that are more likely to achieve reliable and locally-relevant assessments of land degradation and SLM across multiple scales, and lead to the adoption of appropriate remediation strategies.

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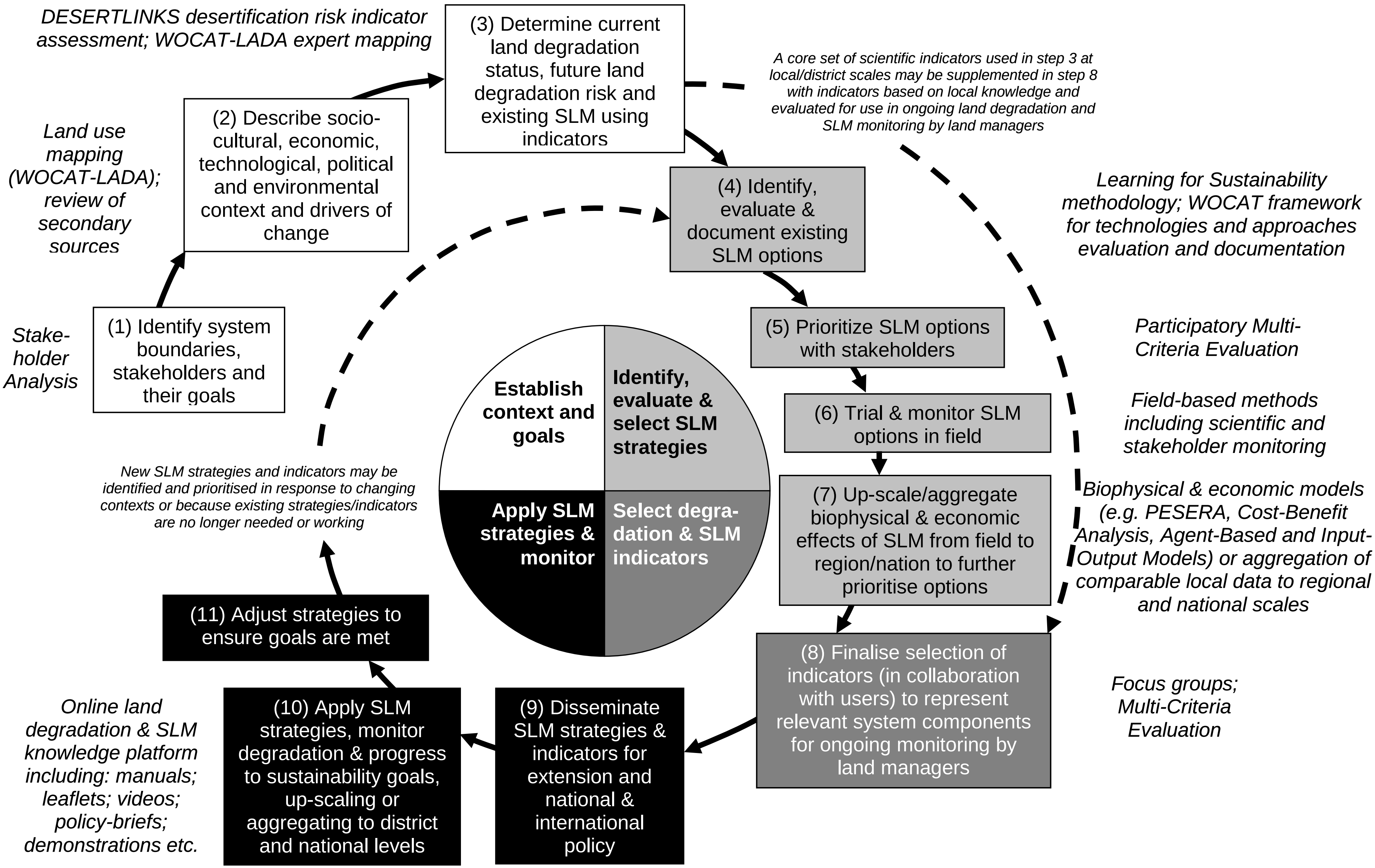

Figure 1: Integrated methodological framework for land degradation and SLM monitoring and assessment, showing how DESIRE builds on the WOCAT, LADA and DDP approaches, providing examples in italics around the outside of the figure that show how each step may be operationalised (drawing on experience from the DESIRE project). Dashed arrows represent potential links that may not always be realised (adapted from Reed *et al.*, 2006 and Reed *et al.*, 2011)