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From Framework to Action: The DESIRE Approach to Combat Desertification

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Abstract It has become increasingly clear that desertification can only be tackled through a multi-disciplinary approach that not only involves scientists but also stakeholders. In the DESIRE project such an approach was taken. As a first step, a conceptual framework was developed in which the factors and processes that may lead to land degradation and desertification were described. Many of these factors do not work independently, but can reinforce or weaken one another, and to illustrate these relationships sustainable management and policy feedback loops were included. This conceptual framework can be applied globally, but can also be made site-specific to take into account that each study site has a unique combination of bio-physical, socio-economic and political conditions. Once the conceptual framework was defined, a methodological framework was developed in which the methodological steps taken in the DESIRE approach were listed and their logic and sequence were explained. The last step was to develop a concrete working plan to put the project into action, involving stakeholders throughout the process. This series of steps, in full or in part, offers explicit guidance for other organizations or projects that aim to reduce land degradation and desertification.

Keywords Sustainable land management · Land degradation · Desertification mitigation · Participatory approach · Conceptual framework · Methodological framework

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Introduction

Land degradation is a complex global environmental problem that can threaten future global food and energy security (World Bank 2008), water availability (MA 2005), capacities to adapt to and mitigate climate change (Neely et al. 2009) and biodiversity conservation (UNCBD 1992), affecting millions of livelihoods adversely (Pretty and Ward 2001). Desertification (land degradation in drylands) is perceived to be one of the major problems that mankind faces at present. The UNCCD (United Nations Convention to Combat Desertification), for example, states that 250 million people are directly affected, and that drylands vulnerable to desertification cover 45 % of the Earth's land surface (Lean 2009). Furthermore, 1 billion people in more than 100 countries are reported to be at risk (UNCCD 2008).

Despite this, the threat of desertification is not universally recognized, and approaches to combating desertification have not always been successful. There are several interrelated reasons for this.

The first is that the fundamental concept of desertification is not above debate. According to Thomas (1997), for example, more than 100 definitions of desertification exist. There have also been discussions about the degree to which humans cause desertification (e.g. UNEP 1991; Johnson and Lewis 1995; Biot 1993; Reynolds and Stafford Smith 2002; Geist and Lambin 2004) and about whether desertification is extension of deserts or degradation in drylands. Today the general consensus is that the causes of desertification are both natural (climate) and man-made (land use, socio-economic), and the UNCCD definition (UNCCD 2008; Lean 2009) that is used in this paper represents the most authoritative definition on desertification (Vogt et al. 2011): 'land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic fluctuations and human activities'. Desertification implies a process that progressively worsens, and that will ultimately result in a, perhaps irreversible, loss of the functions that ecosystems provide.

The second is that desertification is a very broad term that encompasses all kinds of physical, chemical and biological degradation processes in drylands, such as erosion by water and wind, overgrazing, salinization, forest fires. Desertification is a problem that is usually caused by an interplay of different causes, including socio-economic and political ones as these affect how the land is used. These different causes can be local or remote (Bisaro et al. 2013), and they interact across organizational levels (Geist and Lambin 2004) and spatial and temporal scales. Desertification is thus a complex problem, that is furthermore highly site-specific in the ways in which it manifests itself. This means that the desertification problem is also difficult to solve, and that any solutions need to be site-specific too.

Finally, there is also uncertainty about the extent to which the world's drylands are affected by desertification. In his review of many studies on land degradation in drylands, Dregne (2002) pointed out that a lack of good information on extent and severity of land degradation in drylands still hampers attempts to determine its significance. Besides, a lack of precise estimates of the extent of desertification opens the door to misuse of the concept (Verón et al. 2006). For example, maps of desertification risk have been used as if they were maps of actual desertification (Thomas 1997). Vogt et al. (2011) and D'Odorico et al. (2012) demonstrated that estimates of areas affected by desertification continue to vary widely as a result of different definitions and different methodologies used for estimation.

Within the Desertification mitigation and remediation of land (DESIRE) project a methodology to combat desertification was developed that can be applied globally, but that also takes into account the unique context of each study site. Thus, DESIRE provided a global approach to find local solutions to desertification in collaboration with stakeholders. This paper first introduces the DESIRE project, then reviews frameworks that have so far been used to combat desertification and finally presents a conceptual framework that describes the problem of desertification, and a methodological framework that presents the approach that was taken to tackle desertification in the DESIRE project. Together, these two frameworks were applied in a range of international contexts, and the results of some of this work are presented in the rest of this special feature. The main focus of this paper is on the development of the conceptual and methodological frameworks that underpinned this research, and on the lessons that have emerged from testing and refining these frameworks in these very different contexts.

DESIRE

The DESIRE project started in 2007 with the main aim to select sustainable land use and management strategies based on a close participation of researchers with various stakeholder groups such as land users, technicians, policy makers and NGOs. The integrative participatory approach ensured both the acceptability and feasibility of conservation techniques, and a sound scientific basis for their effectiveness at various scales. The project used an interdisciplinary and to a certain extent also a transdisciplinary approach, involving stakeholders throughout the project.

It is increasingly recognized that local populations possess knowledge about their environment that can be very valuable for planning new strategies to curb land degradation (Reed et al. 2013a). The idea that local populations are ignorant, and that they cause degradation, e.g. by overgrazing (Hardin 1968), is rightly losing ground. Local

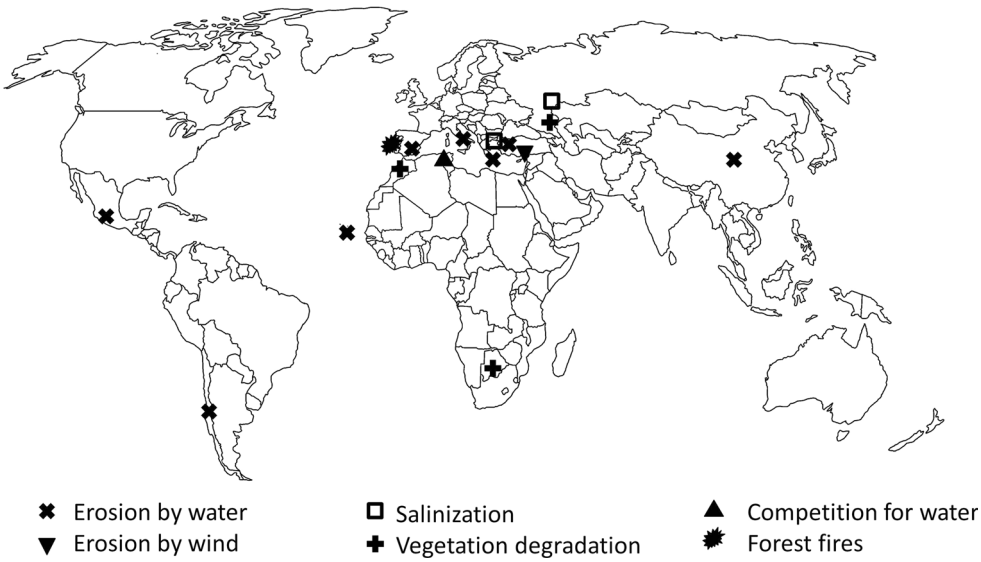

Fig. 1 Location of DESIRE study sites, and most significant desertification process in these sites

populations generally have a high level of understanding of the local conditions, and the way to deal with those (e.g. Bollig and Schulte 1999; McNeely 2003). They have often lived in the area for generations, and are therefore more knowledgeable about local circumstances and local land management strategies than external researchers can ever be. Living in the drylands requires adaptation to the conditions in these areas, and it is now recognized that indigenous people have developed strategies to cope with the inherent uncertainties of climate and vegetation that make economic and ecological sense (Mazzucato and Niemeijer 2001; Tiffen and Mortimore 2002; Herrmann and Hutchinson 2005; Stringer et al. 2009). Nevertheless, local populations might not always possess the necessary knowledge, e.g. if they have migrated into the region relatively recently, or if changes have occurred that make their previous knowledge less applicable, such as changes in climate. The nature of knowledge held by local land users and researchers also differs markedly. Local knowledge is typically context specific, socially constructed and embedded in local culture and traditions, and is often tacit or implicit in nature. In contrast, scientific knowledge about desertification tends to seek more universal theories and mechanisms, is explicit and formal (Raymond et al. 2010). Both local and scientific knowledge can be expert and can be contested. As such, a collaboration between local stakeholders and scientists is needed in which both can learn from each other; in DESIRE this was achieved by involving stakeholders from the start.

DESIRE worked in 17 diverse study sites located in 13 countries around the world, with a particular focus on the Mediterranean area (Fig. 1). These sites all had their own bio-physical and socio-economic characteristics and various desertification processes.

Frameworks to Combat Desertification

In this research, a distinction was made between conceptual and methodological frameworks. A conceptual framework describes the problem of desertification in terms of processes that are involved and of relationships between these processes; thus it describes how the problem of desertification is perceived. A methodological framework presents the approach that was taken to gain new insights and tackle desertification. These two frameworks are closely related as the conceptual framework determines which approach is taken, and in practice the distinction between the two is not always made. Therefore, this section will review some of the main frameworks that have been developed to combat desertification, as well as some recent projects about desertification (for a more complete overview of desertification projects see e.g. Baartman et al. 2007[1]). As discussed by Reed et al. (2013b), attempts are being made to link land degradation (LD) monitoring and assessment to Sustainable Land Management (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 (MA) 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). The DESIRE methodological

[1] Information can also be found at: http://www.desire-his.eu/en/recent-european-research

framework incorporates and builds on the strengths of previous approaches (Table 1), notably the DDP (Reynolds et al. 2007), the UN Food & Agriculture Organisation's UNEP/GEF-funded LD Assessment in Drylands (LADA 2009a, b) and WOCAT (Schwilch et al. 2011). Current approaches to assessing LD and SLM increasingly attempt to integrate data and information from many different knowledge sources, including local knowledge. For each project/framework it is also indicated in Table 1 to what extent it has been used in DESIRE.

Table 1 shows that DESIRE builds extensively on earlier work, especially on WOCAT, LADA, PESERA, DESERTLINKS. The link with some other frameworks is smaller, mostly because these frameworks were developed in parallel to DESIRE. Nevertheless, the basic assumptions of all listed frameworks are similar in the sense that they all stress the complex nature of desertification, the need to truly involve stakeholders and the need for an integrated approach. Despite this growing knowledge of the causes and effects of desertification, and despite a basic agreement in the listed frameworks, real progress in mitigation of desertification is not taking place (Winslow et al. 2011). The causes for this are complex. Some research projects have made 'scientifically based' suggestions and recommendations on ways to mitigate or reverse the process of land degradation, but this advice tended to be too fragmented for practical use by land users and in policy-making, and was also often too case-specific and therefore not easily transferable to new situations. Other projects and frameworks have, however, stressed the need to provide recommendations that are of practical use to those who are affected, but have still not been able to achieve real improvement in the field (e.g. DESERTLINKS). In an attempt to change this situation, DESIRE has made an effort to develop and implement an integrated approach with active involvement of stakeholders. Hence, the main innovations in DESIRE are in integrating the different aspects of desertification, and in involving stakeholders throughout the project. Although scientific advances have been made in the individual

Table 1 Overview of Desertification projects and frameworks

Framework/ project	Type	Reference	Fundamental elements	Use in DESIRE
Dryland Development Paradigm (DDP)	CF	Reynolds et al. (2003, 2007)	Improved integrated understanding of dryland degradation and development	Principles of DDP taken into account, focusing in particular on principles 1 and 5. DDP partly developed parallel to DESIRE
WOCAT	MF	WOCAT (2007, 2008a, b)	Questionnaires to describe measures that can be taken, and the approaches needed to implement these measures	Questionnaires embedded in participatory process
DESERTLINKS	MF	Kosmas et al. (2003)	DIS4ME Indicator system for Mediterranean Europe	Indicator system adapted and applied worldwide
LADA	MF	FAO (2011)	Mapping of degradation status and conservation	Mapping made suitable for local scale
PESERA	MF	Kirkby et al. (2011)	Soil erosion model for Europe	Degradation processes added Simulation of SLM measures Integration with socio-economic modelling
DESURVEY	CF/ MF	DeSurvey (2011)	Desertification assessment, monitoring and forecasting. Evaluation of vulnerability to desertification	Mostly parallel to DESIRE, some aspects included through partners involved in both projects
Millennium Ecosystem Assessment (MA)	CF	MA (2005)	Ecosystems Approach and ecosystem services framework puts human wellbeing and stakeholder engagement at the heart of nature conservation	The DESIRE project implicitly follows the Ecosystems Approach, and explicitly considers how desertification affects a range of ecosystem services, and how remediation can secure these services and thereby secure human well-being in drylands long into the future
Causes and Pathways of desertification	CF	Geist and Lambin (2004)	Desertification proximate causes and underlying drivers, both biophysical and socio-economic	Similar drivers considered in DESIRE, with larger focus on agriculture. Does not deal with remediation, and thus only covers part of DESIRE CF
Drivers and feedbacks of global desertification	CF	D'Odorico et al. (2012)	Desertification drivers and feedbacks, bistable ecosystems. Focus on climate, salinity and grazing, more biophysical than socio-economic. Builds on MA	Not used but compatible. Published after the end of DESIRE

aspects of the project, for e.g. degradation and conservation mapping, desertification indicators, modeling and dissemination, the main contribution of DESIRE is not in advancing science in the individual disciplines, but rather in trying to integrate and implement knowledge that is in principle not new, but that has seldom been fully used. To this end, new conceptual and methodological frameworks were developed.

Conceptual Framework

Introduction

The DPSIR (Drivers, Pressures, State, Impact, Response) framework adopted by the European Environmental Agency (EEA) can be useful to structure information and to demonstrate theoretical relationships (Tscherning et al. 2012) and is therefore a suitable starting point for a conceptual framework. The DESIRE conceptual framework (Fig. 2) uses terms from the DPSIR framework in that it distinguishes drivers, impacts and responses explicitly, while pressures and state are included implicitly. As the conceptual framework was developed early in the DESIRE project, it is based on existing literature rather than on DESIRE results.

What is new in this framework is therefore not the science behind it, but rather the focus that is used. The conceptual framework of DESIRE explains how the DESIRE project saw the problem of desertification. In DESIRE, there was a focus on local stakeholders who are trying to make a living in rural areas, mainly through agricultural activities. Therefore, the conceptual framework was also meant specifically for agricultural use of the land, and for the same reason the impacts focused on rural livelihoods. This focus has implications for the processes that are included in the framework, and for the relationships that are considered.

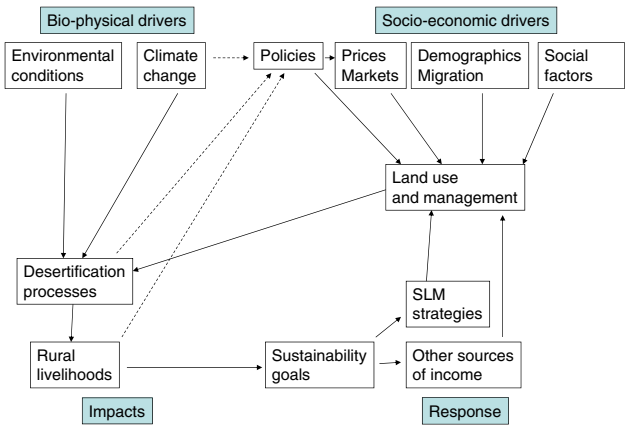

Fig. 2 Conceptual Framework of DESIRE, illustrating which processes are considered in DESIRE and how these are linked

Description

As shown in Fig. 2, the starting point of the DESIRE conceptual framework is in socio-economic and bio-physical drivers. Both influence desertification processes, but the influence of socio-economic drivers is assumed to be via land use and land management. Some of the drivers might affect both land use, and land management, while others might only influence management. Desertification processes in turn affect rural livelihoods, which causes (local) stakeholders to develop or adapt sustainability goals, resulting in either the adoption of sustainable land management (SLM) strategies or in other sources of income. These then influence land use and management.

As these processes are well understood and described in literature, they will not be fully described here. A more extensive description of the framework can be found in Hessel et al. (2012). Here, only some aspects that are especially relevant for DESIRE will be highlighted.

1. It is often assumed that increasing population pressure will result in increased degradation. This is often true, but not always. There are also examples in which increased population did not result in degradation. Furthermore, in some areas, decreasing population, rather than increasing population, is a cause for desertification. In the Mediterranean region, for example, population in many rural areas is decreasing because people migrate to urban and coastal areas to earn a living in e.g. the tourism industry. A familiar pattern is that traditional land use is continued by the older generation, while the younger generation migrates. This results in abandonment of fields, and as conservation measures fall into disrepair, levels of land degradation may increase.
2. Climate change is often listed as one of the main causes of desertification, but it is important to realize that drought is not the same as desertification, and that drought, in itself, does not need to result in degradation (Le Houérou 1996; Thomas 1997; Slegers and Stroosnijder 2008; Karavitis et al. 2012). Aridity is also often confused with land degradation (Martínez-Fernández and Esteve 2005), and indices indicating the degree of aridity have been used as if they indicated the susceptibility to degradation (Pinet et al. 2006). One of the basic characteristics of drylands is their variability in climate, especially with regard to rainfall (Le Houérou 1996; Reynolds et al. 2007; D'Odorico et al. 2012). According to Le Houérou (1996), climate change alone is insufficient to explain desertification; rather it could reinforce desertification caused by human action.
3. Agriculture affects the environment in various ways; natural vegetation is replaced by crops, irrigation is applied, the soil is tilled, fertilizers are added etc. Whether

or not this results in degradation problems depends, amongst others, on site conditions, and management. Management can often provide protection against erosion by water and wind, but if there is insufficient protection, or if weather is extreme, erosion on agricultural fields can be a large problem. Problems can arise when farmers that are new to an area use methods that cannot deal with the local climatic circumstances, or the variability in local climate. Irrigated agriculture is sometimes seen as a way to prevent desertification, but it can also be a cause of desertification if it causes over-exploitation of scarce water resources or salinization. Overgrazing has also often been reported as a cause for desertification. This has led to policies that discourage grazing, and that promote the sedentarization of nomadic herders. However, such policies have sometimes been based on dubious assumptions (Thomas 1997) and have often been based on political and economic, rather than ecological motivations (Davis 2005). Root causes such as privatization of land, which reduces the availability of grazing land, are seldom addressed. There is no doubt that grazing can result in destruction of the vegetation, and thus to desertification, if applied in a way not suited to the environment (e.g. D'Odorico et al. 2012). However, extensive or rotational grazing, as practiced by many indigenous populations, can also be a suitable and sustainable way to use drylands (Davis 2005), and for the driest areas, pastoralism is often the most sustainable or even the only possible use of land (Mainguet and da Silva 1998; McNeely 2003).

4. It is an intrinsic feature of drylands that only a limited amount of water is available, and land use should take this into account. Natural ecosystems are adapted to this availability of water, but planned land use often is not. Conflicts about the use of water can easily arise, because e.g. irrigated agriculture, greenhouses, urbanization, tourism and industry all require water, as do the natural ecosystems and traditional livelihoods of the area. In such conflicts, nature and indigenous populations are likely to lose out. Furthermore, increasing the availability of water may result in increased pressure on the environment, as e.g. shown by D'Odorico et al. (2012) for grazing pressure resulting from the use of artificial watering points and for salinization caused by irrigation. Thus, ill-guided land use planning and water management can aggravate degradation.
5. In the study sites of the DESIRE Project the impacts are clearly defined in terms of biophysical impacts on the natural and agricultural environments and socio-economic impacts on the livelihoods of stakeholders. The scale of impact varies according to the intensity and combination of drivers. Therefore no single driver will have the same impact in all locations. Instead, the impact varies depending on both the drivers, and the biophysical characteristics of the land. Factors such as soil texture, soil depth, slope, slope shape, aspect and climate together define resilience to different types of drivers. This needs to be understood to avoid the risk that a technology that is sustainable on one type of land is transferred to another type of land where it is not sustainable.

Response

As desertification problems are complex, simple solutions are rare. Too often, generalized solutions have been proposed without sensitivity to local context. Reynolds et al. (2007, 2011) defined five lessons learned about sustainable development in the drylands, all of which show the complexity of the problem: 1. Integrated approaches are needed that simultaneously consider human and ecological drivers; 2. Short term measures cannot solve slowly evolving conditions; 3. Dryland systems have nonlinear processes; 4. Cross-scale interactions must be anticipated; and 5. Greater value must be placed on local environmental knowledge.

Thus, desertification problems can only be tackled if the complex interplay of causes is understood, and if the uniqueness of the local situation, both in terms of biophysical and socio-economic conditions is considered. Such site-specific understanding can be obtained through the use of a conceptual framework that has general applicability, but that can be made site specific. In Fig. 2, all drivers, processes, sustainability goals and responses can be made site specific to show how and why the process of desertification is progressing in each of the study sites.

The conceptual framework, and the understanding resulting from it, can also be used to see how changes could be achieved that have a positive impact. In the chart, there are two feedback loops that are highly relevant in this regard:

1. The SLM loop (Fig. 3). This loop goes from land use and management to desertification processes and livelihoods. People respond by having sustainability goals that are translated into SLM strategies (and/or other sources of income), which in turn influence land use and management. This is the loop that is followed by local land users.
   In many areas, SLM has been applied for generations, as SLM is often the only way in which production can be achieved sustainably. A multitude of SLM technologies and approaches exist, and the choice on the most suitable SLM strategy depends on the human and natural context and on the kind of degradation process (WOCAT 2007). To limit water erosion, for example, measures such as terracing, strip cropping, buffer

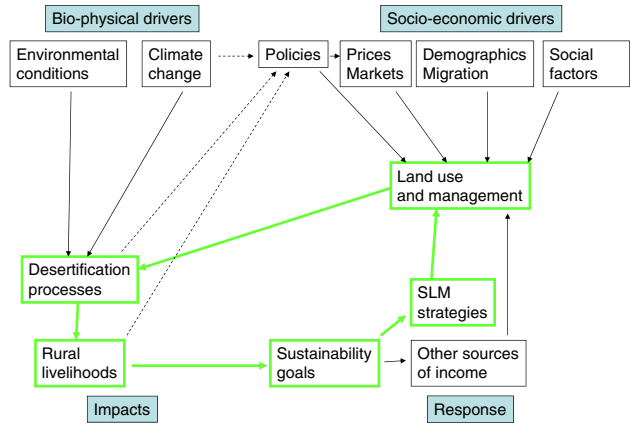

Fig. 3 The SLM loop, illustrating how SLM can influence desertification

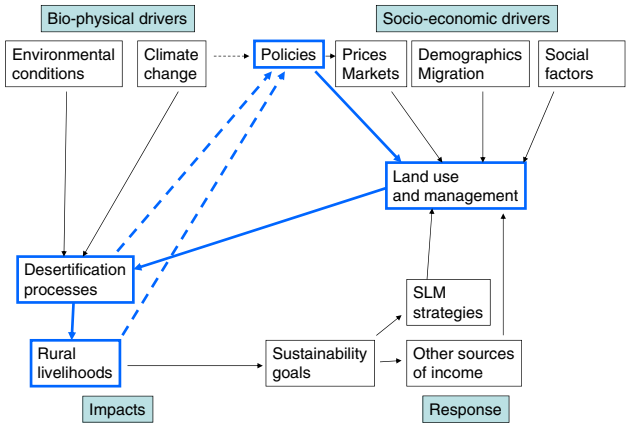

Fig. 4 The policy loop, illustrating how policies can influence desertification

strips, no tillage, agroforestry and mulching can be used. These measures generally aim to decrease detachment or to reduce the amount and velocity of overland flow, and therefore transport capacity (Unger 1996; Toy et al. 2002). Measures against wind erosion mainly aim at decreasing the wind speed at the soil surface, e.g. by using shelter belts and wind breaks. Similarly, there are also measures that can be taken to combat other desertification processes (for a more comprehensive overview see Schwilch et al. 2013).

Ideally, SLM measures should be physically effective in decreasing degradation, while at the same time being economically profitable, e.g. because yields increase, or because products or income can be obtained from the measures (e.g. fodder from grass strips, fruit and wood from agroforestry). SLM measures should also be socially acceptable to the local population. This clearly requires that measures are adapted to local physical and socio-economic circumstances, and are selected in collaboration with land users.

2. The policy loop (Fig. 4). This loop also goes from land use and management to desertification processes and livelihoods, but then goes to policies. Climate change, degradation of the environment as well as impacts on rural livelihoods should influence the (land use) policies that are being formulated by government, as indicated by the dotted arrows in Fig. 2, with the aim to improve the state of the environment, and the living conditions of the people. The policies that are developed have an effect on land use and management.

   SLM measures have often been advocated by governments, but with varying degrees of success and using different policy instruments. Broadly, there are five types of policy instrument that can be used to promote SLM: direct state control, where the state nationalizes and then manages land; regulation e.g. through prohibiting certain types of land use or management, issuing licenses/permits or creating planning zones; information provision and capacity building; financial instruments such as grants, subsidies, taxes and tax breaks; and the creation of new markets e.g. through Payments for Ecosystem Services (Reed et al. 2011b). When measures were enforced through regulation, resistance has often occurred, and measures have been discontinued when government pressure ceased, e.g. because of independence in many African countries, as shown for example for Kenya by Ekbom et al. (2001). Subsidies have been shown to be central to the decisions of farmers to adopt more sustainable land management practices across Europe (Defrancesco et al. 2008; Dobbs and Pretty 2008), but have sometimes also resulted in intensification and increased degradation (Kairis et al. 2013). For example, the EU Common Agricultural Policy (CAP) that was amongst others meant to provide farmers with a reasonable standard of living, to ensure reasonable prices and to preserve cultural heritage (e.g. de Graaff et al. 2008) also resulted in intensification or abandonment of agriculture (Onate and Peco 2005; Juntti and Wilson 2005; de Graaff et al. 2008). National and international policies do directly affect the choices land users make, and in many cases even prescribe certain land management practices. Payments for Ecosystem Services are now increasingly being used to promote sustainable land management and enhance livelihoods in drylands through carbon markets (e.g. Stringer et al. 2012).

   Referring to the SLM loop, policy makers should respond by developing policies that allow local stakeholders to implement the SLM they have selected. Policies would certainly also be expected to influence

the possibilities for other sources of income, but these policies would not be the agricultural policies that are targeted in this chart. It is, however, important to realize that there are also many other factors that influence the development and implementation of policies, such as the balance of power between groups with conflicting interests (Kaimowitz 2002), so that policies in practice do not always serve the interests of the environment and the rural population.

Use in DESIRE

Based on the focus of DESIRE, a conceptual framework was developed that indicated that there are two main loops which DESIRE could try to influence in order to combat desertification. DESIRE did this in the following ways:

1. Developing SLM strategies together with stakeholders was the main aim of DESIRE. Following the SLM loop, this should result in an improvement of both the environment and the rural livelihoods.
2. By providing policy advice, DESIRE also tried to influence policies that are being developed. Following the policy loop, this should also result in an improvement of both the environment and the rural livelihoods.

These two feedback loops focused the work of DESIRE, as described in the Methodological Framework, not only in the project activities and results, but also in dissemination to a wider range of interested persons. The main stakeholders that were addressed in DESIRE were on the one hand the local land users (SLM loop) and on the other hand regional, national and international policy makers (policy loop).

Methodological Framework

Before the conceptual framework described above can be put into practice, a methodological framework is needed that describes the sequence and logic of work, and shows how the different parts of the project are related. Managing land degradation effectively is an information intensive endeavor requiring an in-depth understanding of social-ecological interactions. There have been many attempts to address this complex methodological challenge (as discussed in Sect. Frameworks to Combat Desertification), 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 more quantitative approaches using field-based and remotely sensed data, analysed and interpreted using models and Geographical Information Systems (see e.g. Vogt et al. 2011).

Based on a review of current approaches used to assess LD and SLM (Reed et al. 2011a; Schwilch et al. 2011), four broad themes were defined that form the core of the DESIRE methodological framework (the central circle in Fig. 5):

i Establishing LD and SLM context and sustainability goals;
ii Identifying, evaluating and selecting SLM strategies;
iii Trial strategies and model regional effects; and
iv Applying SLM options and monitoring LD and progress towards sustainability goals.

Although these themes are applicable across a range of contexts, the way in which each of these themes is operationalized may need to be adapted to different situations. Figure 5 shows how this was done for the DESIRE project (steps 1–10 in Fig. 5, explained below in detail).

Figure 5 is based on a combination of frameworks proposed by Reed et al. (2006), WOCAT, LADA and the DDP (see Table 1), and is a DESIRE specific version of the more general framework by Reed et al. (2011a). Figure 5 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. In DESIRE the framework was used in a 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.

The framework in Fig. 5 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 process, 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. (2013) gave an example of how this framework is being operationalised through the DESIRE project internationally, using Botswana as a case study. The different steps in the framework are discussed in much more detail in the other papers of this special feature (Kosmas et al. 2013; Kairis et al. 2013; Schwilch et al. 2013; Fleskens et al. 2013; Stringer et al. 2013; Geeson et al. 2013) and elsewhere (Fleskens et al. 2009; van Lynden et al. 2011; Mantel et al. 2011; AUA 2011; Jetten and Shrestha 2012; Schwilch et al. 2012c).

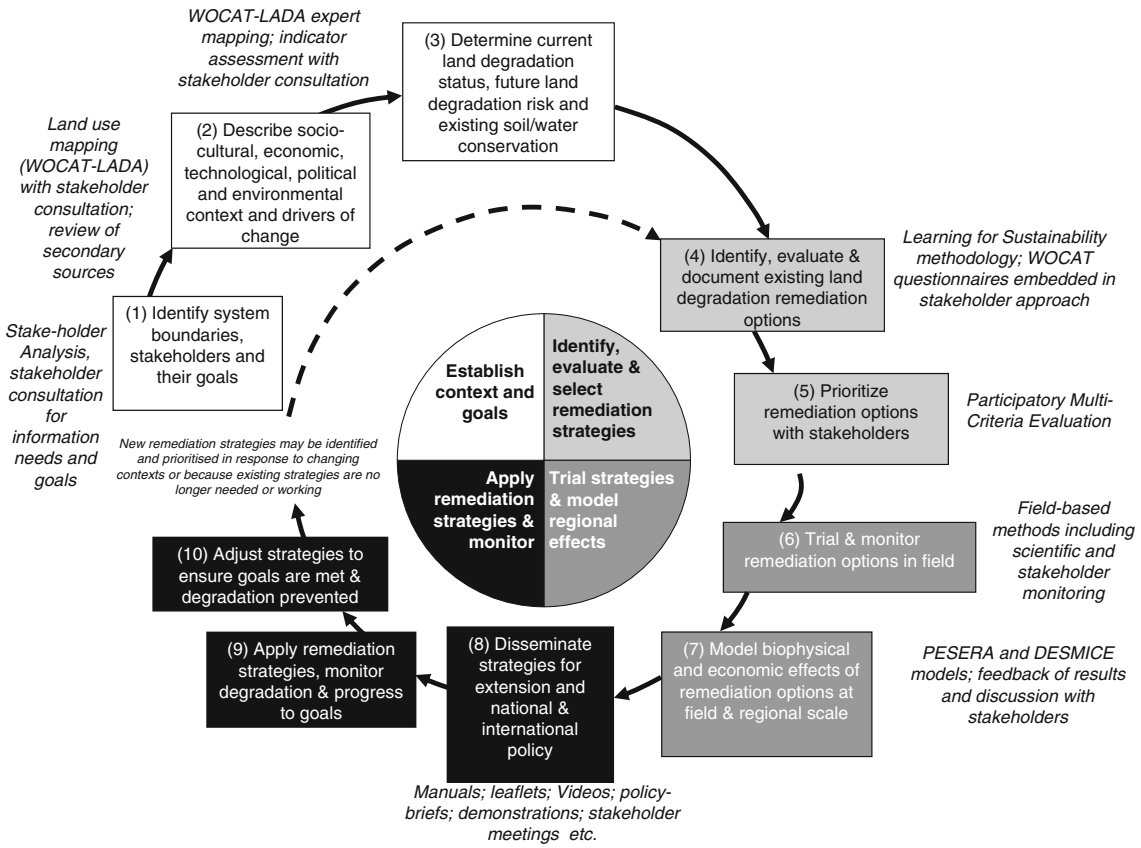

Fig. 5 Methodological Framework of DESIRE, illustrating the logic and sequence of the work executed in DESIRE

Establishing LD and SLM Context and Sustainability Goals

First it is necessary to determine the biophysical, socio-economic and policy conditions that exist in the study site. This is established through three components:

Identifying system boundaries, stakeholders and their goals (Fig. 5, step 1)

Before stakeholders can be identified, it is necessary to establish the boundaries of the system, i.e. to define the study area. Then, it has to be determined who has a stake in the area. 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). In DESIRE, stakeholder analysis was used to provide a systematic approach to identify all relevant stakeholders, ranging 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. Once stakeholders were identified, they were consulted to develop sustainability goals for the area, and to obtain insight into what kind of information needs the different stakeholders had.

Describing the socio-cultural, economic, technological, political and environmental context and identifying key drivers of change (Fig. 5, step 2)

Once relevant stakeholders were identified and selected, the study areas where described and analysed using existing information sources such as maps, remote sensing images, reports, other written sources and information provided by stakeholders. Analysing this information can amongst others be done by making the conceptual framework (Fig. 2) site specific. To do that, available scientific information as well as civil information and information provided by stakeholders and policy makers was used in order to get the complete picture. In addition to understanding the socio-cultural, economic and environmental context, it is important to understand the drivers that are resulting in changes in land use and land management, which in turn, may result in desertification (Mantel et al.

2011). Because of increased global interconnections, global drivers such as rising food prices, emerging carbon markets and increased demand for biofuels increasingly impact on what happens locally in drylands (Bisaro et al. 2013) and should thus be considered too. In addition to an understanding of drivers, an understanding of constraints that may prevent land managers from adopting more sustainable practices (e.g. financial, institutional capacity and knowledge constraints) is also needed (Douthwaite et al. 2008). Through identifying constraints it was possible to make more informed decisions about the sorts of SLM options likely to be viable and sustainable in the long term.

Determining current LD status, future LD risk and existing SLM measures (Fig. 5, step 3)

Next, it is necessary to establish a baseline of LD status against which future progress can be monitored. In the DESIRE project, assessments of desertification risk have been undertaken using sets of existing LD indicators developed through previous research (Kosmas et al. 2003). Using methods developed in the DESERTLINKS project,[2] regression equations were developed to calculate desertification risk based on indicators (Kosmas et al. 2013). This was done for different land uses and different desertification processes separately. In this way, it was possible to tailor indicators effectively to different contexts. As not all indicators entered the regression equations, this also resulted in a selection of the most relevant indicators (Kosmas et al. 2013). An expert system was developed that allows users to assess desertification risk for different desertification processes, using the indicators that were found to be most relevant (AUA 2011). By identifying areas at greatest risk of future LD, it may be possible to prioritize areas for action in the next step of the framework.

Apart from LD risk, it is also important to know the current status of LD and areas where successful SLM measures have already been put in place. The areas at highest risk of degradation and those currently with highest degradation might be different, because 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 prioritize the locations and types of SLM that might be most appropriate in step 4. Current status, as well as current SLM measures were mapped using the WOCAT/LADA/DESIRE (2008) approach (van Lynden et al. 2011). This methodology creates maps identifying LD and areas of good land management practices, enabling decision-makers to be informed about likely degradation impacts and where to invest.

At national and international scales, a group of indicators such as those proposed in the UNCCD's global minimum set of indicators[3] or by the GEF-funded project on 'Ensuring impacts from SLM' (GEF MSP 2011) can ensure comparability across spatial and temporal scales. At local scales however, local 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. As such, the core set of scientific indicators used during step 3 to establish a baseline for LD risk and status can be supplemented with indicators used by local communities, ensuring that land managers are able to use the indicators themselves and feed their monitoring results into SLM decisions. As land managers use such local indicators themselves, often on a regular basis, such indicators are particularly useful to monitor change over time.

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.

Identifying, assessing and prioritising possible SLM options (Fig. 5, 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; Schwilch et al. 2013) to select SLM options. The methodology consists of three parts: (i) identifying LD 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; Schwilch et al. 2013); and (iii) jointly selecting promising strategies for trial implementation with the help of a decision-support tool (Schwilch et al. 2012a, b). The participatory process that was used brings together "technological and expert" options and local practices and innovations. The key to success lay in finding a balance between local knowledge and technical expertise as well as between socio-cultural, economic, and ecological impacts of SLM, in order to find SLM options that are suitable for the particular conditions in each study site.

[2] For information on the DESERTLINKS project see: http://www.kcl.ac.uk/projects/desertlinks/.

[3] See UNCCD website at: http://www.unccd.int/cop/officialdocs/cop9/pdf/cst4eng.pdf

Trial Strategies and Model Regional Effects

Trial SLM options at field scale (Fig. 5, step 6)

Field trials were conducted to test the effectiveness of selected SLM options (Jetten and Shrestha 2012). These trials were monitored to determine the biophysical and economic effects of the selected technologies, in collaboration with local land managers. Given climatic variability in drylands, data should ideally be collected over many seasons to detect trends. Within DESIRE, most technologies were monitored for 2–3, and sometimes 4 years. As treated plots were compared to untreated plots, the effects of the implemented technologies could be studied for those weather conditions that occurred. Although in some cases no definite conclusions could be drawn, the collected data generally provided clear indications whether certain technologies worked or not. In addition, the WOCAT questionnaires were used again, thus providing standardization that allowed a comparison with the situation before implementation as well as between technologies and study sites (Jetten and Shrestha 2012).

Up-scale/aggregate biophysical and socio-economic effects of SLM from field to regional and national scales to further prioritise SLM options (Fig. 5, 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 6) and use secondary data to evaluate the regional implications of SLM strategies. In DESIRE this was done via biophysical and socio-economic modeling of scenarios (Fleskens et al. 2013).

The DESIRE project used a biophysical model that builds on and extends the Pan-European Soil Erosion Assessment (PESERA) model (Kirkby et al. 2008). This model has been adapted to each study area to closely reflect desertification processes (including potential threshold effects) and LD drivers identified in steps 2 and 3, and also to be able to simulate the effects of the selected technologies. Model outputs are used to look at the biophysical effects of different SLM options that have been trialed in study areas at a district or coarser scale, to help formulate extension and policy recommendations (Fleskens et al. 2013). 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 use of models for this purpose has the potential to capture the sorts of non-linearities, feedbacks and thresholds effects that are inherent in complex socio-ecological systems (Prell 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 effects as determined by the PESERA model. This was done by developing and applying the Desertification Mitigation Cost Effectiveness (DESMICE) model (Fleskens et al. 2009), which was developed within DESIRE and which is able to use the PESERA output as input. 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. These model results were then discussed with stakeholders (Stringer et al. 2013), and can finally inform decision-making by local and national stakeholders to prioritise the selection of SLM options for implementation.

Applying Remediation Options and Monitoring LD and Progress Towards Sustainability Goals

Finally, the lessons learned in the previous steps need to be shared with the stakeholders identified in step 1. The last three steps to complete the framework therefore comprise dissemination, application, and review of strategies:

Disseminate strategies and indicators for extension and national and international policy (Fig. 5, step 8)

It is necessary to consider how LD 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 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 including for example: scientific papers, policy briefs, leaflets for land managers, and pictorial posters or videos for school children. In DESIRE, this information is made available via an online knowledge platform or Harmonised Information System (DESIRE-HIS),[4] (Geeson et al. 2013) to act as a knowledge repository and to facilitate knowledge exchange. Care was taken to ensure that information is also available to those without internet access. This was done by creating dissemination products that could be printed and distributed by the local DESIRE partners, and also translated to local languages as required. Key messages in various formats for a wide range of stakeholders, including policy makers, may be found on the DESIRE-HIS.[5] Additionally, a compilation of options

[4] Homepage of the DESIRE-HIS is: http://www.desire-his.eu/

[5] Key messages are found at: http://www.desire-his.eu/en/key-messages

for SLM in drylands was presented in a book (Schwilch et al. 2012c), describing the DESIRE approach and WOCAT methodology for a range of audiences, from local agricultural advisors to scientists and policymakers. The book provides links to manuals and online materials, enabling application of the various tools and methods in similar projects. Step 8 was the last step that was taken within the DESIRE project, but for real change to occur in the field, the last two steps are also vital.

Apply SLM strategies, monitor degradation and progress towards SLM goals (Fig. 5, step 9)

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 LD. This monitoring may be done using existing indicators (step 3). 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 were already discussed during steps 4 and 5.

Adjust strategies to ensure goals are met (Fig. 5, step 10)

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 10 and 4.

Discussion

This paper has presented a simplified conceptual framework that identifies linkages between the key drivers and processes of desertification. This conceptual framework can be applied globally, but can also be made site-specific to take into account that each study site has a unique combination of bio-physical, socio-economic and political conditions. Building on these insights, the paper has proposed a methodological framework for working with stakeholders to understand their goals and land degradation context, and work with them to select, trial and model land degradation remediation options that can then be applied and monitored, to combat desertification in a wide range of international contexts. The application of the methodological framework was done via six sets of tasks in the DESIRE project that respectively set the context, applied indicators to assess degradation risk, selected promising SLM strategies, implemented and monitored these strategies, modeled these strategies for various scenarios and disseminated the DESIRE results. Such an approach of developing and applying a sequence of conceptual framework, methodological framework and project working plan is essential to do justice to the complex nature of desertification, and therefore this sequence forms the cornerstone of DESIRE's global approach to find local solutions. As such, this approach can form guidance for policy advisors or other degradation projects to follow, especially if the focus of these projects is similar to that of DESIRE.

For the same reason of complexity, however, fully implementing the approach is not easy. The other papers in this special feature (Kosmas et al. 2013; Kairis et al. 2013; Schwilch et al. 2013; Fleskens et al. 2013; Stringer et al. 2013; Geeson et al. 2013), as well as other publications (Fleskens et al. 2009; van Lynden et al. 2011; Mantel et al. 2011; AUA 2011; Jetten and Shrestha 2012; Schwilch et al. 2012c), provide further detail on how each of the steps of the Methodological Framework was actually implemented in DESIRE, while the DESIRE-HIS (2012) shows how the approach was implemented in each of the study sites. The papers mentioned above show that in some cases, deviations from the proposed methods occurred because of circumstances that had for example to do with local realities in the study sites (e.g. attitude of stakeholders, existence of policies that are unfavorable for local stakeholders) and with the flow of information from one step of the Methodological Framework to the next. Despite these imperfections in the implementation of the framework, the principles proved valid, and the results confirmed the usefulness of the DESIRE approach.

However, to have a real impact on the ground beyond the DESIRE project, such approaches should be mainstreamed into governmental structures and regional initiatives. This will require commitments from governments and donors in terms of human and financial resources. Time and resources and the establishment of long-term partnerships are needed by both scientific and policymaking bodies. Additionally, in-depth and long-term field-based research is important, but requires sufficient resources and long-term commitment in order to provide adequate evidence and data for monitoring. In the DESIRE study sites, it was observed that many stakeholders were reluctant to choose new technology options. They often preferred to adapt existing technologies they already had some confidence in. This is natural, because they could not afford to take risks with their livelihoods. This also means that take-up of new ideas is not often instant. Like seeds that are sown, under the right conditions ideas will gradually grow and take root. This process cannot be monitored by a research project, but requires long term commitment from governments and donors.

As shown by Schwilch et al. (2011), the DESIRE approach also supports recommendations for UNCCD: (1) common conceptual framework, (2) common methodological framework, (3) nested scales, (4) common indicators and variety of data sources, (5) participation and interdisciplinarity, and (6) knowledge management from local to international scales. The developed approach and project results could therefore help UNCCD to monitor progress towards its goals and to find effective ways to combat desertification in different locales around the world.

Conclusions

Desertification is a highly complex issue resulting from an interplay of socio-economic, political and bio-physical factors and processes. As such it is also highly site-specific in the way in which it occurs. To be able to deal with this complexity and site-specificity, a conceptual framework for desertification was developed. This shows which factors and processes can be considered the most significant drivers, and therefore which aspects should be priorities to address in each site specific case in order to come up with viable solutions of SLM. Furthermore, the conceptual framework also identified the pathways through which the DESIRE project could influence desertification. This could be done through two feedback loops, namely the sustainable land management loop and the policy loop. Next, a methodological framework was developed in which the methodological steps taken in the DESIRE approach were listed and their logic and sequence were explained. From these two frameworks, a concrete working plan to put the project into action was developed, involving stakeholders throughout the process. The approach developed and suggested can guide land users, policy advisors and other projects that aim to reduce land degradation anywhere in the world.

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