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Land-based adaptation to global change: What drives soil and water conservation in western Africa?

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ABSTRACT

Conservation of land resources is a promising strategy for sustainable agricultural intensification in order to adapt dryland farming systems to climate, market and other stresses. At a local level, factors that drive the adoption of conservation measures operate and interact in specific ways. Linking our knowledge of the local specifications of these drivers to regional and global patterns of vulnerability can significantly enhance our understanding of land-based adaptation to global change. However, the factors that influence the adoption of conservation practices remain actively debated. Therefore, this study presents a meta-analysis of case studies that investigate the adoption of soil and water conservation measures, as an important approach to resource conservation. Synthesising 63 adoption cases in the drylands of western Africa, this meta-analysis reveals a multitude of factors that drive the adoption of soil and water conservation practices. The drivers differ strongly between particular practices and methods of analysis used in the case studies. Contributing to the broader debate on resource conservation, the findings highlight the adoption of soil and water conservation measures as an emergent property of farming systems. They demonstrate the need to better understand the socio-ecological foundation of adoption and the pathways along which adoption evolves in space and time. This study concludes with methodological principles to advance future research on the factors that drive the adoption of soil and water conservation measures as a pre-requisite of improving land-based adaptation efforts.

1. Introduction

Low and variable agricultural productivity remains a major development challenge in drylands worldwide. Though primarily caused by the low and variable rainfall, limitations in agricultural productivity also arise from low soil fertility, the degradation of soils, vegetation and water as well as constraints in markets and institutions (Lepers et al., 2005; Safriel et al., 2005; Hein and De Ridder, 2006; Reynolds et al., 2007; Zika and Erb, 2009). These conditions significantly undermine the basis of people's food and livelihood security, particularly in developing countries, and thus contribute to their vulnerability to climate and market variability (Sietz et al., 2011; FAO et al., 2014; Sterzel et al., 2014; Kok et al., 2015). To improve adaptation to current and future global change challenges, dryland agriculture needs to be intensified without inducing adverse environmental impacts. This study aims to improve our understanding of sustainable agricultural intensification that offers a promising way to transit towards enhanced land-based adaptation to global change and responsible dryland development (Safriel and Adeel, 2008).

Agricultural intensification is one of the major land-use and land-cover changes globally (Lambin et al., 2001). Intensification can take sustainable forms based on resource conservation and managerial shifts, which increase the efficiency of labour, land and other inputs (Garnett and Godfray, 2012), and non-sustainable forms, which increase inputs but bear the potential to level or even decrease input use efficiency. Sustainable agricultural intensification seeks to unify principles of sustainability and the enhancement of productivity. It presents an effective approach to increasing food security in order to adapt farming systems to climate and socio-economic challenges. Resource conservation is a cornerstone of sustainable agricultural intensification and aims to replenish soil nutrients, reduce soil erosion and harvest rainwater based on approaches such as soil and water conservation as well as conservation agriculture (WOCAT, 2008; Lahmar et al., 2012). Successful adoption of conservation measures has been attributed to, among other factors, the development of agricultural markets

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and infrastructure, knowledge management, the diversification of farmers' incomes, institutional and technological innovations and the triggering effects of crises (Mortimore, 2005; Reij et al., 2005; Reij and Smaling, 2008). Yet, the factors that drive the adoption of conservation measures remain actively debated from, for example, political-ecologic, demographic and agronomic perspectives (e.g. Mazzucato and Niemeijer, 2000a; Ito et al., 2007; Giller et al., 2009; Mortimore et al., 2009; Lahmar et al., 2012).

Case study approaches serve to investigate the factors that influence the adoption of conservation measures, focusing on particular measures implemented in one or a few villages. Local-level evidence provides valuable insights into why farmers use conservation practices and how they adjust these practices to their local farming context. However, a synthesis of these local insights is needed to gain a broader understanding of the factors that typically foster or impede the adoption of conservation measures. Global change research has greatly benefitted from synthesising local-level evidence on the drivers of desertification, agricultural intensification and food security using meta-analysis (Geist and Lambin, 2004; Keys and McConnell, 2005; Misselhorn, 2005). In view of the prevailing problems of dryland development, meta-analysis of the adoption of conservation measures is essential to differentiate generic drivers of agricultural intensification that capture sustainable and non-sustainable approaches (Keys and McConnell, 2005). Synthesised insights will help improve our capacity to address fundamental questions of adaptation research pertaining to the assessment and management of the interactions between the well-being of people living in drylands and ecosystem services (Reynolds et al., 2007).

This study presents a meta-analysis of factors that drive the adoption of soil and water conservation (SWC) measures, as an important type of resource conservation, investigated in case studies. Using meta-analysis for conducting a 'study of studies', we aim at exploring those factors that typically determine the adoption of SWC practices in order to contribute to a meaningful generalisation of adoption drivers. Adoption drivers are socio-economic and biophysical factors, such as farm properties and external interventions, that influence the use of SWC practices. Focusing on the drylands of western Africa, this study synthesises adoption drivers for a range of SWC measures in an important dryland region in which both severe land degradation and food insecurity prevail (Sietz et al., 2011; FAO et al., 2014; Kok et al., 2015), SWC adoption drivers are highly contested, and the successes and failures of SWC adoption have occurred in close vicinity. After developing a conceptual framework of SWC adoption drivers, this study assesses patterns in these drivers and discusses their implications for advancing dryland science (Reynolds et al., 2007) in order to support farming systems' adaptation to global change based on the conservation of land resources. This synthesis is an essential step towards enhancing our capacity to understand and model critical adaptation processes by providing insights at a level in between the extremes of a universal theory of SWC adoption and the unachievable description of every single adoption case.

2. Background: SWC practices and adoption in the drylands of western Africa

Farmers in the drylands of western Africa employ a wide range of SWC measures. In this study, SWC measures are categorised according to the type of soil degradation they primarily aim to reduce (WOCAT, 2008), as outlined below.

First, soil fertility (SF) measures refer to agronomic practices such as composting, mulching, manure applications, planting pits (zai and tassa) and micro-catchments. SF measures serve to increase organic matter content, reduce splash erosion and surface runoff, to harvest rainwater and to rehabilitate degraded land. SF measures are mainly carried out at a household level and are of seasonal or annual duration. Second, erosion control (EC) practices include structural and vegetative measures such as stone bunds, rock dams, grass strips and contour vegetation barriers. They serve to control soil erosion and surface runoff as well as to harvest rainwater. EC measures often change the slope profile in the longer run due to the sedimentation of eroded soil. The establishment of EC measures often involves substantial inputs of labour and building materials such as stones and wood, thus requiring collective action at the village level. However, once established, EC measures last long, although they necessitate maintenance. Third, mixed (MIX) measures encompass above all farmer-managed natural regeneration, alley farming and other agroforestry systems. Mimicking natural ecosystems and their successional stages, agroforestry systems effectively combine efforts to retain soil nutrients and prevent erosion through the integration of trees, shrubs and crops. Diversification is a key aspect of agroforestry systems related to species and structural as well as functional diversity at various spatial and temporal scales. The third category further captures one case study that assessed the simultaneous adoption of micro-catchments and stone bunds. On gentle slopes, stone bunds built around micro-catchments can reduce surface runoff, which contributes to water retention and the protection of micro-catchments and thus interrelates adoption decisions.

This study defines the term 'SWC adoption' as the sustained integration of SWC measures in farming practices. Besides conservation measures introduced through development projects, adoption also includes the spontaneous and autonomous diffusion of SWC practices from farmer to farmer. In the case of development projects, adoption refers to the time after a SWC intervention has been completed, thus describing a long-term use without further external intervention. In the case of farmer-to-farmer diffusion, adoption relates to the long-term use after knowledge on a SWC practice had been spread through farmers' networks (Rogers, 1995). Overall, SWC adoption is considered a dynamic process involving sequences of the uptake, intensification, innovation, spread, abandonment and replacement of SWC practices (Feder et al., 1985; Rogers, 1995). In contrast, this study does not consider the period in which farmers use SWC measures while a development project actively promotes these measures since initially adopted measures are often abandoned after the closure of development projects. Similarly, periods during which a SWC practice is actively communicated through farmers' networks remain outside the scope of this study.

In some dryland regions of western Africa, farmers have adopted SWC measures as an effective way of sustainably increasing agricultural productivity and related food security (Mortimore, 2005; Reij et al., 2005; Reij and Smaling, 2008). Therefore, substantial gains are expected from improving the implementation of SWC practices beyond these success regions. However, successes are surrounded and vastly outnumbered by failures, and interventions have failed to regularly increase SWC adoption (Reij et al., 1986; Hudson, 1991; Mortimore et al., 2009). These insights raise questions about the drivers of SWC adoption, taking into account the complexity and pronounced variability of dryland systems (Reynolds et al., 2007).

3. Methodology: Meta-analysis of SWC adoption drivers

Meta-analysis of case studies is a valuable tool for synthesising and generalising findings identified in a larger set of case studies (Rudel, 2008). In performing meta-analysis, results from the case studies are contrasted and combined to reveal patterns in the findings, sources of disagreement and other relationships that only become apparent when case studies are reviewed