Managing Dryland and Water: A Review of Chapter 4 Soils and Water in the Book Managing Dryland Resources an Extension Manual for Eastern and Southern Africa

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Abstract *: Drylands are areas that are vulnerable to environmental degradation due to low rainfall, soil erosion, and limited water resources. The book Managing Dryland Resources – An Extension Manual for Eastern and Southern Africa (IIRR, 2002) presents a variety of practical approaches to managing these challenges. This article reviews Chapter 4: Soils and Water, which focuses on soil and water conservation strategies, pit composting, irrigation and drip irrigation utilization, rainwater harvesting, and sandy river water utilization innovations. The results of the review show that this chapter is strong in presenting field experience and local wisdom combined with modern technology, although it is still limited in quantitative data and socio-economic analysis. These findings confirm that the chapter is relevant as a practical guide for smallholders, extension workers, and stakeholders in sustainable agricultural management in arid regions, both in Africa and in similar regions such as West and East Nusa Tenggara in Indonesia.*

Keywords : *Soil conservation, Water management, Local innovation.*

INTRODUCTION

Drylands are one of the largest ecosystems in the world, covering about 41% of the global land surface and being home to more than two billion people (Stroosnijder et al., 2012). Dryland conditions are characterized by low rainfall, uneven distribution throughout the year, and are vulnerable to soil degradation due to erosion and unsustainable management practices. Water scarcity in this region is a major factor affecting agricultural productivity, food security, and community welfare. For this reason, land and water management in drylands is a strategic issue that receives wide attention in sustainable development studies. Various strategies for soil conservation, rainwater harvesting, and the use of water-saving technology have been proposed and tested as an effort to increase ecosystem resilience and land productivity. In this context, Chapter 4 Soils and Water of the book Managing Dryland Resources – An Extension Manual for Eastern and Southern Africa (IIRR, 2002) presents a series of practical approaches that can be used as a reference for extension workers, smallholders, and policymakers in addressing resource management problems in dry areas.

The main problems faced by drylands can be categorized into four main aspects. First, low and seasonal rainfall leads to uncertainty in the availability of water throughout the year. Second, severe soil erosion and degradation reduce land productivity and worsen vulnerability to climate change. Third, limited access to irrigation water reduces the capacity of farmers to maintain production sustainability. Fourth, the socio-economic conditions of generally low-income dryland communities narrow their ability to adopt modern, high-cost technologies. Studies have shown that soil and water conservation can have a positive impact on agricultural yields and water use efficiency. Yu et al. (2022), through a global meta-analysis, found that soil and water management practices have a significant influence on water use efficiency and crop productivity in dry regions, although their effectiveness is highly dependent on environmental factors and local practices applied.

As an alternative solution, a sustainable land management (SLM)-based approach has proven effective. Schwilch et al. (2013) emphasized that SLM practices such as terrace, agroforestry, and rainwater harvesting are able to reduce soil erosion, increase water reserves, and strengthen ecosystem resilience. Similarly, Văn et al. (2013) stated that SLM technology can address various dryland threats such as soil degradation, resource conflicts, and climate change impacts, especially through increased soil moisture as well as reduced water runoff. However, despite many successful conservation practices at the local level, there are still limitations in research in providing broad-scale empirical data and long-term cost-benefit analysis, especially in the context of small communities in developing countries. This is an important research gap in dryland management.

From a state-of-the-art perspective, recent research has placed a lot of emphasis on the integration between traditional methods and modern innovations. For example, drip irrigation technology has been shown to be effective in saving water for high-value horticultural crops, while local wisdom in the form of water utilization from sandy rivers through underground dams has been recognized as an innovative solution that is rarely the focus of formal studies (Lasage & Verburg, 2015). On the other hand, simple practices like pit composting offer smallholder farmers an inexpensive alternative to increase soil fertility while maintaining moisture. Chapter 4 Soils and Water of the IIRR book uniquely showcases such integration with an instructional approach that is easily adopted by the community. This is a strength as well as a differentiator compared to conventional academic literature which generally emphasizes technical and quantitative analysis.

In terms of novelty, the discussion in Chapter 4 makes an important contribution as it not only describes conservation technologies, but also presents real-life case studies of farmers and communities in East and Southern Africa. The success story of the rehabilitation of ravines into productive land, for example, shows how individual initiatives can be transformed into effective adaptation models. This narrative approach enriches the typically technocratic literature on soil and water conservation. By combining technical practices, local experiences, and institutional aspects, this chapter adds a new perspective to the study of sustainable agricultural development.

The purpose of this article is to critically review the contents of Chapter 4 Soils and Water of the book Managing Dryland Resources with an emphasis on four main points. First, it analyzes various approaches to soil and water conservation, including traditional techniques and modern innovations. Second, compare the findings in the chapter with the latest academic literature to identify their strengths and limitations. Third, highlight the research gap that still exists, especially related to the lack of empirical data, cost-benefit evaluation, and socio-economic analysis of the conservation practices discussed. Fourth, evaluate the relevance of the content of the chapter to the context of sustainable agricultural development in drylands in Indonesia, especially in the West and East Nusa Tenggara regions which have agro-ecological characteristics similar to Africa.

The urgency of this research cannot be separated from the increasing pressure of global climate change which makes dry areas increasingly vulnerable to drought and land degradation. The soil and water management practices presented in this chapter can contribute directly to improving the food security of communities in these vulnerable areas. In addition, resource constraints in developing countries demand solutions that are not only technically effective, but also cost-efficient and easy to adopt by smallholders. Simple practices such as rainwater harvesting, composting pits, or small dams in sandy rivers can be strategic choices. This research is also important to fill research gaps related to the long-term effectiveness of conservation practices in drylands. The integration between technical, institutional, and local wisdom approaches emphasized in Chapter 4 offers an adaptive framework that can be replicated in the tropics.

Overall, the urgency of this review lies not only in its contribution to academic understanding, but also in its potential application for the development of sustainable development policies and programs in drylands. With the growing population and global demand for food, success in managing land and water in drylands will determine the extent to which people in the region can escape the trap of ecological and economic vulnerability.

LITERATURE REVIEW

Studies on soil and water management in *drylands* have grown rapidly in the last two decades, as attention has increased on the issues of global food security, environmental degradation, and the impact of climate change. According to Reynolds et al. (2007), drylands cover more than 40% of the land surface and are home to nearly two billion people worldwide. With increasing population pressures, severe land degradation, and water scarcity, a sustainable resource management approach is an urgent need. Soil and water problems in drylands are interconnected, so the strategies applied must be integrated (see Figure 1).

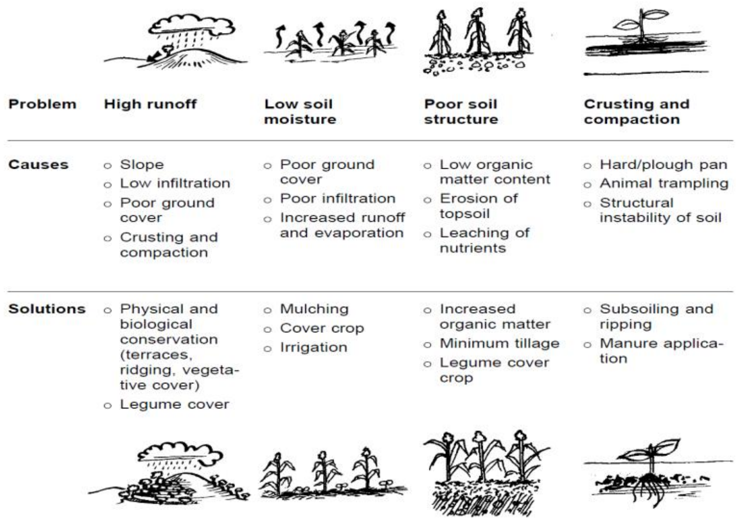

Figure 1. Soil and water problems, and some ways to address them

One of the main themes in the literature is soil conservation. Conservation practices such as terraces, conservation *tillage*, and the use of organic mulch have been proven to reduce erosion, increase soil moisture, and improve land productivity (Montgomery, 2007). In contrast, conventional tillage practices exacerbate degradation by increasing soil erosion and moisture loss (see Figure 2).

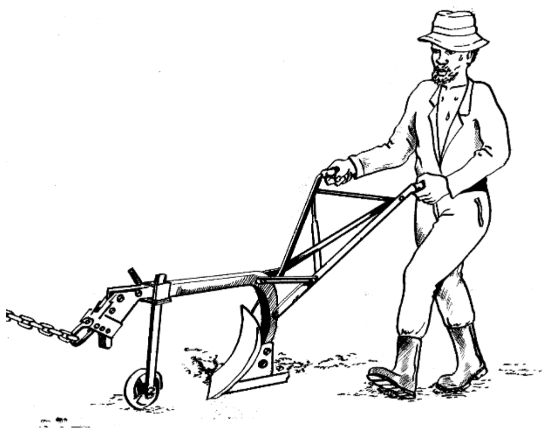

Figure 2. Problems of conventional tillage

Various studies show the effectiveness of soil conservation. A meta-analysis study by Adil (2024) shows that the application of *conservation tillage* to wheat farming in China's drylands can significantly improve groundwater storage and water use efficiency. This is in line with the findings of Schwilch et al. (2013) who affirm that *sustainable land management* (SLM) practices can reduce soil degradation by up to 60% and contribute directly to increasing agricultural yields on dry land. In comparison to conventional *tillage, conservation tillage* offers a more sustainable alternative (see Figure 3).

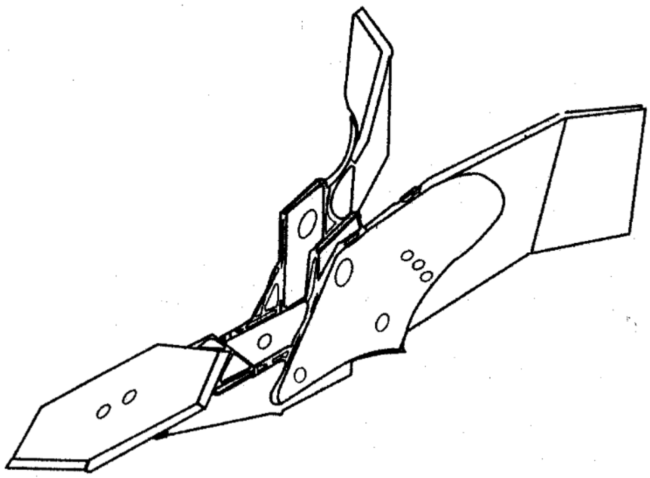

Figure 3. Preservation of tillage.

In addition to soil conservation, water management is a very important issue. In dry land, most of the rainfall is lost through evaporation, runoff, and deep percolation, making it unavailable to plants (see Figure 4). Therefore, a water-saving strategy is crucial.

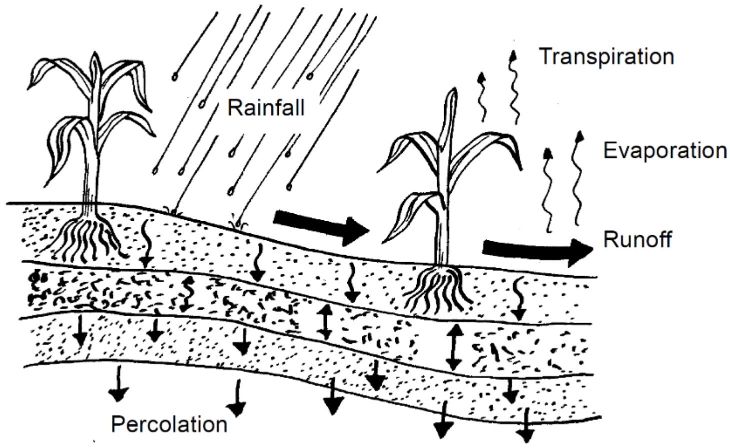

Figure 4. Rainwater lost through evaporation, runoff and deep percolation is not available to the crop.

Rainwater *harvesting is* widely studied as an effective and inexpensive solution for smallholders in semi-arid regions. Văn et al. (2013) noted that technologies such as *half-moon catchments* and small reservoirs not only increase water availability, but also strengthen household food security. On the other hand, modern innovations such as drip *irrigation* offer very high water use efficiency, especially in horticultural crops with economic value (Keller & Bliesner, 1990). However, limited access to capital and high upfront costs are often major barriers to the adoption of this technology, especially for smallholder farmers (Postel et al., 2001).

The literature also emphasizes the importance of utilizing local wisdom in managing dryland resources. An example that is widely practiced in East Africa is the construction of underground dams on sandy rivers. Lasage and Verburg (2015) show that this technique is able to provide sustainable water reserves while reducing evaporation. Its advantages lie in its suitability with local conditions and low maintenance costs. This community-based approach is considered more adaptive than large-scale technological interventions, because it strengthens a sense of ownership and long-term sustainability (Pretty, 2003).

In the context of climate change, the literature highlights the importance of integrating adaptation strategies into dryland management. Yu et al. (2022) assert that water use efficiency is affected by natural conditions such as rainfall and soil properties, but can be improved through proper management practices. This reinforces the idea of hybrid innovation that blends modern science with local experiences.

Although many studies highlight the success of soil and water conservation techniques, there is still a *research gap*. First, most studies have focused on short-term technical effectiveness, while long-term cost-benefit analysis and socio-economic impacts have not been extensively explored. Second, research is generally based on local cases, so it is difficult to generalize on a regional or global scale. Third, the role of institutions and public policies in supporting the adoption of conservation technology is still relatively little discussed (Nkonya et al., 2011).

Thus, *the state of the art* research shows that the approach to soil and water management in drylands needs to be more cross-disciplinary, integrating ecological, economic, social, and institutional aspects. The novelty offered by practical literature such as *Chapter 4: Soils and Water* is its emphasis on real experience and local wisdom, which can fill a void in the academic literature.

METHODS

This article uses a qualitative literature review approach to evaluate the contents of Chapter 4: Soils and Water in the book Managing Dryland Resources – An Extension Manual for Eastern and Southern Africa published by the International Institute of Rural Reconstruction (IIRR, 2002). The review process is carried out systematically through several stages. First, the researcher identified the content of the chapter to find the main themes that include soil conservation, pit composting, irrigation and drip irrigation, rainwater harvesting, and the use of sandy river water. This identification is important to obtain a conceptual framework that can be compared with contemporary academic literature. Second, these themes were then analyzed by comparing the results of the field studies from the chapter with the results of empirical research published in the international journal Scopus.

The literature sources used were selected based on relevance to the issue of soil and water management in drylands. Priority articles are scholarly publications in the last two decades, including meta-analyses, field case studies, and policy studies. Some of the keywords used in the literature search include "soil and water conservation in drylands," "rainwater harvesting," "drip irrigation," "sustainable land management," and "local water harvesting innovations." Literature searches are conducted through international scientific databases such as Scopus, ScienceDirect, SpringerLink, and the Wiley Online Library, which guarantee access to peer-reviewed articles.

Literature analysis was carried out using the comparative synthesis technique, which is comparing the findings of Chapter 4 with relevant scientific research. This technique allows researchers to identify similarities, differences, and uniqueness of the chapter compared to recent academic studies. In addition, the researcher also emphasizes critical evaluation of emerging research gaps, such as the lack of quantitative data in practical chapters compared to more measurable scientific research. This approach is in line with the narrative review method widely used in sustainable development studies, where narrative and empirical data are combined to provide a comprehensive picture (Snyder, 2019).

To maintain the validity of the analysis, the review process is carried out with the principle of academic transparency. Each finding from the book chapter is examined triangulatively against empirical evidence from other relevant research. If there is a gap between field practice and scientific evidence, it is used as a basis for identifying areas of further research. Thus, the methods used are not only descriptive, but also evaluative and reflective, with the aim of producing critical analysis and can be used for future research and policy development.

This approach was chosen because it is in accordance with the purpose of the research, which is to provide a critical evaluation of the book chapters that are practical in nature by comparing them to a broader scientific evidence base. Through this method, it is hoped that this article will be able to make an academic contribution in the form of a synthesis between practical knowledge in the field and an academic conceptual framework, so as to strengthen the literature on soil and water management in drylands, both in the context of Africa and Southeast Asia.

RESULTS AND DISCUSSION

1. Soil and Water Conservation Strategy

Soil and water conservation is a fundamental aspect of sustainable development in dryland areas. Chapter 4: Soils and Water emphasizes that soil conservation techniques such as fanya juu terraces, tied ridges, agroforestry, and mulching are relatively simple solutions but have a significant impact on increasing productivity. The main goal of this technique is to reduce the rate of erosion, improve water infiltration, and maintain soil fertility. With dry land conditions characterized by low rainfall and soils that are vulnerable to degradation, soil and water conservation is key in maintaining ecosystem stability while supporting community food security.

The global literature supports the urgency of this strategy. Montgomery (2007) showed that soil conservation practices can reduce topsoil loss by up to 50%, which has direct implications for the sustainability of agricultural productivity. A meta-analysis by Adil (2024) confirms that the conservation tillage system in China's drylands improves the soil's ability to store water while improving wheat yields. These findings are in line with Schwilch et al. (2013), who concluded that the implementation of sustainable land management (SLM) can reduce soil degradation by up to 60% and increase agricultural yields by 40% in the medium term. Thus, there is a scientific consensus that soil and water conservation strategies are not only relevant, but also empirically effective.

Even so, Chapter 4 places more emphasis on technical descriptions without including quantitative data as a measure of success. This is in contrast to academic approaches that tend to emphasize numbers-based evaluation. For example, Schwilch et al. (2013) used quantitative methods to assess the impact of SLM on agricultural yields, resulting in more objective and measurable data. The lack of numerical data in the book chapter shows that there is a research gap that needs to be bridged, especially through field research that can systematically measure the effectiveness of conservation techniques practiced by the community.

In addition to technical aspects, soil and water conservation is also closely related to social and institutional factors. Nkonya et al. (2011) emphasized that the success of conservation in drylands is not only determined by technical methods, but also by institutional support, public policies, and economic incentives for farmers. In this context, Chapter 4 is still relatively limited in discussing how local institutions or farmer organizations can strengthen the implementation of conservation techniques. In fact, the literature shows that long-term success is highly dependent on institutional factors and resource governance.

Overall, the soil and water conservation strategies presented in Chapter 4 are relevant to the practical needs of smallholder farmers on drylands. However, to strengthen its contribution in the academic literature, further research is needed that presents quantitative data, cost-benefit analysis, and institutional studies. The integration of practical knowledge with scientific approaches will allow these conservation strategies to become not only technical guides, but also a more robust conceptual framework in dryland management.

2. Fertility Improvement and Land Rehabilitation

In addition to soil and water conservation, Chapter 4: Soils and Water emphasizes the importance of improving soil fertility as the foundation of agricultural productivity in drylands. One of the main methods introduced is pit composting, which is the technique of making compost in holes in the ground by utilizing local organic waste. Compost functions as a nutrient enhancer, while increasing the soil's capacity to store moisture. For smallholders with limited access to chemical fertilizers, this method is a cheap, simple, and sustainable solution.

Scientifically, this practice has strong support. Lal (2020) stated that organic inputs such as compost can increase the soil's water-holding capacity as well as improve the chemical and physical properties of the soil, including nitrogen, phosphorus, and organic carbon content. The research of Mäder et al. (2002) also showed that organic-based farming systems with the use of compost increase the diversity of soil microbes that play an important role in nutrient cycling. Thus, pit composting is not only a short-term solution, but also supports the long-term sustainability of soil ecosystems.

In addition to compost, this chapter presents the success story of gully rehabilitation that has been severely eroded into productive land. This story confirms that land degradation, although severe, can still be reversed with appropriate intervention and individual perseverance. This approach is in line with the literature on community-based land management, which emphasizes the important role of local communities in the long-term success of land conservation and rehabilitation (Pretty, 2003). This story also shows the potential for social and ecological transformation that can occur through local innovation.

However, the narrative in this chapter is still limited to inspirational descriptions and is not accompanied by a systematic analysis of the factors that affect the success of rehabilitation. The academic literature highlights that dryland rehabilitation requires institutional and public policy support. Descheemaeker et al. (2009), for example, emphasize that access to resources, policy support, and coordination between stakeholders are key determinants in the success of ravine rehabilitation in Ethiopia. This shows that there is a gap in the chapter, where institutional and policy factors have not received adequate attention.

In addition, the economic aspects of fertility improvement and land rehabilitation practices are also rarely discussed. In fact, according to Pimentel et al. (1995), global soil degradation causes economic losses of billions of dollars per year due to lost productivity and increased rehabilitation costs. A cost-benefit analysis of practices such as pit composting or ravine rehabilitation can provide a clearer picture of their economic value to smallholders.

Thus, the fertility improvement and land rehabilitation introduced in Chapter 4 have high practical relevance. This practice not only improves soil quality, but also shows the potential for social transformation through local innovation. However, in order to be stronger as an academic reference, this practice needs to be supported by quantitative data, economic analysis, and institutional studies. The integration between local practice and scientific analysis will enrich the soil conservation literature and make it more applicable in supporting food security and environmental sustainability in drylands.

3. Water Management: Irrigation and Rainwater Harvesting

Water management is the most crucial issue in dryland areas due to low rainfall, erratic seasonal distribution, and high evaporation rates. Chapter 4: Soils and Water emphasizes two main approaches to water management: water-saving irrigation, especially drip irrigation, and rainwater harvesting. These two strategies offer different but complementary solutions in an effort to increase water availability for agriculture and households.

Drip irrigation is seen as one of the most efficient technologies in the utilization of agricultural water. This system delivers water directly to the plant's root zone through a small network of pipes, reducing water loss due to evaporation and percolation. Keller and Bliesner (1990) noted that drip irrigation can increase water use efficiency by up to 90%, much higher than traditional surface irrigation systems. Postel et al. (2001) added that the implementation of small-scale drip irrigation can help poor farmers increase agricultural yields while saving water, thus having a dual impact on food security and resource management. However, the main challenges in the adoption of this technology are the high initial investment costs, limited input market access, and lack of technical capacity for maintenance. Unfortunately, Chapter 4 only presents technical instructions for installation and maintenance, without discussing in detail the economic or policy aspects that affect adoption.

In addition to irrigation, this chapter also emphasizes rainwater harvesting as an adaptive strategy to deal with climate uncertainty. Techniques such as small reservoirs, water storage tanks, and half-moon catchments were introduced as community-based solutions that were easy to implement. Văn et al. (2013) emphasized that rainwater harvesting can increase household and agricultural water reserves, as well as strengthen food security in semi-arid regions. Research by Rockström et al. (2010) shows that rainwater harvesting practices are able to increase agricultural yields by up to 50% in sub-Saharan Africa, with the greatest positive impact occurring in dry seasons.

Although it has great potential, the main challenge in rainwater harvesting is the institutional aspect. Ngigi (2003) emphasized that the success of this technology is highly dependent on collective governance, especially in terms of water distribution and infrastructure maintenance. Chapter 4 does not address this aspect very well, whereas the academic literature shows that long-term success is determined not only by technology, but also by the capacity of local organizations and policy support.

Overall, Chapter 4 succeeds in highlighting water management as the key to adaptation in drylands, but it is still weak in discussing the socio-economic dimension. By strengthening the integration between technical, institutional, and policy aspects, irrigation and rainfall harvesting strategies can be a comprehensive solution for water management in dry areas, including in Indonesia.

4. Local Innovation and Global Relevance

One of the most interesting contributions of Chapter 4: Soils and Water is the emphasis on local innovations that have proven to be effective in the context of drylands. This chapter reviews the use of sandy rivers through the construction of subsurface dams, which allow for the storage of water under the sand layer. This technique reduces evaporation, maintains water quality, and provides a sustainable supply even months after the rainy season ends.

The uniqueness of this technology lies in its simplicity and affordability, which makes it suitable for communities with limited resources. Lasage and Verburg (2015) show that underground dams in Kenya are capable of providing clean water for up to months after rain, with low maintenance costs and significant social impacts on people's well-being. These findings reinforce the idea that locally-based solutions are often more adaptive and sustainable than large-scale technology interventions that require expensive investments and complex institutional support.

From a scientific perspective, the integration of local innovations such as underground dams with modern technologies such as drip irrigation creates a framework of hybrid innovation that is gaining more and more attention in the sustainable development literature. Pretty (2003) emphasizes that the success of natural resource management depends heavily on the involvement of local communities, who are not only recipients of technology, but also as developers of solutions according to their needs. Local innovation is not only technical, but also social, as it reinforces a sense of belonging, community solidarity, and long-term sustainability.

The relevance of this innovation is not limited to Africa. Dry tropical regions in Indonesia, such as West Nusa Tenggara (NTB) and East Nusa Tenggara (NTT), have agro-ecological conditions similar to East Africa, namely low rainfall, soil susceptible to erosion, and uneven water distribution. Simple practices such as composting pits, rainwater harvesting, and underground dams can be directly adapted. This supports the idea that knowledge transfer across the world's dry regions can accelerate the search for sustainable solutions to global challenges (Reynolds et al., 2007).

However, despite its great potential, Chapter 4 is still limited in providing a comparative analysis of local innovation and modern technology, especially in terms of cost-effectiveness and long-term impact. Further research is needed to evaluate the potential replication of these innovations in different social, cultural, and institutional contexts. Thus, the integration of local innovation with national policies and scientific support is crucial for this practice to evolve from a local solution to a global contribution.

Overall, the local innovations highlighted in Chapter 4 affirm the importance of valuing local wisdom in dryland management. Its relevance is vast, not only for Africa but also for Southeast Asia. By combining local innovation and scientific approaches, there is a great opportunity to develop a more inclusive, adaptive and sustainable land and water management framework at the global level.

CONCLUSION

A review of Chapter 4: Soils and Water in the book Managing Dryland Resources – An Extension Manual for Eastern and Southern Africa shows that soil and water management is the key to maintaining agricultural productivity and sustainability in dryland areas. This chapter presents a variety of strategies, ranging from soil and water conservation, improved fertility through pit composting, rehabilitation of degraded land, water management through economical irrigation and rainfall harvesting, to local innovations such as underground dams in sandy rivers.

In terms of relevance, the techniques introduced are proven to be in line with the academic literature that emphasizes the importance of sustainable land management (Schwilch et al., 2013; Lal, 2020). However, the main weakness of this chapter is the lack of quantitative data, economic analysis, and discussion of institutional and policy aspects that greatly determine the success of implementation. This opens up a research gap that needs to be bridged through data-driven empirical research, especially related to the long-term effectiveness, cost-benefits, and socio-economic impact of the proposed practice.

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