land

Perspective

Sustainable Land Management and Climate Change Adaptation for Small-Scale Land Users in Sub-Saharan Africa

William Critchley [1,*], Nicole Harari [2,*], Eefke Mollee [3], Rima Mekdaschi-Studer [2] and Joana Eichenberger [2]

[1] Associate Researcher, World Overview of Conservation Approaches and Technologies (WOCAT), Sustainable Land Management Associates, Ltd., Pitlochry PH165EW, UK
[2] WOCAT, Centre for Development and Environment, University of Bern, 3012 Bern, Switzerland; rima.mekdaschi-studer@unibe.ch (R.M.-S.); joana.eichenberger@unibe.ch (J.E.)
[3] School of Natural Sciences, Bangor University, Bangor LL572DG, UK; e.mollee@bangor.ac.uk
* Correspondence: williamcritchley01@gmail.com (W.C.); nicole.harari@unibe.ch (N.H.)

Abstract: Land is both a source and a sink of carbon dioxide (CO_2), the chief greenhouse gas. Through sustainable land management (SLM), it can capture extra CO_2 and store it as carbon in vegetation and soil. SLM can also reduce CO_2 emissions from the land. Thus, SLM is viewed as the key land-based solution for climate change mitigation. Yet, SLM also provides effective climate change (CC) adaptation practices—such as agroforestry, mulching and water harvesting—which confer resilience, and simultaneously help secure production. This is especially valuable for land users in sub-Saharan Africa (SSA) who depend on rainfed agriculture. They are amongst the poorest on Earth and the most vulnerable to CC impacts, despite their minimal carbon footprint. The World Overview of Conservation Approaches and Technologies (WOCAT) manages the Global SLM Database: this holds a rich and ever-growing collection of SLM practices. Analysis of the database for rainfed SSA sheds light on which SLM technologies are effective in CC adaptation, and how well they cope with changing rainfall and temperature. Both "mechanisms" and "attributes" are explored, yielding new insights. This perspective paper showcases current developments in the field, and summarizes future directions for SLM as a CC adaptation solution for land users in SSA.

Keywords: sustainable land management; climate change adaptation; climate change mitigation; sub-Saharan Africa; Global SLM Database

check for updates

Citation: Critchley, W.; Harari, N.; Mollee, E.; Mekdaschi-Studer, R.; Eichenberger, J. Sustainable Land Management and Climate Change Adaptation for Small-Scale Land Users in Sub-Saharan Africa. *Land* **2023**, *12*, 1206. https://doi.org/10.3390/land12061206

Academic Editors: Dongxue Zhao, Daniel Rodriguez, Feng Liu and Tibet Khongnawang

Received: 18 April 2023
Revised: 26 May 2023
Accepted: 30 May 2023
Published: 10 June 2023

1. Introduction

The land has close links with climate change (CC), being both a source and a sink of carbon dioxide (CO_2)—the chief greenhouse gas (GHG) [1]. Importantly, there is considerable potential for the land to absorb much more CO_2, thus augmenting the sink. This can be achieved principally through increased photosynthesis, and greater storage of carbon in vegetation, surface litter and the soil. It is also possible to reduce CO_2 emissions, thereby decreasing the source. In this case, the key pathway is minimizing land use change and land degradation. Lal suggests that the potential of carbon sequestration (storage) in soil and vegetation—between 2020 and 2100—is drawdown of atmospheric CO_2 by "roughly" 157 ppm [2]. This represents just over a third of the current atmospheric levels of CO_2. The means to reach this goal is through improved sustainable land management (SLM).

SLM comprises a range of actions that maintain and improve the land and its ecosystem functions (see Box 1) [3]. Although SLM is most widely known for its role in soil and water conservation [4], more recently, it has been acknowledged as the key "land-based solution" in achieving CC mitigation through the twin pathways of capturing more CO_2 and reducing CO_2 emissions.

Less widely known is the fact that SLM can provide effective CC adaptation solutions, thereby enabling people to cope with CC impacts [1,5–7]. Various SLM options, for example, agroforestry, reduced till farming, mulching the soil surface with plant residues, and water harvesting, deliver adaptation benefits and resilience. This is of massive importance to small-scale land users in developing countries. SLM practices can strengthen their ability to adapt to impacts—such as rising temperatures and declining rainfall—at a household scale. At a higher level, CC adaptation through SLM can confer greater resilience to farmland ecosystems. However, SLM's role in relation to CC has often been seen simply in terms of CC mitigation. CC adaptation, when considered at all, has been perceived as a fortunate co-benefit of mitigation. Thus, since the early 2000s, projects and programs have prioritized CC mitigation in their rural interventions—especially through tree planting—and CC adaptation has been underplayed. The World Bank expresses grave concern:

"The urgent need for boosting investment in climate change adaptation and resilience cannot be overestimated . . . finance flows . . . still fall short of what is needed to avoid severe economic and human impacts from climate change, especially in developing countries. Adaptation has been underplayed despite it being a priority for land users struggling to deal with a rapidly changing—and hostile—natural environment" [8,9].

Sections of the international press share this view: the Economist wonders "why poor farmers in Africa who have done almost nothing to make the climate change [should] be abandoned to suffer", when "a lot of adaptation is affordable" [10]. Land users in developing countries who depend on low-input, rainfed agriculture are amongst the poorest on Earth and the most vulnerable to climate change impacts, despite having a minimal carbon footprint [11]. They are the least culpable of causing CC, yet amongst the most afflicted by its consequences [12]. Figure 1 shows just how low the GHG emissions per capita are in Africa compared with the USA, the EU and China. Total emissions for the whole of Africa in 2021 were, for example, only 1.45 billion tons CO_2-eq[1] compared with China at 11.47 billion tons [13]. Furthermore, African emissions are strongly skewed towards North Africa: the poorest countries in sub-Saharan Africa (SSA) produce, and have produced, insignificant amounts of global GHGs.

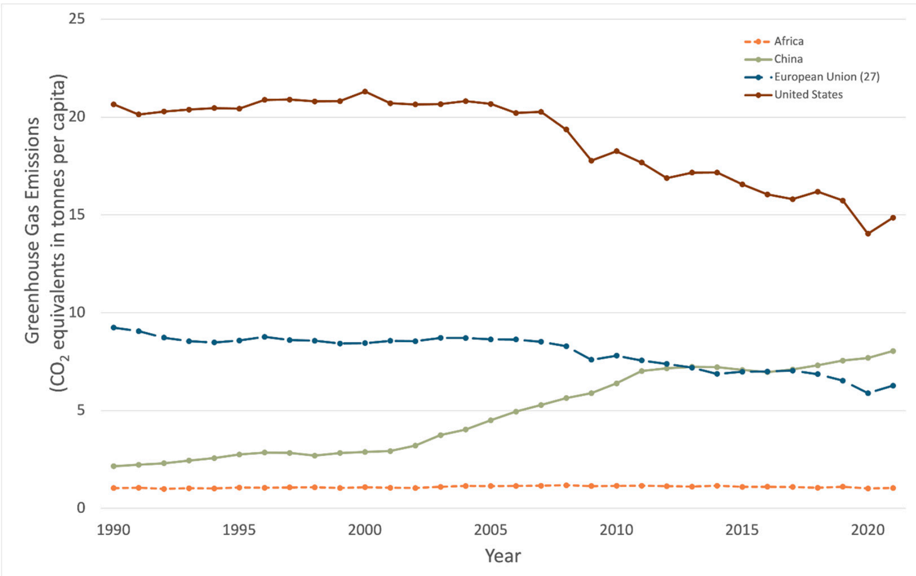

Figure 1. Per capita greenhouse gas emissions (selected). Source: Our World in Data based on the Global Carbon Project [13].

It is time to turn the spotlight on climate change adaptation through SLM for smallholders within rainfed zones of SSA. We argue that more rapid progress is likely to be made in securing the livelihoods of these land users if their perceived needs are prioritized: needs that often coincide with what SLM can provide, including greater resilience through CC adaptation. This community of people—women, men; young and old—respond to SLM options that can help them protect and enhance their livelihoods, and most especially secure production from the land.

Our "perspective paper" showcases current developments in the field of CC adaptation through SLM. Specifically, it assesses the role of SLM in adaptation through analysis of the World Overview of Conservation Approaches and Technologies (WOCAT)'s Global SLM Database. The attributes of SLM groups are discussed, and the mechanisms through which the technologies achieve impact are examined. Finally, future directions are proposed to stimulate the adoption of SLM solutions for better CC adaptation and thus more resilient land and livelihoods.

2. Problems and Principles: The Need for Climate Change Adaptation and the Role of Sustainable Land Management

2.1. Climate Change, Challenges and Coping Capability

Approximately 3.4 billion people live in rural areas and many are highly vulnerable to climate change [11]. Amongst them are smallholders who are dependent on rainfed farming in SSA—they provide up to 80% of the region's food and manage vast areas of land [14]. They are especially vulnerable, and that vulnerability is a significant driver of fragility [15,16]. Climate change will exacerbate vulnerability and increasingly put pressure on production, undermining food security and nutrition. Impacts will not be evenly spread, and they will be unpredictable. In some areas, there may even be benefits from increased rainfall—for example, in specific locations of West Africa where rice yields could increase, but such cases are exceptions [17]. The negative consequences heavily outweigh any incidental, and localized, benefits.

More than 30 years ago, Simonett predicted one specific detrimental impact of a 2 °C rise in temperature—the shrinking suitability zones for the cash crops of robusta coffee (*Coffea canefora*) in Uganda, and tea (*Camellia sinensis*) in Kenya [18]. More recently, a modelling exercise has shown that under different CC scenarios, the area under arabica coffee (*Coffea arabica*)—with its stringent climatic requirements—is under severe threat in East Africa. The most favorable outcome by 2080 is a 38% reduction in suitable bioclimatic space, and the least favorable is a *circa* 90% reduction [19]. Already, agricultural growth in Africa has been reduced by 34% since 1961 due to climate change—more than any other region [11,20]. In SSA, loss of lives, reduced food production, biodiversity loss, water shortages, and reduced economic growth have already occurred [20] and are accelerating. Despite drier and hotter conditions overall, the intensity and erosivity of rainfall when it occurs is likely to increase, triggering floods and accelerating soil erosion.

Land users have always had coping mechanisms to deal with a broad array of environmental and economic pressures and shocks: amongst them, droughts, pests, diseases, and erratic markets. Coping mechanisms have their ancient origins in local innovation, and have been absorbed into tradition over time [21]. Now, innovative capacity—and the age-old means of learning from one another—is being given more immediacy as new, and more virulent threats from climate change are emerging, even if it appears that "the speed and intensity of environmental change is outpacing that capacity" [14]. This comment arguably underestimates the abilities of smallholders but underscores the urgency of stimulating the process of innovation, for example, see [22,23].

Adaptation to climate change will help to stabilize production through buffering extremes and improving the resilience of systems. It will simultaneously deliver adaptation against other stresses and shocks. The Intergovernmental Panel on Climate Change (IPCC) acknowledges that adaptation "can generate multiple additional benefits such as improving agricultural productivity, innovation, health and well-being, food security, livelihood[s] and biodiversity conservation as well as reduction of risks and damages [sic] . . . but most observed adaptation is fragmented [and] small in scale" [11].

2.2. Adaptation and Resilience: The Ability to Absorb and Bounce Back

Definitions of adaptation abound, and increasingly tend to merge with those of resilience. Indeed, the two terms are often used interchangeably. The IPCC characterizes resilience as being "the ability to maintain essential function, identity and structure with a capacity for transformation" and adds that adaptation may be anticipatory or reactive [11]. This does not differ significantly from IFAD's description of resilience as the "extent to which social or ecological systems can maintain integrity and functionality when subject to disturbance" [14]. The disturbance may be gradual and persistent stress, or abrupt shocks. The Green Climate Fund puts it simply: "Climate change adaptation aims to improve resilience of communities and ecosystems" [24]. Explicit in this latter definition is that adaptation is to do with resilience of both people and the land [25]. "Sustained system stability" can be considered an overarching goal of adaptation. Based on the Natural Capital Framework, resilient systems share various characteristics [14,26]. These capitals/assets are:

- Financial capital:
  - For example, on-farm income and access to markets.
- Social capital:
  - For example, equity, inclusiveness, connectivity and social cohesion.
- Human capital:
  - For example, knowledge management, learning and innovation.
- Physical capital:
  - For example, labor availability and infrastructure.
- Natural capital:
  - For example, soils and plant and livestock resources.

2.3. Mitigation and Adaptation: Related, but Different

Mitigation of climate change through SLM is a clear concept. It can be quantified in terms of a carbon-dioxide-equivalent balance (a calculation of (a) carbon sequestered and (b) greenhouse gas emissions reduced: see Section 2.5). However, adaptation to a changing climate is a "fuzzier" notion—less clear-cut, and notoriously difficult to measure. The benefits of adaptation through SLM are equally hard to calculate, or indeed to specify, and the ways and means of how adaptation is achieved are complex and intertwined. Building up soil organic carbon (SOC), which is a direct goal of mitigation projects, is generally accepted as establishing the natural resource base to ensure adaptation solutions and underpin strategies. "Re-carbonization" of the terrestrial biosphere is considered by some as being a bedrock of sustainable development, and the importance of restoring soil organic matter (SOM)[2] is stressed in order to set in motion a "nature-positive trend" towards both adaptation and the mitigation of climate change [2]. However, increased SOC/SOM levels cannot be taken as a direct proxy for improved resilience, and the assumption that adaptation is merely a beneficial by-product of mitigation is simplistic and unhelpful. This point is elaborated further in the context of how SLM "works" (Section 2.5).

While mitigation potential and targets are often specified for various forms of land-based SLM, adaptation has no equivalent. Furthermore, its boundaries are vague: according to the IPCC, there are "soft limits" (where options exist but are currently not available in specific settings) and "hard limits" (where no further adaptative options are currently known to be effective) [11]. Adaptative capacity, at the smallholder level, can obviously be exceeded by increasing climate change extremes, and land users overwhelmed. Because of the hard limits, it can only provide a partial remedy, and may merely confer temporary respite. Nevertheless, adaptation through SLM can, at least, enable land users to engage in the struggle, become more self-reliant, and earn a reprieve from the most immediate CC impacts.

2.4. Sustainable Land Management: From Soil Conservation to an Environmental, Livelihoods and Climate Change Approach

"Sustainable land management" emerged as concept in the late 1990s, having evolved through "soil conservation" in the early 20th century and "soil and water conservation" in the 1980s. There has been a gradual but profound transformation from the narrow confines of engineering-based solutions to soil erosion problems, onto a broader land husbandry emphasis [28]. The new concern reflects and supports land users' priorities of securing their natural resource base for production and economic gain. This has brought it fully into line with the aims of the United Nations Convention to Combat Desertification (UNCCD) and the goal of achieving land degradation neutrality (LDN), and there has also been a fortuitous convergence with the aims of the other two "Rio Conventions": the UN Convention on Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC). SLM, with its broad remit, has helped unite the three interconnected purposes and delivers on all fronts (see Figure 2). The Global Environment Facility (GEF) states that "The three Rio Conventions have overlapping concerns . . . [and] . . . through adoption of SLM, countries can implement the conventions in a collaborative way that address climate change . . . " [29].

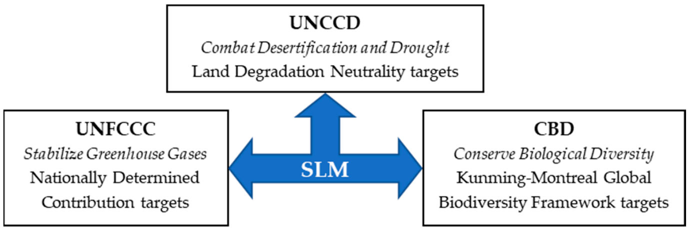

Figure 2. The Three Rio Conventions grouped around SLM: adapted from Sanz et al. [5].

In response to concerns about the land and ecosystem deterioration, a number of methodologies and approaches have emerged that are related to, or are partly synonymous with, sustainable land management. Some of the key terms are defined in Box 1 and a simple description has been allocated to each as an *aide memoire*.

Box 1. Relevant terminology: official definitions *(with simplified definitions in the context of this publication in italics)*.

Sustainable land management: *"looking after the land to maintain & improve its functions"*

- The use of land resources, including soils, water, animals and plants for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions [3].

Climate-smart agriculture: *"farming for production, CC mitigation & CC adaptation"*

- Systems that aim to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible [30].

Ecosystem-based disaster risk reduction: *"reducing risk & building resilience in ecosystems"*

- The sustainable management, conservation and restoration of ecosystems to provide services that reduce disaster risks by mitigating hazards, and by increasing livelihood resilience [31].

Ecosystem-based adaptation: *"managing ecosystems to help people adapt to CC impacts"*

- The use of biodiversity and ecosystem services as part of an overall adaptation strategy. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change [32].

Land restoration: *"regenerating degraded land for multiple purposes"*

- The process of avoiding, reducing and reversing land degradation to recover the biodiversity and ecosystem services that sustain all life on Earth. Land restoration refers to a regenerative process along a continuum of SLM practices that can be applied to conserve or rewild natural areas, upscale nature-positive food production in rural landscapes and green urban areas, infrastructure and supply chains [33].

Nature-based solutions: *"solutions to societal problems supported by natural processes"*

- Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits [34].

Regenerative agriculture: *"integrated & diverse farming systems that restore soil health"*

- An integration of agroecology and sustainable intensification, with a strategy of creating a soil/ecosystem carbon budget so that the terrestrial carbon stock (soil and vegetation) is restored and on an increasing trend. At its core is the goal of restoring soil organic matter (derived from [2]).

2.5. Sustainable Land Management: How It Works for the Land and the People

Sustainable land management functions by protecting and restoring land—meaning soil, water in the soil, flora and fauna—with an overarching aim of achieving land degradation neutrality and ecosystem restoration [3,7]. As already noted, production is improved, biodiversity increased, hydrological function enhanced, and there are both CC mitigation and adaptation benefits (Figure 3). Soil organic carbon levels can be raised, and vegetative production increased. This biomass is fundamental to circular agricultural systems [35]. The UNCCD has recently produced valuable guidelines for estimating SOC in the context of addressing LDN [36]. The report fully acknowledges the role of SLM in building up stocks of SOC, which it sees as being the "potential centerpiece for collaborative action to improve soil health and functions". While the focus is on SOC's role in securing soil health, a meta-analysis that was quoted in the report shows that crop yields are boosted up to SOC concentrations of around 2% [37]. The report points to the role of SOC in terms of climate change mitigation and—though to a lesser extent—climate change adaptation.

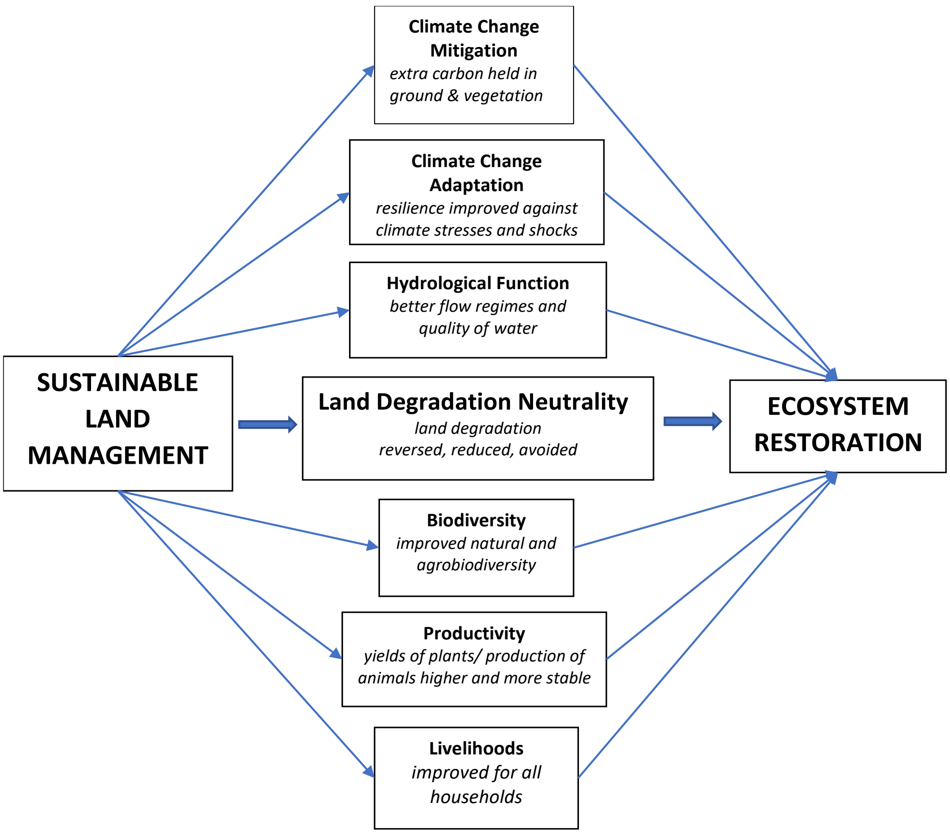

Figure 3. Sustainable land management: multiple roles and impacts (adapted from Critchley et al. [7]).

Monitoring and modelling of carbon benefits from projects and other interventions has been recently developed through the "carbon benefits tool" [38]. The relevant tools are available online [39] and provide a simple assessment of the impacts of land use and land management on carbon storage and GHG emissions. For all interventions, net GHG benefits are expressed as tons of carbon dioxide equivalents (CO_2-eq) per hectare.

At the global level, Nationally Determined Contributions (NDCs), introduced in 2015 at the UNFCCC Conference of Parties (CoP) in Paris, have focused sharply on reduced future emissions compared with "business-as-usual". In 2016, the FAO reported that the land use, land use change and forestry (LULUCF) sector was the most frequently cited under countries' mitigation targets and actions [40]. As welcome as this is, the NDC program has, perhaps, acted inadvertently to draw attention away from National Adaptation Plans (NAPs)—introduced in 2010 at the UNFCCC CoP in Cancun, which (where they exist) are inevitably more qualitative and less precise, with their tendency to list on-going and planned projects which touch upon adaptation. Mitigation is self-evidently important, but it can overshadow adaptation. In an analysis of NDCs, it is CC mitigation that receives the lion's share of attention and certainly the emphasis, with adaptation often mentioned merely as an associate of mitigation [40]. There is certainly scope for better coordination between NAPs and NDCs [41]. The corollary is that many international initiatives and associated public awareness continue to focus strongly on CC mitigation. Even more worryingly, land-based solutions to mitigation rely overwhelmingly on afforestation/reforestation (see Box 2).

As we have noted, SLM is attractive to impoverished land users, primarily because it improves crop and livestock production. This attribute often flies under the radar and is not given sufficient notice or attention. In sub-Saharan Africa, land users in rainfed, increasingly drought-prone areas comprise the target group of many development agencies. Those farmers and pastoralists' livelihood priorities are, and have been for centuries, coping with adversity for their own survival through forms of SLM. Their priorities must be respected and supported.

Box 2. Planting trees as the solution? Or alternative answers? SLM for carbon sequestration.

Over the last fifty years in sub-Saharan Africa, **tree planting** has consistently been promoted as a solution, first for environmental woes, and more recently for climate change concerns. The number of trees planted is often a target in itself. Trees can indeed sequester carbon very rapidly: rates of up to 15 t/C/ha/yr have been estimated for rapidly growing plantations [42]. However, one of several concerns with large-scale **afforestation** (planting trees where there were none before) is the opportunity cost of land [1]. Indeed, "**maladaptation**" can occur where, without consulting land users or considering future management, afforestation has been popularized as a "green solution" [11,43]. Commonly, inadequate consideration is given to species suitability, and monitoring is generally woeful; one study shows that only 5% of tree planting agencies have measured seedling survival [43]. Even where monitoring is in place, for example, under the "Great Green Wall" initiative across the Sahara and the Sahel, achievements are modest; just 20% of the 100 million ha. targeted by 2030 have been "restored" [44].

Afforestation in blocks should not be confused with **agroforestry** (usually voluntarily by land users themselves), which is a key pathway to improved agricultural systems, providing climate change mitigation, adaptation and other multiple co-benefits. Trees are planted in and around farmers' fields to restore degraded lands, protect crops and livestock against heat, and restore humidity as well as to enhance biodiversity and increase food security [45]. The success of this agroecological approach is notable: the total global carbon biomass on agricultural land has risen in the last ten years by around 4.6%, with trees accounting for more than three quarters [35,46]. Where indigenous forests exist, it goes without saying that their protection is paramount to protect carbon stocks and to secure vital biodiverse ecosystems.

An alternative for land-based carbon sequestration are the **grasslands**: the most threatened and least protected biome [47]. Existing grasslands—some 34 million km^2 or about 25% of the world's surface—can absorb vast extra amounts of carbon, with improved grassland management able to sequester potentially 0.47 tC/ha/yr. This feeds directly into the resilience of rural populations that depend on livestock [48]. Biodiverse grasslands also provide multiple ecosystem services. However, grasslands have not captured development attention [49]; it could be said that "grass lies low where trees stand tall" in the popular image of confronting climate change.

Peatlands are generally ignored in terms of carbon sequestration. Globally, peatlands cover 3–4% of the land surface and hold twice as much carbon as forests. Africa holds about 8% of the world's peatlands, notably in the Nile and Congo basins. Healthy peatlands sequester vast amounts of carbon (around 0.37 $GtCO_2$/yr); conversely, degrading peatlands contribute significantly to GHG emissions. They are also extremely biodiverse. For multiple reasons, the protection and rehabilitation of peatlands must be a priority [50,51].

Recently, the potential role of **biochar** in global carbon dioxide removal (CDR) and long-term storage has been highlighted [52]. Biochar—the product of partially oxidized biomass—has been proposed for several years now, especially as a soil amendment that confers long-lasting benefits to crops (see examples from Kenya and Sri Lanka documented by WOCAT [53], but the massive investment required to scale it up to the levels suggested by the authors (capture of 0.3–6.6 $GtCO_2$/yr) is currently unrealistic. Nevertheless, biochar certainly has a role to play in carbon sequestration—and in climate change adaptation—through its role in soil improvement.

Finally, a focus throughout this article is **soil organic carbon** increase through better SLM: a foundation for better production and land-based CC adaptation, as well as having huge potential for CC mitigation [2,36].

3. Practices: Sustainable Land Management Solutions for Climate Change Adaptation

3.1. WOCAT and its SLM Database

The World Overview of Conservation Approaches and Technologies (WOCAT) [54] manages the Global SLM Database [55]: this holds a rich and ever-growing collection of SLM solutions. It is officially recognized as the definitive SLM database by the UNCCD. From its inception in the mid-1990s, it has grown to house, at the end of 2022, over

1250 SLM "technologies" (on-the-ground solutions, such as terraces or windbeaks) and more than 500 associated SLM "approaches" (the ways and means of implementing those technologies, such as joint forest management or promoting farmer innovation). The entries in the database are derived from questionnaires compiled by those with hands-on knowledge of the practices. The questionnaire was first developed in 1994/95 and its core has remained constant, though specific questions have evolved. The focus here is on the technology questionnaire [56], and the documentation of those practices.

WOCAT's firm commitment, from the onset, has been to allow practitioners to record *their* experiences, and to seek *their* insights into the practices[3]. This was a deliberate attempt to move away from the prevailing system of outside "experts" producing technical guidelines. Nevertheless, submissions pass through an official quality control and review process before approval. However, many of the questions put to the contributors can only be answered in semi-quantitative terms [56]. For example, practitioners' views regarding the on-site impacts of a technology (including crop/fodder production, food security, surface runoff, soil cover, drought impacts, etc.) are requested on the basis of a scale, with seven grades ranging from "very negative" through to "very positive". This means that an analysis of the database (for many parameters) yields only semi-quantitative data. However, this represents the reality of those working with SLM in the field: where database entries lack the precision of trials carried out on research stations, these compensate by being more meaningful to practitioners, namely, land users and front-line field staff. A frequent reaction to the questionnaire is the appreciation of its educational value. Completing the questionnaire is a learning exercise itself, mainly because it enables the contributor to articulate—and appreciate the importance of—their (often) tacit knowledge in words, numbers, ratings and categories.

While the database does not claim to provide a fully representative sample or to be comprehensive, it is a unique collection of on-the-ground SLM solutions with good coverage, especially of the Global South. A very broad spectrum of activities in SLM are documented. Of the SLM technologies recorded, 419 originate from SSA, and of those, 384 are located on cropland or grazing land, or various combinations. This is a rich resource and provides the data to underpin our empirical analysis and arguments. Analysis of this database sheds light on SLM technologies in relation to climate change, as well as other related parameters. It is a unique opportunity to investigate what land users are doing in terms of SLM, how they perceive gradual climate change and how well their technologies are coping. The subset of 384 (see above) is the focus. As far as it is possible to determine from the records, 169 were submitted prior to 2016 (when specific climate change questions were introduced) and 215 after that date. Key findings from the analysis are presented here and discussed under relevant sub-sections of the database.

3.2. Cropland and Grazing Land in Sub-Saharan Africa: An Analysis

This first section of the analysis considers the "main purpose" of the technologies, as recorded in the questionnaire by the contributors, and entered in the database. This illuminates the multiple objectives of each technology, and importantly, in the context of this paper, shows how often CC aims are articulated. Figure 4 ranks the purposes cited by contributors.

a. Main purpose

The data presented in Figure 4 show clearly how contributors not only view SLM as being an antidote to land degradation (264 out of 384, or 69%: top bar), but simultaneously how the majority (198 or 52%) consider the practice they describe as being helpful in improving production from the land. More than a third (143 or 37%) anticipate extra income.

While the data regarding CC ("adapt to climate change" and "mitigate climate change") are included in Figure 4, it should be recollected that these potential answers were only introduced into the questionnaire post-2016. Thus, those numbers need to be analyzed in the context of the sub-sample of 215 technologies documented post-2016. A total of 1 in

3 of all contributors (66 out of 215, or 31%) specifically thought/perceived that their SLM technologies help them adapt to CC, while only 1 in 9 (26 or 12%) gave mitigation of CC as an impact. This highlights a clear land users' focus on adaptation rather than mitigation, underlining a central point that we are making in this paper.

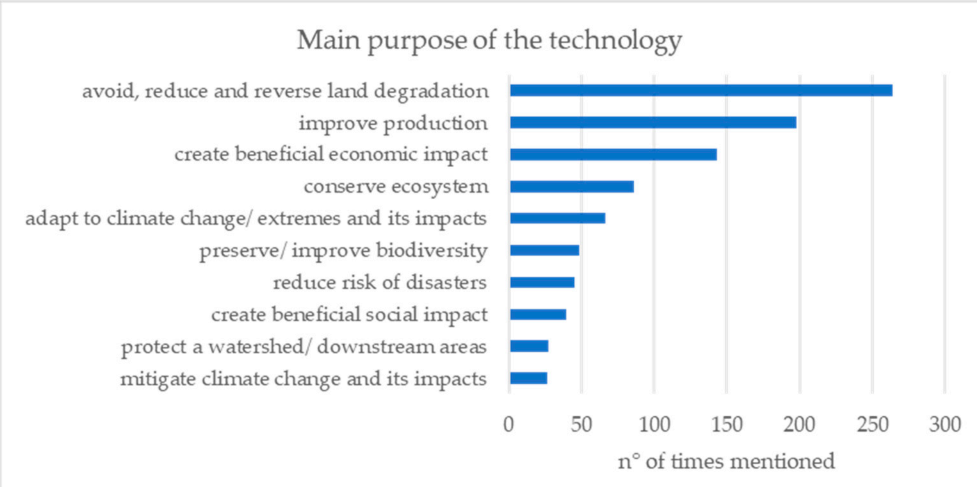

Figure 4. Main purpose of the SLM technology according to the contributors: up to five options can be chosen.

b. Response to gradual climate change

Moving on to how well the technologies respond to gradual changes in temperature and rainfall, Figure 5 shows the analysis, drawing on the sample of 215 that answered questions about CC. Temperature change was noted by almost all the contributors (208 or 97%), with a large majority pointing to a rise (199 or 96%). Of those noting the change in temperature, 70% of the technologies dealt "well" or even "very well" with that change; this became 82% when coping "moderately well" was included. A change in rainfall was much less frequently observed: only 56 (26%) noticed a change, of which 44 noted a fall and 12 observed a rise. Once again, the technologies were stated to cope well with these changes: 50% dealt "well" or "very well", and if "moderately well" was added, then 88% were coping to one extent or another.

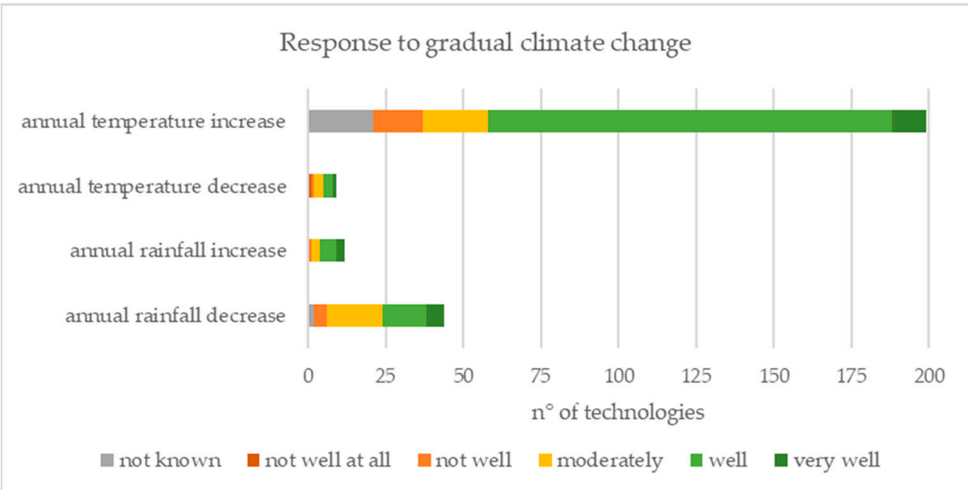

Figure 5. Response of the SLM technology to gradual climate change according to the contributors.

These answers broadly address the questions "have people perceived climate change?" and "is SLM effective in CC adaptation?". Yes, is the basic answer to both questions. Furthermore, more than four in five of those SLM technologies exposed to gradual CC were said to be coping. This points firmly to the inherent capacity of SLM to provide at least some protection from CC impacts.

c. Source of practice

We now look at the origin or source of the practice: was it introduced through an external intervention, or developed by the land users themselves? This is both relevant and interesting. Figure 6 presents the findings from the Global SLM Database.

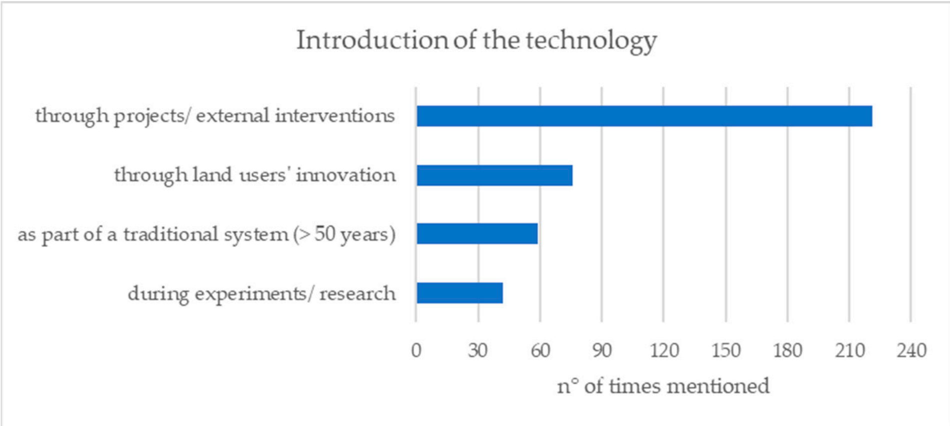

Figure 6. Introduction/origin of the SLM technology according to the contributors; more than one option can be chosen.

Land users' recent innovation accounted for 76 cases (20% of the overall sample), while tradition (which can be interpreted as a result of "historical" innovation) accounted for 59 cases (15%)[4]. This confirms that land users are being (and have traditionally been) creative and have come up with solutions for themselves in around a third of the technologies documented. It points towards an avenue for future support: stimulating land users to innovate and generate new adaptation solutions themselves.

d. SLM Grouping

The sample of technologies was examined for how it segregated into SLM groups. Under WOCAT, 26 groups are defined [56]. However, each technology can either be assigned by the contributor to a single group, or up to three in total if a single group does not cover that practice entirely. For example, a "two group technology" may be one that describes a combination of trees with crops (thus, a first group: *agroforestry*) but also incorporates composting and manuring (thus, a second group: *integrated soil fertility management*). Most practices (217 or 57%) of the overall sample of 384 "belong to" two or more groups according to the contributors. Because of this, a single technology, as described in the database, often appears more than once in Table 1 below, and it explains why the total of these six (most common groups) exceeds the overall total of technologies in the sample.

Two things stand out. The first is the wide variety of grouping (and thus, the range of SLM), and secondly, the fact that so many groups are combined. In other words, when describing a technology for the database, contributors are regularly painting pictures of complex systems. This already hints at skillful combinations that are likely to spread risks and yield multiple co-benefits, including that of CC adaptation. Table 2 now looks at the "main purposes" of the groups listed above in relation to CC—the option introduced post-2016 (Figure 4).

Table 1. Most common SLM groups in SSA under cropland and grazing land.

SLM Group	Total (Number of Times Cited in the 384 Technologies)	Alone (Number of Times Alone)	Mixed (as % of Total) (Number and Percent of Times Cited Alongside)
Improved ground/vegetation cover	97	8	89 (92%)
Cross-slope measure	80	41	39 (49%)
Integrated soil fertility management	61	11	50 (82%)
Water harvesting	51	10	41(80%)
Pastoralism and grazing land management	46	15	31 (67%)
Agroforestry	42	5	37 (88%)

Table 2. SLM groups and climate change: their purpose and how well they cope.

SLM Group	Main Purpose		How Well They Coped with Gradual Climate Change (Where Noted)	
	Mitigate climate change	*Adapt to climate change*	*Coped well/ very well with change in temperature*	*Coped well/ very well with change in rainfall*
Improved ground/vegetation cover	12%	20%	68%	67%
Cross-slope measure	03%	05%	83%	50%
Integrated soil fertility management	10%	25%	49%	47%
Water harvesting	12%	31%	63%	36%
Pastoralism and grazing land management	17%	33%	53%	35%
Agroforestry	17%	38%	56%	56%

We have already shown in Figure 4 that, taking the post-2016 sub-sample of 215 practices, 12% include "mitigate climate change", while 31% include "adapt to climate change". Therefore, the breakdown in Table 2 is no surprise. However, there is one notable exception: cross-slope barriers. There are two probable reasons for this. First, during the early years of documentation, there was an emphasis on cross-slope barriers—which were the most familiar type of SLM (or "soil and water conservation")—namely terraces, stone bunds, and vegetative barriers. Secondly, these classic soil conservation structures tended to have their origin in the need to stabilize steep slopes for cultivation while reducing soil erosion and controlling runoff, and little thought was given to documenting or analyzing other co-benefits. This ties in with Table 1, where cross-slope barriers are the only group where less than half are reported as being mixed (where "mixed" tends to imply multipurpose).

3.3. Technology Group Options for Climate Change Adaptation

Thus, six SLM technology groups headed the list in terms of frequency of reporting. These groups have emerged because of their direct relevance to livelihoods in the croplands and grazing lands of sub-Saharan Africa (see Table 1). They have, furthermore, demonstrated that, in general, they are all considered relatively important in terms of CC adaptation (see Table 2). Table 3 describes what these groups entail: the wording is taken from the WOCAT questionnaire where guidelines have been prepared for the contributors [56]. For each, an example is cited from the sample analyzed. Links are given to the database for ease of access.

Table 3. The SLM groups: a description and examples of each.

SLM Group	Brief Description [5]	Example of Technology from Global SLM Database [6]	
Improved ground/vegetation cover	Measures that aim to improve ground cover, be it dead material, mulch or living vegetation.	Name	Soil Productivity Improvement Using a Combination of Technologies
		Country/Link	Tanzania/T1221
		Single or Mixed Groups?	*Mixed:* Improved ground/vegetation cover + Agroforestry + Integrated soil fertility management
Cross-slope measure	Earth or soil bunds, stone lines, vegetative strips across the slope—often along a contour—to reduce runoff and soil loss.	Name	*Traditional Stone Wall Terraces*
		Country/Link	South Africa/T1369
		Single or Mixed Groups?	*Single*: Cross-slope measure
Integrated soil fertility management	Managing soil by combining methods of fertility amendment with soil and water conservation. Aims to maximize organic fertilizer, minimize loss of nutrients and use inorganic fertilizer judiciously.	Name	*Push-Pull Integrated Pest and Soil Fertility Management*
		Country/Link	Kenya/T958
		Single or Mixed Groups?	*Mixed:* Improved ground/vegetation cover + Improved plant varieties/animal breeds
Water harvesting	The collection and management of rainwater runoff or floodwater to increase water availability for domestic use or for crops/livestock.	Name	*Runoff Water Harvesting for Bananas*
		Country/Link	Uganda/T1390
		Single or Mixed Groups?	*Mixed*: Water harvesting + Irrigation management + Water diversion and drainage
Pastoralism and grazing land management	The grazing of animals on natural or semi-natural grasslands, grasslands with trees or open woodlands.	Name	*Couloirs de Passage (Livestock Passageways through the landscape)*
		Country/Link	Niger/T1353
		Single or Mixed Groups?	*Single:* Pastoralism and grazing land management
Agroforestry	Integration of woody perennials with crops or animals for a variety of benefits and services, including the better use of soil and water resources; multiple fuel, fodder and food products; and habitats for associated species.	Name	*Agroforestry Parkland*
		Country/Link	Senegal/T1167
		Single or Mixed Groups?	*Mixed:* Agroforestry + Improved ground and vegetation cover + Improved plant varieties/animal breeds

Already noted is the fact that many technologies (that is, entries in the database) are characterized by "belonging to" more than one SLM group—see Section 3.2 d. A key reason is that various SLM measures[7] are mixed and matched to make up the composite technology. When these measures are used together, the combination often adds up, effectively, to more than the sum of its parts because of synergies. Conservation agriculture, which involves mulching, crop mixes/rotations and minimum tillage, is a well-known case in point (e.g., in Namibia [57] and Kenya [58]). Mixed systems with zero-grazed livestock, which make use of fodder grown specifically, including that from agroforestry tree species, and contribute to soil fertility management through manure, constitute another (e.g., in Uganda [59] and Ethiopia [60]). These composite technologies may be considered as pieces within an overall jigsaw depicting an integrated and diverse system. This is a strong starting point for adaptation, at various levels, from "climate-smart" households to climate-resilient ecosystems.

4. Attributes and Mechanisms: How SLM Confers Climate Change Adaptation

4.1. Aspects of Adaptation: An Analysis

A fundamental question is: what aspects of SLM practices help provide adaptive capacity? Thus, in this section, the six SLM groups are analyzed for their reported, and potential, ability to deliver CC adaptation. We follow the methodology, and means of presentation, established by Sanz et al. [5]. A dedicated section in that paper "attempts to qualitatively assess the positive relative impacts of SLM technologies in addressing DLDD ("desertification, land degradation and drought" in UNCCD terminology), climate change adaptation, climate change mitigation and safeguarding biodiversity". Sanz et al. [5] cluster SLM technologies under groups [61] (14 in total) following the typology adopted by the UNCCD. While these do not match one-to-one with the WOCAT groups (26 in total), the 6 WOCAT SLM groups that have been selected for their popularity here are clearly comparable with, and equivalent to, specific UNCCD SLM groups, as shown in Table 4.

Table 4. SLM technology groups: WOCAT compared with UNCCD.

WOCAT SLM Group	UNCCD SLM Group	Comparison
Improved ground/vegetation cover	Vegetation management	Similar
Cross-slope measure	Soil erosion control	UNCCD group is broader: covers cross-slope measures but also gully control, water spreading weirs, windbreaks, etc.
Integrated soil fertility management	Integrated soil fertility management	Similar
Water harvesting	Water management	UNCCD group is broader: covers water harvesting but also micro-irrigation, drainage in rice paddies, etc.
Pastoralism and grazing land management	Gazing pressure management	Similar
Agroforestry	Agroforestry	Similar

Sanz et al. [5] examine six impact parameters of SLM. These are (1) soil fertility/structure, (2) soil erosion control, (3) soil organic carbon increase, (4) non-carbon-dioxide greenhouse gas reduction, (5) water availability/retention and (6) yield/productivity. A further impact parameter has been derived from the results of the other six: (7) biodiversity. These impacts are clearly not all on the same level (for example, reducing erosion is a specific remedy, while yields and productivity are outputs contingent on other impacts) nor are they discrete (soil fertility and structure are closely interconnected with soil organic carbon). Nevertheless, this is a step forward in the disaggregation of the potential effects of SLM on adaptation.

There is another dimension to this comparison: each of the seven impact parameters are weighted against their relative positive impact on (a) land degradation, (b) CC adaptation and (c) CC mitigation [5]. Although presented in a figure with color bars of graded intensity—to deliberately show that these are merely indicative and relative—this can be interpreted quantitatively and is represented in Table 5. Thus, the impact "soil organic carbon" is considered very important for CC mitigation, but somewhat less so for adaptation and even less for addressing land degradation. Non-CO_2 GHG reduction is a particularly interesting impact; it is key in CC mitigation, but of little or no importance in terms of CC adaptation. Thus, while reducing livestock numbers may diminish methane emissions, it could simultaneously weaken the resilience of integrated production systems: thus mitigation and adaptation objectives are not always aligned. This table, partially at least, is reflected in a similar figure in [1] (p. 60) which looks at these and other "food system response options" in terms of their impact on mitigation and adaptation.

Table 5. Weighted impacts of SLM technology groups (UNCCD system) on land degradation, CC adaptation and CC mitigation (interpreted from Sanz et al. [5]).

	Land Degradation	Adaptation	Mitigation
Soil erosion control	***	*	zero
Soil fertility/structure	***	***	**
Water availability/retention	*	***	*
Yield/productivity	**	***	**
Soil organic carbon (SOC)	*	**	***
Non-CO_2 GHG reduction	Zero	Zero	**

* = low or non-impact; ** = medium impact; *** (in tables) = high impact.

The results are presented in heptagonal spider diagrams—one for each SLM group—with each point representing one of the parameters. See Figure 7 for the framework used.

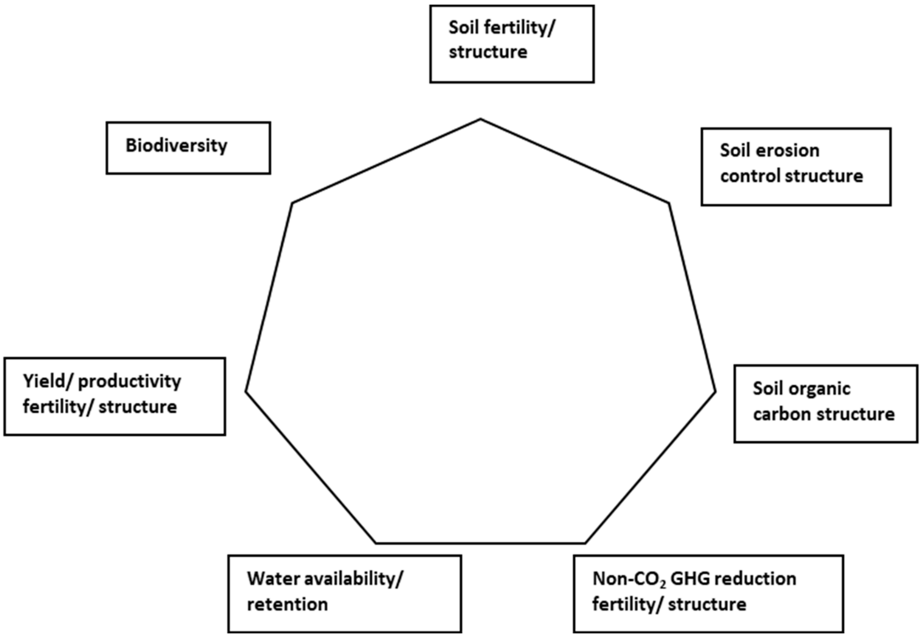

Figure 7. Spider diagram framework used by Sanz et al. [5] to display the impacts of SLM technology groups.

4.2. The Attributes and Mechanisms That Help SLM Achieve Climate Change Adaptation

It is reconfirmed that SLM has in-built adaptation properties, helping to stabilize yields and make systems more reliable in the face of stresses and shocks [5,7,62–67]. However, there are particular ways in which SLM acts, and that is not simply by improving soil health alone.

Under the current review, we took the six SLM groups which were identified as the most common under cropland and grazing land in SSA, then assessed them—in a similar way to Sanz et al. [5]—through a mixture of a literature review, professional judgement, and evidence from the Global SLM Database—against seven specific parameters that we proposed as being key in climate change adaptation. While of particular relevance to SSA, they have global applicability also. Four of the parameters cover "attributes" and three relate to "mechanisms". By **attributes**, we refer to the properties or characteristics of SLM groups that make them particularly suited to, and ubiquitous in, CC adaptation—namely, (a) versatility, (b) reliability, (c) adjustability, and (d) robustness. By **mechanisms** (or technical functions), we mean how they confer adaptation to systems—namely, (e) creating a micro-environment, (f) concentrating resources, and (g) buffering extremes. These three mechanisms are closely related but there are subtle and important differences. Though the labels are largely self-explanatory, Table 6 lays out, in simple terms, what is meant.

Table 6. Properties of SLM groups that help to provide adaptation/resilience against climate change stresses and shocks.

1. ATTRIBUTES	
VERSATILITY	Versatile systems are those that can be used in a wide array of situations (though often in different forms and varieties), e.g., agroforestry. In contrast, water harvesting—at least for crop production—is mainly focused on/applicable to semi-arid areas.
RELIABILITY	Reliability speaks for itself: does the SLM group consistently perform well? Or, like mulching (an example of IG/VC), does it require materials that have an opportunity cost (e.g., fodder for livestock)? Or, like water harvesting, is it dependent on runoff-generating rain?
ADJUSTABILITY	Some systems can be easily adjusted to fit a changing situation. Those based on seasonal operations can be modified. However, trees in agroforestry systems, for example, need time to have impact. Adjustability can imply ease of mixing and matching with other groups, meaning it can be readily "upgraded".
ROBUSTNESS	This describes whether the SLM group can stand up to extreme events without breaking or losing integrity. Cross-slope barriers of earth are especially susceptible to overland flow and can fail in a "domino" sequence, while stone-built barriers are hardier. Vegetative barriers can cope better still, and are self-regenerating.
2. MECHANISMS	
MICRO-ENVIRONMENT	Some groups confer CC adaptation by creating a favorable micro-environment; this may be by blanketing the earth with mulch, under which the soil surface becomes a protected and protective micro-environment, or by establishing a wind break (where it can create a microclimate—a specific form of micro-environment).
CONCENTRATING RESOURCES	The concentration of fertility, water, plants and livestock, and labor and investment is characteristic of agrobiodiverse, productive, and adaptative systems in SSA. Home gardens and urban agriculture thrive on this. A critical mass of concentrated resources may be essential for production in poor years—if thinly spread, they may not provide a yield.
BUFFERING EXTREMES	Covering the ground by vegetation or mulch protects against high (or low) temperatures and against rainfall splash where there is more intense and erosive rainfall. Soil fertility and the water-holding capacity help ensure yields during droughts. Buffering provides a "shock absorber", ironing out climatic extremes.

Table 7 examines these parameters against each of the groups and proposes, in a similar way to that followed by Sanz et al. [5], a rating from 0 to 3.

Table 7. Attributes and mechanisms of specific SLM groups in relation to the provision of adaptation/resilience against climate change stresses and shocks (0 = no/little importance/impact; 3.0 = very important/high impact).

SLM Groups	Improved Ground/ Vegetation Cover	Cross-Slope Barriers	Integrated Soil Fertility Management	Water Harvesting	Pasture and Grazing Land Management	Agroforestry
1. ATTRIBUTES						
VERSATILITY	Widely applicable. Constraints in drier areas with competition for mulch [2.5].	Applicable on range of slopes. Vegetative barriers less effective in semi-arid areas. Stone lines limited by availability [2.0].	Widely applicable in various forms [2.0].	Focus on drier areas for crop production. Widely applicable for ponding/roof tanks, etc. [1.5].	Limited to systems with pastures [1.5].	Very widely applicable through all agroecosystems and climatic zones [2.5].
RELIABILITY	Good except when mulch limiting [2.0].	More reliable on lower slopes [1.5].	Good [2.5].	Problems with too much/too little rainfall [1.0].	Good except in severe drought [2.0].	Good [2.5].
ADJUSTABILITY	Adjustments can be made seasonally with, e.g., crop mixtures [2.0].	Barriers fixed: costly to move. Can be built up or vegetated [1.0].	Availability of resources may limit changes [2.0].	Micro-catchment systems easier to adjust than macro-catchments [1.5].	Management can be adjusted in response to needs [1.5].	Trees limited by establishment time. Crop component adjustable [1.5].
ROBUSTNESS	Not easily damaged. Easy to amend/repair [2.0].	Rigid structures—especially earth bunds—vulnerable to breaching [1.0].	Not easily damaged [2.0].	Damage by floods/excess runoff common [1.0].	Management responsive to vegetative changes [2.0].	Tree component vulnerable to wind damage [2.0].
2. MECHANISMS						
MICRO-ENVIRONMENT	Good: especially under deep mulching [2.0].	Only around barrier: where strips are wetter/more fertile [1.0].	Good where resources are concentrated [1.5].	Pronounced where water concentrates. Harvests rich organic matter in runoff [2.5].	Limited [1.5].	With windbreaks, etc., a distinct microclimate is established [2.0].
CONCENTRATING RESOURCES	Yes, especially where mulch used: creates resource-rich areas [2.5].	May occur where nutrient-rich particles trapped [2.0].	Especially true for manure; fertility-rich areas created [2.0].	Concentration of runoff is core principle. Also of nutrients in (e.g.) *zaï* pit systems [2.5].	Skilled management improves selected areas [1.5].	True of intensive systems. In extensive systems, fertile spots under large trees [2.0].
BUFFERING EXTREMES	Buffers against temperature/rain. Crop mixes spread risk [2.5].	Effective barrier buffer against floods at catchment level [1.5].	Fertility/SOM buffers against crop failure [2.0].	Effective except when rainfall fails and no runoff generated [2.0].	Through production of hay/dry season grazing [1.5].	Effective especially under intensive systems [2.0].

Sources: [3,5,46,62–69].

This means we can consider the "impacts" estimated by Sanz et al. [5] for each of six groups summarized in Figure 8, alongside the "attributes" and "mechanisms" used in this current study, which are presented in Figure 9. There is no contradiction between the two sets of graphs: they are complementary.

Looking first at the results of the impact factors calculated by Sanz and colleagues (ibid) in Figure 8, it must be recollected that soil fertility/structure, yield and water availability are considered by them to be very important in CC adaptation—in SOC as well, but less so (see Table 5). One key difference is that those impact factors are global, and not limited to SSA in contrast to the figures calculated for this current study. Vegetative management has strong, positive impacts with the exception (surprisingly) of biodiversity. Soil erosion control performs best against erosion control (unsurprisingly), but is obviously not considered to be fully effective (presumably in practice rather than principle). Integrated soil fertility management scores well against all parameters. Water management scores quite poorly in terms of yields. Indeed, it scores poorly against water availability and retention itself. In SSA—where moisture is so often a limiting factor—this would warrant a higher rating. Grazing land pressure management scores well throughout, but not as well as agroforestry, where SOC is awarded a maximum (which appears to be a generous score, presumably based on a mature system). Yields, which are a function of the other parameters, also achieve a good score under agroforestry.

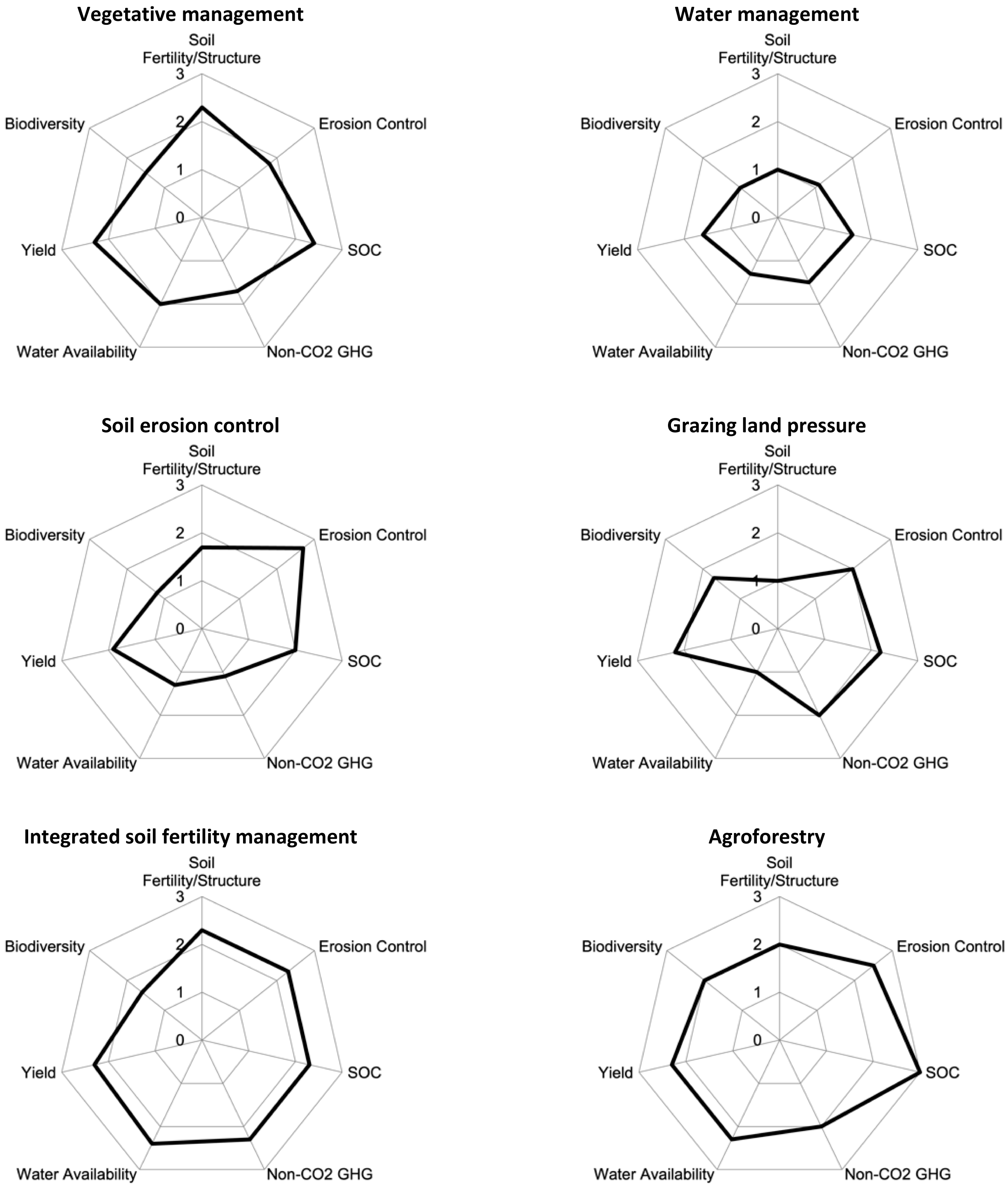

Figure 8. Six SLM groups against seven impact factors: global. Key: 0 = no/little importance/impact; 3.0 = very important/high impact. (Adapted from: Sanz et al. [5]).

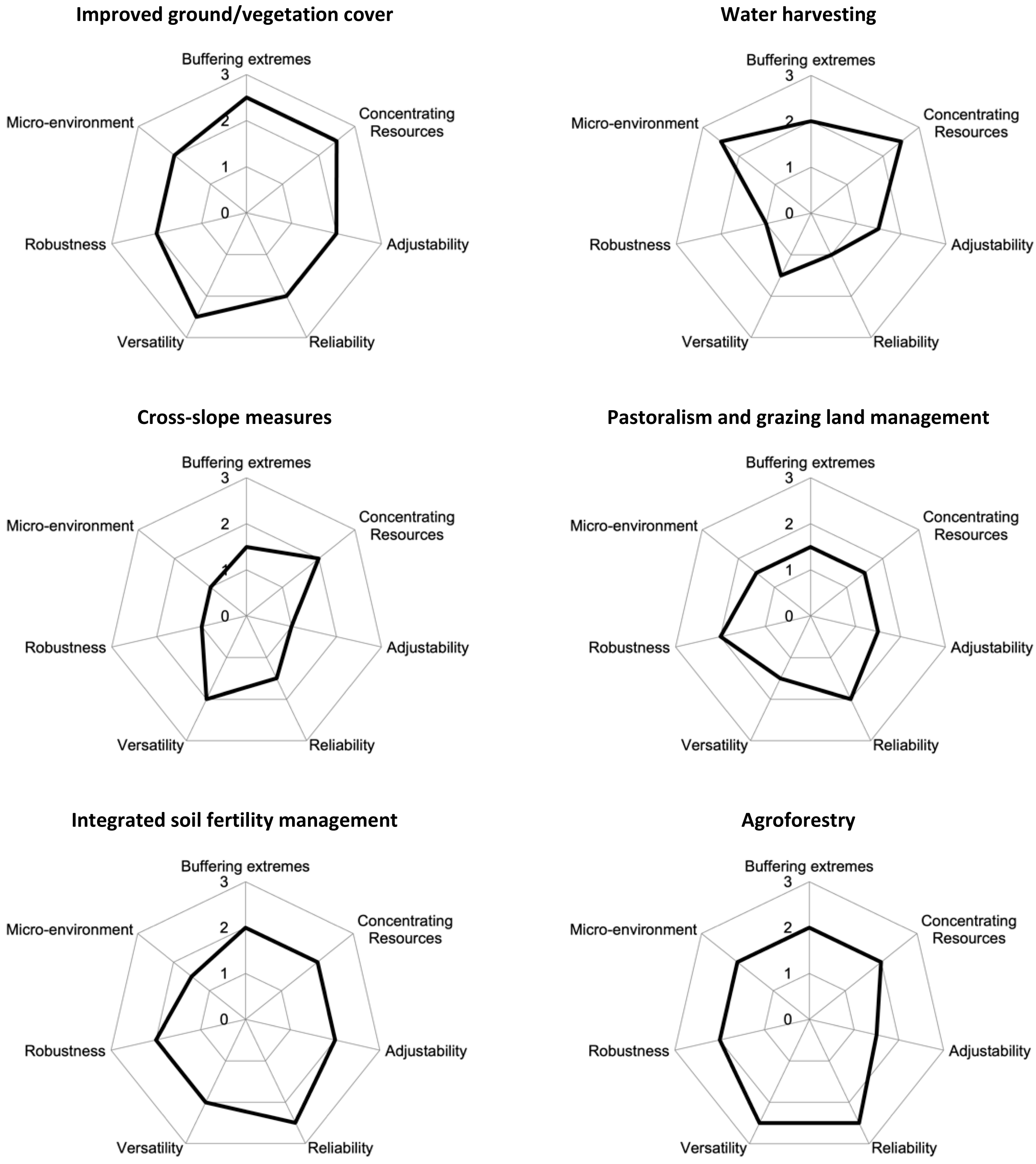

Figure 9. Six SLM groups against three mechanisms (creating a microenvironment, buffering extremes and concentrating resources) and four attributes (adjustability, reliability, versatility and robustness), with a focus on sub-Saharan Africa. Key: 0 = no/little importance/impact; 3.0 = very important/high impact. (Source: this study, Table 7).

Turning to the six spider diagrams created for this current study, as shown in Figure 9, explanations for the scores have been laid out in Table 7. There are some close links to Figure 8. For example, where soil fertility and yield tend to be high in Figure 8 (impacts linked strongly with adaptation), buffering and concentration of resources (mechanisms that favor adaptation) in Figure 9 are also high. This would be expected. Taking micro-environment, the other mechanism scored under Figure 9, this is quite pronounced in five of the groups, with cross-slope barriers being the exception.

The four "attributes" vary considerably. Versatility is scored highly under three of the groups (improved ground/vegetation cover, cross-slope barriers and agroforestry), indicating that these groups of technologies are applicable, and indeed applied, in many diverse settings. One key reason is that they are very varied in type. Reliability is good all round, except under water harvesting (and to a lesser extent under cross-slope barriers). This is because where many water harvesting systems are used (i.e., for field crops in semi-arid areas), they are especially vulnerable to drought, and periodically exposed to damaging floods. Nevertheless, they offer a good degree of adaptation where there is no alternative. As has been noted already, "adjustability" can be a useful attribute, but it is most applicable to groups that are associated with recurrent application (e.g., integrated soil fertility management; improved ground/vegetation cover) rather than longer-lasting frameworks (e.g., water harvesting; agroforestry). "Robustness" refers to fragility; thus, cross-slope barriers and water harvesting structures (especially when made of earth) can be breached by runoff. The other four groups score well.

Helpful as this conceptualization and analysis might be, it must be re-stressed that technologies based on single measures and falling under just one SLM group seldom exist; so, the analysis here (both for Sanz et al. [5] and for this current study) is based on reductionism. As technologies become more complex and combine more groups, interconnections and synergies develop, and the impacts, attributes and the mechanisms become less easy to tease apart.

5. Future Directions

5.1. Scaling-Up of SLM for Adaptation: Delivering on Lessons Learned

Much has been written about obstacles to the spread of SLM, and the main messages remain valid in the context of SLM as a CC adaptation option. Consequently, action should be guided in the first place by "lessons learned": a mantra that is often heard but seldom heeded, especially in this internet age, where documentation tends to become rapidly buried by searches for the most recent publications.

Certainly, there are multiple lessons that could, and should, be acted upon. There is no harm in revisiting historical documents such as "Coping with African Drought", written in 1987 [70], which talks, itself, about learning from the 1968/73 and 1983/85 droughts in Africa. Amongst the lessons learned were that afforestation, supported by food-for-work, was largely a failure, while the successes included small-scale water harvesting and improvements to marketing. These lessons will be familiar to a modern development audience. They tend to re-emerge; a specific case in point is the IPCC's warning of "maladaptation" regarding inappropriate afforestation [11]. Summaries of barriers to the scaling-up of SLM (or soil and water conservation) have been regularly presented over the last 30 years. Hudson's 1991 "Study of the Reasons for the Success or Failure of Soil Conservation Practices" for FAO was one of the earliest [71]. Three recent publications from WOCAT and the UNCCD are drawn upon here to distil the key points that emerge time and again in SLM initiatives [3,7,72]. The fundamental constraints demonstrate the need to improve the enabling environment and realign attitudes:

1. Institutional and legal bottlenecks: lack of institutional support; inappropriate rules and regulations.
2. Market and input supplies: inability to access inputs or market produce.
3. Insecure right to resources: land users lacking security to land and water, inhibiting investment.
4. Top-down approaches: smallholders assumed to be ignorant while they are often skillful innovators.
5. Lack of knowledge and/or extension service advice: inability to provide knowledge required.
6. Lack of decision support: little or no guidance to smallholders (or advisors) to facilitate choices.

7. Short-term projects instead of processes: obsession with short-term assistance and monitoring.
8. Inadequate or inappropriate incentives: no incentives where needed, or dependency created.
9. Gender insensitivity: a perception that smallholder decision-makers are always men.
10. Emphasis on conservation rather than production: "saving the soil" instead of a focus on production.

5.2. International Action on Climate Change Adaptation: Funding and Relevance to Smallholders in SSA

While it is argued here that international action has failed to adequately recognize CC adaptation concerns, it is nevertheless true that a number of dedicated funds have been set up, and multilateral agencies have created, and expanded, CC adaptation portfolios. Indeed, one "fortunate" outcome of climate change has been the provision of new sources of funding for SLM, but under CC headings.

The 7th UNFCCD CoP in 2001 set the stage for the international "Adaptation Fund" [73], and in 2010, the Green Climate Fund [74] was established. The World Bank has a strong CC program in its agricultural portfolio and continues to be committed to "climate-smart agriculture" (CSA) with the simultaneous, triple aims of (a) increased productivity, (b) enhanced resilience, and (c) reduced GHG emissions [75]. The Global Environment Facility (GEF) channels support CC adaptation mainly through the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF) [76]. The current FAO-Adapt framework program provides general guidance for climate change adaptation [77]. Of particular relevance to this paper is IFAD's pioneering "Adaptation for Smallholder Agriculture Programme" (ASAP: now ASAP+), which provides co-finance to its investment program. The first of five outcomes is given as "improved land management and gender sensitive climate resilient agricultural practices and technologies". The other four cover water, human capacity, rural infrastructure and dissemination of knowledge [14,78].

5.3. Five Specific Lines of Action

This section now summarizes five specific lines of action, all rooted in experience and lessons learned, and are outlined in various publications, e.g., [3,5,62,66,72,79,80]. Adaptation and resilience need to be stressed at various levels of scale. On the one hand, spatial units: the field, the farm or landscape level. On the other hand, sociological units: households and the community. The IPCC's concept of "soft" and "hard" limits is useful here [11]. The first challenge is breaking through the "soft limits" which constrain the expansion of known adaptation technologies and strategies. One obvious route is by improving the enabling environment. However, the boundaries of soft limits can also be pushed back by improving the adaptive capacity of SLM until that adaptation potential is reached at the "hard limit". "Hard limits" mean there is no further room for maneuver: no further meaningful adaptation options are available. At least, up to that point, adaptation through SLM can bring some breathing space and smallholders can protect their livelihoods for longer.

i. Spread existing, well-known and documented SLM solutions:

Many SLM solutions are "good to go" and a large number are understood to be particularly effective in delivering adaptation. These SLM practices, popular as many are because they improve production, now have an elevated role and a new importance. What is more, many associated practices (agronomic, livestock husbandry, etc.) are also relevant and can be revitalized in the light of adaptation needs and their contribution. Thus, the precision placement of fertilizers, choice of crops (drought tolerant/drought evasive/tolerance of inundation/ability to ratoon, etc.), intercropping practices and manure management can all add value to SLM. Upscaling SLM is primarily a question of removing the barriers already summarized. Specifically, improved extension services are vital to deliver both awareness-raising and technical recommendations. An essential component of this process is decision support. The WOCAT SLM Decision Support methodology can be employed in making enlightened choices through a guided participatory process [25,26]. There is experience in targeting specific segments of the community—especially women and youth. The IPCC lends support to "a gender inclusive approach [that] offers opportunities to enhance the sustainable management of land" [1] and IFAD holds "women's empowerment" to be one of five key activities under its "enhanced" Adaptation for Smallholder Agriculture Programme: ASAP+ [78]. The UNCCD also has a "Gender Action Plan" [81]. Scaling-up, however, is not just a matter of spread and dissemination, it must be accompanied, to be effective in the long term, by mainstreaming or "institutionalizing" the process while remaining adaptive and iterative [28,82,83].

ii. Help the development of climate-smart thinking and innovation.

There is a need for programs to integrate coaching and the stimulation of "resilience understanding" and "response-readiness". This means working with land users—but students and technical staff also. It should begin with underlining the potential of SLM to deliver immediate benefits to land users; adaptation then ensures that benefit streams continue despite CC impacts. It will emphasize aspects of preparedness (anticipatory adaptation) and responsiveness (reactive adaptation). There should also be training in the adaptation-related impacts of SLM as well as the understanding of SLM's attributes and mechanisms. Principles and pragmatics merge in the following list:

a. Awareness of local and/or documented options: *pushing back the "soft barrier".*
b. Risk-spreading: *diversification within the landscape; the farm; the field.*
c. Recycling and circularity: *making full use of by-products and keeping resources within the system—building on "value retention loops"*; see [84].
d. Opportunism: *making tactical and creative use of unexpected events—adding an intercrop (a "relay crop") when the rains are prolonged, for example.*
e. Creating synergies: *mixing and matching measures for optimum impact.*
f. Appreciating the power and potential of creating a critical mass of resources: *where fertility, water, mulch, labor, etc., are too thinly spread.*
g. Innovation: *being dynamic—constantly testing and trying new ideas: adapting existing, and developing new, coping mechanisms.*
h. Knowledge seeking and sharing: *making full use of traditional market place sharing as well as general advice and information from early warning system (EWS) information through digital devices.*

Comprehension of concepts is the foundation stone to understanding principles and practices [85]. Traditional coping strategies may have worked in the past, but more innovative answers are now required to keep pace with change.

iii. Continue to build a critical mass of knowledge as a basis for decision-making.

WOCAT's questionnaire continues to be used to document new practices in the Global SLM Database. There is a major role for the promotion of farmer innovation, and there are established methodologies to uncover, document and build-on innovation at individual and community levels, e.g., [22,23]. Farmer innovation became a niche development focus in the 1990s and spawned several projects and resultant publications, e.g., [23,86–88]. The proven hypothesis was that smallholders are constantly creative, responsive to the environment and should be recognized for this, and supported in their efforts. There are signs that these early initiatives have left a legacy. Thus, a new methodology from ICRAF—demonstrating a paradigm shift in thinking at an international research level, "Options by Context"—may also prove useful in combining the recognition of local innovation and decision support [89,90]. Encouragingly, the IPCC gives recognition to "diverse forms of knowledge, such as scientific, as well as Indigenous and local in understanding and evaluating climate adaptation processes and actions" [20]. Hybrid knowledge, the combination of local and Indigenous know-how with conventional scientific knowledge, both applied and theoretical, is starting to receive the attention it deserves.

iv. Underpin the spread of SLM adaptation solutions with support and scientific back-up.

One key area for scientific support is climate services—a central plank of IFAD's ASAP+ program [78]. Commonly, there is an emphasis on EWS. These are systems already proliferating throughout Africa, aided by developments in remote sensing, improved weather forecasting and the spread of the mobile phone. Much has been written on this topic over the last decade by development agencies and the international press, e.g., [10,91,92]. Insurance schemes to protect land users against crop failure and livestock loss are important too. Scientific back-up also includes the development of value-chains: if farm products can be expeditiously marketed, processed and value-added, this helps smallholders to secure their livelihoods and broaden their production base, thus reducing risk. A third dimension to this scientific support is simply making sure that smallholders have access to more appropriate and varied genetic material through crop and livestock selection and breeding. Fortunately, in Africa, there is still a wealth of traditional landraces of indigenous crops that are drought evasive and/or drought resistant—such as sorghums, millets, and pulses—as well as hardy livestock breeds that have proven, over centuries, their ability to thrive under severe conditions. However, despite work carried out by specific agencies (e.g., the International Centre for Research in the Semi-Arid Tropics, ICRISAT and the International Livestock Research Institute, ILRI), there has been relatively little impact on subsistence farming in rainfed SSA. Maize breeding and seed marketing for the higher potential areas of East and Southern Africa are notable exceptions. Field operations with attributes and mechanisms that confer adaptive capacity, which have been highlighted in this paper (see Section 4), are commonly those with their origin in traditions. It is not difficult to see a case for "back to the future" as part of a route towards improving resilience. Finally, a better understanding of how SLM confers adaptation—as explored in this paper—surely warrants more attention.

v. Improve methods to measure climate adaptation and climate resilience.

One of the fundamental aspects that sets adaptation and mitigation projects so clearly apart is measurement: mitigation can be quantified precisely, and adaptation cannot. It is little wonder that many projects find it simplest to measure mitigation benefits, and then state that adaptation is delivered as a co-benefit. Resilience remains an imprecise concept and can be interpreted in various ways. It follows that it is notoriously difficult to quantify in a meaningful way. Years ago, IFAD commissioned a report on "Measuring Climate Resilience" [93]. Here, the concept of vulnerability is taken as the inverse of resilience, and thus, the calculation of a vulnerability index was suggested as a means of establishing a resilience index, taking a low vulnerability score to indicate strong resilience. However, the author believed this methodology "may not withstand the scrutiny of many academics in the resilience field". By the same token, it is surely unlikely to be adopted as a pragmatic means to measure the impact of climate adaptation projects. Tellingly, the ASAP program, under IFAD, chose specific proxy indicators as a subset of household resilience, measuring ex-ante rather than just ex-post [14]. The follow-up program (ASAP+) will continue to use IFAD's "results management framework" to set out a "comprehensive results logic" [78]. An evaluation of climate-smart agriculture across a portfolio of UK Government programs noted that many found "defining and measuring resilience to be challenging" and "there remains uncertainty in the wider development world about the appropriate indicators to measure resilience" [94]. It could be argued that the most compelling results could be garnered from tracking the spread of specific SLM practices, or simply by asking smallholders how they are coping. This would represent an extension of the questions put in the WOCAT technologies questionnaire. Certainly, there is scope for adaptation to be better monitored to measure the impact and show the results, both qualitatively and quantitatively.

6. Conclusions

Sustainable land management offers land-based options that help achieve targets of the three international conventions that cover CC (UNFCCC), land degradation (UNCCD) and biodiversity (CBD). Under CC, it is mitigation that attracts the most international attention, but far more important to small-scale land users in sub-Saharan Africa is the adaptation that SLM can help confer, alongside its other benefits. Adaptation helps them adjust to both sudden shocks and more gradual stress brought about by CC. Their overriding concerns are about their immediate survival and prosperity. It is clearly unreasonable to expect them to prioritize CC mitigation activities, except where these confer simultaneous adaptation benefits, or when they are supported by subsidies. Adaptation has been significantly undervalued. An examination of the Global SLM Database for land users' attitudes to CC adaptation leads to the conclusion that smallholders in SSA are aware of the importance of CC adaptation, and there are specific SLM groups that they favor for these purposes. An analysis of adaptation based on what is known has proven to be valuable in attempting to identify what specific mechanisms of SLM help to deliver adaptation benefits, and what attributes of SLM options make them valuable. Under the current speed of CC, the "hard limits" of adaptation are likely to be reached rapidly. However, there is much that can be carried out to accelerate and stimulate adaptation by smallholders to exploit possibilities with the "soft limits"—at least as far as they are able. Self-evidently, progress in understanding how SLM helps in climate change adaptation is crucial to better target assistance to millions in the rainfed areas of SSA whose lives and livelihoods depend on being able to adapt to climate change. This paper provides an initial analysis, but evidently, there is considerable scope for research on these aspects. Nevertheless, we contend that our knowledge base is already adequate to accelerate the implementation of appropriate projects and programs. CC adaptation, though better than SLM, deserves more attention, better understanding and increased prioritization.

Author Contributions: Conceptualization, W.C.; Writing—original draft preparation, W.C.; writing—review and editing, N.H., E.M., R.M.-S. and J.E.; formal analysis, J.E.; visualization, J.E. and E.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data supporting the analysis can be found at https://www.wocat.net/en/global-slm-database/ (accessed on 1 March 2023).

Conflicts of Interest: The authors declare no conflict of interest.

Notes

1. CO_2-eq = Carbon dioxide equivalent is a measure used to compare GHG emissions on the basis of their global warming potential. Thus, total GHG emissions—including carbon dioxide, methane, nitrous oxide, etc.—are calculated as carbon dioxide equivalents.
2. Soil organic matter (SOM) and soil organic carbon (SOC) are closely related (and often confused). SOM contains approximately 60% carbon and, thus, SOM is most readily calculated by determining the SOC content and multiplying by (approx.) 1.7 [27].
3. Practices under WOCAT include both "technologies" and "approaches". In this article, the focus is on the analysis of technologies.
4. In three cases, both innovation and tradition were given. These are included in the figures above; in 73 cases, innovation alone; in 56 cases, tradition alone.
5. From the guidelines in the WOCAT Questionnaire.
6. For detail, search name of technology under the WOCAT Database (https://www.wocat.net/en/global-slm-database (accessed on 1 March 2023).
7. SLM "measures" are categorized by WOCAT as being agronomic, vegetative, structural or management.

References

1. IPCC. Climate Change and Land. An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. 2019 (Revised 2020). Available online: https://www.ipcc.ch/srccl/ (accessed on 1 March 2023).
2. Lal, R. Returning Land to Nature. *Healthy Soil, Healthy People, Healthy Planet*. Richter, S., Ed.; *Rural 21*. 2022, 2, pp. 4–7. Available online: https://www.rural21.com (accessed on 1 March 2023).
3. Liniger, H.P.; Mekdaschi-Studer, R.; Hauert, C.; Gurtner, M. *Sustainable Land Management in Practice—Guidelines and Best Practices for Sub-Saharan Africa*; TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) & Food and Agriculture: (FAO): Rome, Italy, 2011. Available online: https://www.fao.org/3/i1861e/i1861e00.pdf (accessed on 1 March 2023).
4. Liniger, H.P.; Harari, N.; van Lynden, G.; Fleiner, R.; de Leeuw, J.; Bai, Z.; Critchley, W. Achieving land degradation neutrality: The role of SLM knowledge in evidence-based decision-making. *Environ. Sci. Policy* **2019**, *94*, 123–134. [CrossRef]
5. Sanz, M.; de Vente, J.; Chotte, J.-L.; Bernoux, M.; Kust, G.; Ruiz, I.; Almagro, M.; Alloza, J.-A.; Vallejo, R.; Castillo, V.; et al. *Sustainable Land Management Contribution to Successful Land-Based Climate Change Adaptation and Mitigation*; A Report of the Science-Policy Interface; United Nations Convention to Combat Desertification (UNCCD): Bonn, Germany, 2017.
6. IPCC. Climate Change, 2021. The Physical Science Basis. Summary for Policy Makers. WG 1 Contribution to the Sixth Assessment Report of the IPCC. 2021. Available online: https://www.ipcc.ch (accessed on 1 March 2023).
7. Critchley, W.; Harari, N.; Mekdaschi-Studer, R. *Restoring Life to the Land: The Role of Sustainable Land Management in Ecosystem Restoration*; UNCCD & WOCAT: Bern, Switzerland, 2021.
8. The World Bank. Website. Available online: https://www.worldbank.org (accessed on 1 March 2023).
9. World Bank Group. *Climate and Development: An Agenda for Action*; World Bank: Washington, DC, USA, 2022.
10. Economist. The Special Report on Climate Adaptation (and associated leading article). 5 November 2022. Available online: https://www.economist.com/special-report/2022/11/01/the-world-has-to-adapt-to-the-climate-change-it-will-not-avoid (accessed on 1 March 2023).
11. IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability. WG ll Technical Support Unit. 2022. Available online: https://www.ipcc.ch (accessed on 1 March 2023).
12. Tol, R.S.J. The Economic Effects of Climate Change. *J. Econ. Perspect.* **2009**, *23*, 29–51. [CrossRef]
13. Our World in Data. Website. Available online: https://www.ourworldindata.org (accessed on 1 March 2023).
14. IFAD. *Adaptation for Smallholder Agriculture Programme: ASAP*; IFAD: Rome, Italy, 2014.
15. Stern, N. *The Economics of Climate Change: The Stern Review*; UK Government: London, UK, 2006.
16. Radcliffe, D.; Subsol, S. Addressing climate change adaptation for smallholder farmers in fragile situations: Learning from the Adaptation for Smallholder Agriculture Programme. *Agric. Dev.* **2020**, *41*, 5–10.
17. Pugh, T.; Müller, C.; Elliot, J.; Deryng, D.; Folberth, C.; Olin, S.; Schmid, E.; Arneth, A. Climate analogues suggest limited potential for intensification of production on current croplands under climate change. *Nat. Commun.* **2016**, *7*, 12608. [CrossRef] [PubMed]
18. Simonett, O. *Potential Impacts of Global Warming*; GRID-Geneva, Case Studies on Climate Change: Geneva, Switzerland, 1989.
19. Davis, A.P.; Gole, T.W.; Baena, S.; Moat, J. The Impact of Climate Change on Indigenous Arabica Coffee (*Coffea arabica*): Predicting Future Trends and Identifying Priorities. *PLoS ONE* **2012**, *7*, e47981. [CrossRef] [PubMed]
20. IPCC. Climate Change Impacts and Risks. *Fact Sheet—Africa*. 2022. Available online: https://www.ipcc.ch (accessed on 1 March 2023).
21. Critchley, W.; Di Prima, S. SCI-SLM methodology: Origins of the design. In *Community Innovations in Sustainable Land Management: Lessons from the Field in Africa*; Mudhara, M., Critchley, W., Di Prima, S., Dittoh, S., Sessay, M.F., Eds.; Earthscan, Routledge: London, UK; New York, NY, USA, 2016; pp. 20–40, ISBN 978-0-367-02970-8.
22. Critchley, W. *Working with Farmer Innovators. A Practical Guide*; CTA: Wageningen, The Netherlands, 2007.
23. Mudhara, M.; Critchley, W.; Di Prima, S.; Dittoh, S.; Sessay, M.F. *Community Innovations in Sustainable Land Management: Lessons from the Field in Africa*; Earthscan, Routledge: London, UK; New York, NY, USA, 2016; ISBN 978-0-367-02970-8.
24. The Green Climate Fund. Website. Available online: https://www.greenclimatefund (accessed on 1 March 2023).
25. Harari, N.; Mekdaschi Studer, R.; Bastidas Fegan, S.; Schlingloff, S.; Bres, A. *Promoting Sustainable Land Management through Evidence-Based Decision Support—A Guide with Country Insights*; FAO: Rome, Italy, 2022. Available online: https://www.wocat.net/en/decision-support-slm (accessed on 1 March 2023).
26. WOCAT. WOCAT Services: Knowledge Management and Decision Support for Sustainable Land Management. 2021. Available online: https://www.wocat.net/library/media/253 (accessed on 1 March 2023).
27. Ahn, P.M. *Tropical Soils and Fertilizer Use*; Intermediate Tropical Agriculture Series; Longman Scientific and Technical: Harlow, UK, 1993; ISBN 0 582 77507 8.
28. Critchley, W.; Harari, N.; Delve, R. *Supporting Extension Services to Scale up Sustainable Land Management: The Potential of WOCAT's Tools and Methods*; IFAD: Rome, Italy, 2023.
29. The Global Environment Facility. Website. Available online: https://www.thegef.org/what-we-do/topics/sustainable-land-management (accessed on 1 March 2023).
30. FAO. Climate Smart Agriculture Sourcebook. Rome, Italy. 2023. Available online: https://www.fao.org/climate-smart-agriculture-sourcebook/concept/en/ (accessed on 1 March 2023).
31. Doswald, N.; Estrella, M. *Promoting Ecosystems for Disaster Risk Reduction and Climate Change Adaption: Opportunities for Integration*; *UNEP Discussion Paper*; UNEP: Nairobi, Kenya, 2015.

32. Convention on Biological Diversity. Website. Available online: https://www.cbd.int/ecosystem/ (accessed on 1 March 2023).
33. UNCCD. Global Land Outlook. Bonn, Germany. 2022. Available online: https://www.unccd.int/resources/global-land-outlook/overview (accessed on 1 March 2023).
34. United Nations Environment Assembly. 2022. (Fifth Session). Available online: https://www.naturebasedsolutionsinitiative.org/news/united-nations-environment-assembly-nature-based-solutions-definition (accessed on 1 March 2023).
35. Zomer, R.J.; Neufeldt, H.; Xu, J.; Ahrends, A.; Bossio, D.; Trabucco, A.; van Noordwijk, M.; Wang, M. Global Tree Cover and Biomass on Agricultural Land: The contribution of agroforestry to global and national carbon budgets. *Sci. Rep.* **2016**, *6*, 29987. [CrossRef] [PubMed]
36. Chotte, J.; Aynekulu, E.; Cowie, A.; Campbell, E.; Vlek, P.; Lal, R.; Kapović-Solomun, M.; von Maltitz, G.; Kust, G.; Barger, N.; et al. *Realising the Carbon Benefits of Sustainable Land Management Practices: Guidelines for Estimation of Soil Organic Carbon in the Context of Land Degradation Neutrality Planning and Monitoring*; A report of the Science-Policy Interface; United Nations Convention to Combat Desertification (UNCCD): Bonn, Germany, 2019.
37. Oldfield, E.E.; Bradford, M.A.; Wood, S.A. Global meta-analysis of the relationship between soil organic matter and crop yields. *Soil* **2019**, *5*, 15–32. [CrossRef]
38. Easter, M.; Milne, E.; Paustian, K.; Batjes, N.H.; Cerri, C.E.; Gicheru, P.; Hartmann, M.; Kamoni, P.; McKeown, B.; Minxia, M.; et al. *The Carbon Benefits Project—The Component A Toolkit for Assessing the GHG Balance of Sustainable Land Management Projects*; Abstract from 2010 International Annual Meetings ASA, CSA, SSSA: Long Beach, CA, USA, 2010. Available online: https://a-c-s.confex.com/crops/2010am/webprogram/Paper60476.html (accessed on 1 March 2023).
39. WOCAT. Sustainable Land Management and Climate Change Mitigation Co-Benefits (SLM CCMC). Website. Available online: https://www.wocat.net/en/projects-and-countries/projects/sustainable-land-management-and-climate-change-mitigation-co-benefits-slm-ccmc (accessed on 1 March 2023).
40. FAO. *The Agricultural Sectors in the Intended Nationally Determined Contributions*; Environmental and Natural Resource Management Working Paper No. 62 Rome; FAO: Rome, Italy, 2016. Available online: https://www.fao.org/3/a-i5687e.pdf (accessed on 1 March 2023).
41. weADAPT. Website. Available online: https://www.weadapt.org/knowedge-base/national-adaptation-planning/national-adaptation-plans (accessed on 1 March 2023).
42. Evans, J. *Plantation Forestry in the Tropics*; Oxford Science Publications, Clarendon Press: Oxford, UK, 1992; ISBN 0-19-854257-7.
43. Martin, M.; Woodbury, D.; Doroski, D.; Nagele, E.; Storace, M.; Cook-Patton, S.; Pasternack, R.; Ashton, M. People plant trees for utility more often than for biodiversity or carbon. *Biol. Conserv.* **2021**, *261*, 109224. [CrossRef]
44. van Dok, G.; Berlinger, P. The Great Green Wall—Africa's green world wonder? *Rural 21* **2022**, *2*, 56.
45. van Noordwijk, M. (Ed.) *Sustainable Development through Trees on Farms: Agroforestry in Its Fifth Decade*; World Agroforestry (ICRAF): Bogor, Indonesia, 2019. Available online: http://apps.worldagroforestry.org/downloads/Publications/PDFS/B19029.pdf) (accessed on 1 March 2023).
46. HLPE. *Agroecological and Other Innovative Approaches for Sustainable Agriculture and Food Systems That Enhance Food Security and Nutrition*; A Report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security: Rome, Italy, 2019.
47. Scholz, R.; Twidwell, D. The last continuous grasslands on Earth: Identification and conservation importance. *Conserv. Sci. Pract.* **2022**, *4*, e626. [CrossRef]
48. Bai, Y.; Cotrufo, M.F. Grassland soil carbon sequestration: Current understanding, challenges and solutions. *Science* **2022**, *377*, 603–608. [CrossRef] [PubMed]
49. Integrity Council for the Voluntary Carbon Market (ICVCM). Website. Available online: https://iyrp.info/integrity-council-voluntary-carbon-market-icvcm (accessed on 1 March 2023).
50. IUCN. *Peatlands and Climate Change*; Issues Brief; Gland, Switzerland, 2021. Available online: https://www.iucn.org/resources/issues-brief/peatlands-and-climate-change (accessed on 1 March 2023).
51. Global Peatlands Initiative. Global Peatlands Assessment: The State of the World's Peatlands. UNEP, Nairobi, Kenya. 2022. Available online: https://www.unep.org/resources/global-peatlands-assessment-2022 (accessed on 1 March 2023).
52. Smith, S.M.; Geden, O.; Nemet, G.; Gidden, M.; Lamb, W.F.; Powis, C.; Bellamy, R.; Callaghan, M.; Cowie, A.; Cox, E.; et al. The State of Carbon Dioxide Removal—1st Edition. 2023. Available online: https://www.stateofcdr.org (accessed on 1 March 2023).
53. WOCAT. Website. Available online: https://qcat.wocat.net/en/wocat/list/?type=wocat&q=Biochar (accessed on 1 March 2023).
54. WOCAT. Website. Available online: https://www.wocat.net/en/ (accessed on 1 March 2023).
55. WOCAT. Website. Available online: https://www.wocat.net/en/global-slm-database/slm-practices-technologies-and-approaches (accessed on 1 March 2023).
56. WOCAT. Questionnaire on Sustainable Land Management (SLM) Technologies. 2019. Available online: https://www.wocat.net/library/media/15/ (accessed on 1 March 2023).
57. WOCAT. Website. Available online: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1297/ (accessed on 1 March 2023).
58. WOCAT. Website. Available online: https://qcat.wocat.net/en/wocat/technologies/view/technologies_5775/ (accessed on 1 March 2023).

59. WOCAT. Website. Available online: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1207/ (accessed on 1 March 2023).
60. WOCAT. Website. Available online: https://qcat.wocat.net/en/wocat/approaches/view/approaches_2497/ (accessed on 1 March 2023).
61. UNCCD Science-Policy Interface. Report on Sustainable Land Management. 2017. Available online: https://www.unccd.int/land-and-life/land-management-and-restoration/technologies-approaches/technology-groups (accessed on 1 March 2023).
62. Woodfine, A. *Using Sustainable Land Management Practices to Adapt to and Mitigate Climate Change in Sub-Saharan Africa*; Resource Guide Version 1.0.; TerrAfrica: Washington, DC, USA, 2009. Available online: https://www.terrafrica.org (accessed on 1 March 2023).
63. Mekdaschi Studer, R.; Liniger, H.P. *Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern*; Rainwater Harvesting Implementation Network (RAIN): Amsterdam, The Netherlands; MetaMeta: Wageningen, The Netherlands; The International Fund for Agricultural Development (IFAD): Rome, Italy, 2013. Available online: https://www.wocat.net/library/media/25/ (accessed on 1 March 2023).
64. FAO. *Climate Resilient Practices. Typology and Guiding Material for Climate Risk Screening*; FAO: Rome, Italy, 2021. Available online: http://www.fao.org/3/cb3991en/cb3991en.pdf (accessed on 1 March 2023).
65. Critchley, W. *Soil and Water Management Techniques in Rainfed Agriculture. State of the Art and Prospects for the Future*; Background Note Prepared for the World Bank Water Anchor's "Improving Water Management in Rainfed Agriculture"; World Bank: Washington, DC, USA, 2009.
66. Critchley, W.; Gowing, J.; Mollee, E. (Eds.) *Water Harvesting in Sub-Saharan Africa*; Earthscan: London, UK; New York, NY, USA, 2012; ISBN 978-0-415-53786-5.
67. Harari, N.; Gavilano, A.; Liniger, H.P. *Where People and Their Land Are Safer: A Compendium of Good Practices in Disaster Risk Reduction*; CDE, University of Bern: Bern, Switzerland, 2017.
68. Rodenburg, J.; Mollee, E.; Coe, R.; Sinclair, F. Yield benefits from tree integration in smallholder rice cropping systems. *Field Crops Res.* **2022**, *281*, 108504. [CrossRef]
69. Liniger, H.P.; Mekdaschi-Studer, R. *Sustainable Rangeland Management in Sub-Saharan Africa—Guidelines to Good Practice*. TerrAfrica World Bank: Washington, DC, USA; *World Overview of Conservation Approaches and Technologies (WOCAT)*; World Bank Group (WBG): Washington; DC, USA; Centre for Development and Environment (CDE), University of Bern: Bern, Switzerland. 2019. Available online: https://www.wocat.net/library/media/174/ (accessed on 1 March 2023).
70. Overseas Development Institute. *Coping with African Drought*; Briefing Paper; ODI: London, UK, 1987.
71. Hudson, N.W. *A Study of the Reasons for the Success or Failure of Soil Conservation Projects*; Soils Bulletin No. 64; FAO: Rome, Italy, 1991.
72. Verburg, P.; Metternicht, G.; Allen, C.; Debonne, N.; Akhtar-Schuster, M.; Inácio da Cunha, M.; Karim, Z.; Pilon, A.; Raja, O.; Sánchez Santivañez, M.; et al. *Creating an Enabling Environment for Land Degradation Neutrality and Its Potential Contribution to Enhancing Well-Being, Livelihoods and the Environment*; A Report of the Science-Policy Interface; United Nations Convention to Combat Desertification (UNCCD): Bonn, Germany, 2019. Available online: https://knowledge.unccd.int/sites/default/files/2019-08/UNCCD_SPI_2019_Report_1.2.pdf (accessed on 1 March 2023).
73. Adapatation Fund. Website. Available online: https://www.adaptation-fund.org (accessed on 1 March 2023).
74. Green Climate Fund. Website. Available online: https://www.greenclimate.fund/ (accessed on 1 March 2023).
75. World Bank. Website. Available online: https://www.worldbank-org/en/topic/climate-smart-agriculture (accessed on 1 March 2023).
76. Global Environment Fund. Website. Available online: https://www.thegef.org/what-we-do/topics/climate-change-adaptation (accessed on 1 March 2023).
77. FAO. Website. Available online: https://www.fao.org/resilience/resources/resources-detail/en/c/1114449/ (accessed on 1 March 2023).
78. IFAD. *The Enhanced Adaptation for Smallholder Agriculture Programme (ASAP+)*; IFAD: Rome, Italy, 2021.
79. Dinar, A.; Hassan, R.; Mendelson, R.; Benhin, J. *Climate Change and Agriculture in Africa. Impact Assessment and Adaptation Strategies*; Earthscan Climate; Taylor & Francis: Oxon, UK, 2008; ISBN-13 978-0-415-85283-8.
80. IFAD. *IFAD's Strategy and Action Plan on Environment and Climate Change (2019–2025)*; IFAD: Rome, Italy, 2018.
81. Gender Action Plan | UNCCD. UNCCD and WOCAT Collaborate to Improve SLM Gender Responsiveness | UNCCD. Available online: https://www.unccd.int/resources/publications/gender-action-plan (accessed on 1 March 2023).
82. Coe, R.; Sinclair, F.; Barrios, E. Scaling up Agroforestry Requires Research 'in' Rather Than 'for' Development. *Curr. Opin. Environ. Sustain.* **2014**, *6*, 73–77; ISSN 1877-3435. [CrossRef]
83. Thomas, R.; Reed, M.; Clifton, K.; Appadurai, N.; Mills, A.; Zucca, C.; Kodsi, E.; Sircely, J.; Haddad, F.; Hagen, C.; et al. A Framework for Scaling Sustainable Land Management Options. *Land Degrad. Dev.* **2018**, *29*, 3272–3284. Available online: https://onlinelibrary.wiley.com/doi/10.1002/ldr.3080 (accessed on 1 March 2023). [CrossRef]
84. UNEP. Website. Available online: https://www.unep.org/circularity (accessed on 1 March 2023).
85. University of Cambridge. *Climate Change: Implications for Agriculture*; BSR: Cambridge, NY, USA, 2014. Available online: https://www.cisl.cam.ac.uk/ipcc (accessed on 1 March 2023).
86. Scoones, I.; Thompson, J. *Rural People's Knowledge, Agricultural Research and Extension Practice*; Intermediate Technology Publications: London, UK, 1994; ISBN 1-85339-250-2.
87. Critchley, W.; Cooke, R.; Jallow, T.; Lafleur, S.; Laman, M.; Njoroge, J.; Nyagah, V.; Sant-Firmin, E. *Promoting Farmer Innovation*; REMLA, Workshop Report No. 2.; ICRAF: Nairobi, Kenya, 1999.

88. Reij, C.; Waters-Bayer, A. (Eds.) *Farmer Innovation in Africa*; Earthscan: London, UK, 2001; ISBN 1-85383-816-0.
89. Sinclair, F.; Coe, R. The Options by Context Approach: A Paradigm Shift in Agronomy. *Exp. Agric.* **2019**, *55*, 1–13. [CrossRef]
90. Crossland, M.; Chesterman, S.; Magaju, C.; Maithya, S.; Mbuvi, C.; Muendo, S.; Musyoki, M.; Muthuri, C.; Mutua, F.; Njoki, C.; et al. *Supporting Farmer Innovation to Restore: An Illustrated Five-Step Guide to Applying the Options by Context Approach to Land Restoration*; World Agroforestry: Nairobi, Kenya, 2022.
91. CARE International. *Facing Uncertainty: The Value of Climate Information for Adaptation, Risk Reduction and Resilience in Africa*; World Agroforestry: Nairobi, Kenya, 2014. Available online: https://www.careclimatechange.org/adaptation-initiatives/alp (accessed on 1 March 2023).
92. FAO. *Impact of Early Warning Early Action*; FAO: Rome, Italy, 2018. Available online: https://www.fao.org/emergencies/fao-in-action/ewea (accessed on 1 March 2023).
93. IFAD. *How to Defined and Measure "Climate Resilience"*; How To Do Notes; IFAD: Rome, Italy, 2014.
94. NIRAS LTS International. *Climate Smart Agriculture Thematic Review. Evaluation Report*; FCDO, Government UK: London, UK, 2021.