Chapter 11
Sustaining Natural Resources in African Agriculture: What Have We Learned in the Past Two Decades?

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Abstract Calls for increased attention to natural resource management (NRM) in African agriculture have been around for many decades. They became more vocal around the turn of the century following decades of poor yield growth and emerging data showing concerns about land quality and productivity. In recent years, these intensified further with the specter of climate change and continuing rural population growth challenging agricultural systems on the continent. Researchers have responded to these challenges, advancing research frameworks and hypotheses, deploying more research tools, and conducting more studies. However, it is unclear that all this response has significantly advanced our state of knowledge on the extent and nature of land degradation in agricultural land, the particular practices that work in different socioeconomic contexts, and how best to induce their uptake by households facing different priorities and constraints. This chapter will motivate this conclusion and offer options for moving forward in some of these topical areas.

11.1 Introduction

It was not easy to identify the best approach to take in writing this chapter. Initially, I planned to review recent studies on natural resource management (NRM) adoption in Africa, teasing out lessons and then offering some policy-relevant conclusions. However, after probing the literature, it was clear that synthesizing studies would be a great challenge given the heterogeneity in NRM coverage, geographical coverage, and research designs. I then took a different approach; to focus this chapter on how much we have advanced our knowledge and understanding of NRM in Africa. This knowledge is unpacked into subtopics: (1) extent of soil degradation, (2) our research methods used to study NRM adoption, (3) extent of adoption of NRM practices on farms, and (4) our understanding of adoption processes. Given the limitations on chapter length, I have been quite selective on the references used, and this should

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not be taken as a systematic review of the literature. I conclude with some overall observations of whether or not progress has been made and where attention should be paid in the future.

11.2 State of Land Degradation in Africa

In 1991 a novel and influential study concluded that land degradation was an enormous problem globally, including in Africa, and called for urgent attention (Oldeman et al. 1991). Though this relied on expert opinion, several smaller-scale studies would find evidence that supported this general observation. Its conclusion that as much as 65% of the land is degraded is still being cited in 2021 publications (e.g., Mansourian and Berrahmouni 2021). New tools for assessing degradation became available, such as high-resolution remote sensing and near-infrared spectroscopy. These held promise that we would soon have access to up-to-date information on many soil quality indicators and show how different forms of land degradation were changing over time. We would also have at our disposal time-series databases for use by researchers from any discipline, including those interested in incentives for investing in NRM, for example, in earlier studies using remote sensing (e.g., Otsuka and Place 2001) or soil quality data (e.g., Yamano et al. 2011). Unfortunately, this has not been the case. The integration of data related to land degradation into socioeconomic studies has been spotty. The science has proven to be very challenging. Remote sensing is good at identifying some topsoil parameters but not as good for others. High-quality data in certain selected sites are not so easily extrapolated to neighboring 'pixels,' and other approaches to identifying underlying soil health, such as normalized difference vegetation index (NDVI) or net primary production (NPP), can be related to other factors that are not always easy to isolate from soil quality parameters. With these caveats in mind, Kirui et al. (2021) found high rates of land degradation across sites in four African countries; Le et al. (2016) found land degradation in Africa to be less pervasive in cropland than in other land uses; Nziguheba et al. (2021) found that the proportion of cropland unresponsive to fertilizer application is low. An expert opinion-based approach to identifying key soil constraints was presented by Stewart et al. (2020). Therefore, we still are unclear on the extent and nature of land degradation across Africa and have missed opportunities to integrate that information into studies that address the use of NRM practices.

11.2.1 Study of NRM in African Agriculture

Despite the limitations in our understanding of specific degradation problems in particular locations, there has been a healthy interest to pursue our understanding of NRM practices by farmers, especially smallholder farmers, in Africa. The conventional view driving this was that there was underinvestment in NRM and that new configurations of NRM are needed to sustainably increase productivity and adapt to climate change. In the late 1990s and early 2000s, a significant number of socioeconomic studies were generated, investigating a range of NRM practices in sites throughout Africa. Some key studies of the time were conducted by the Consultative Group on International Agricultural Research (CGIAR) and included in the edited volumes of Otsuka and Place (2001), Barrett et al. (2002), and Pender et al. (2006). Some advances in synthesis were made, but those efforts also identified limitations, such as lack of consistency in defining NRM practices, measurement challenges, and improving the statistical rigor of empirical studies. In those days, experimental designs in NRM adoption and impact research were absent.

In the years since then, progress has been modest. There has been more attention given to sets or combinations of practices, and now it is more common to find studies looking at the adoption and impact of conservation agriculture (CA), sustainable intensification, integrated soil fertility management (ISFM), agroecology, regenerative agriculture, or climate-smart agriculture (CSA). These are based on principles, but typical studies of farmer adoption focus on specific practices that may operationalize one or more of the principles. Furthermore, specific practices are often components of more than one integrated NRM approach. For example, crop rotation is a key component of CA but is also recognized as important for regenerative agriculture, CSA, and agroecology. The application of organic nutrients similarly ticks the box of several different integrated NRM practices. There is nothing wrong with multiple approaches claiming a practice as theirs, but it becomes confusing when authors use adoption of crop rotation to indicate partial adoption of CA in one case or of CSA in another case when the study did not, in fact, seek to understand why the farmer practices crop rotations and whether they are done in concert with other practices. This issue is taken up regarding CA by Ward et al. (2018), Ngoma et al. (2021), and Tambo and Mockshell (2018).

Measurement of NRM is still a challenge. A review of recent empirical work shows that NRM practices are almost always measured by discrete variables (e.g., presence or absence at a particular point in time). Glover et al. (2016) questioned the utility of studying 'adoption' as a binary action and called for a better way to assess technological change on farms. Farmers are continuously modifying technologies and practices, while our surveys are simply capturing the presence or absence of an NRM practice that, in some cases, may not be easily described by an enumerator. More quantification of the extent of the practice (e.g., number of trees, size of the area under an NRM practice), as well as the quality of the application (e.g., is there good or poor coverage of the crop residue), would provide more insight, but this is rarely done in practice, due to difficulty or costs of measurement. Even when quantification is done, as for trees on the farm in the more recent Living Standards Measurement Surveys–Integrated Surveys on Agriculture (LSMS-ISA), the results do not always appear to be highly reliable, as noted by Miller et al. (2016). A recent exception is Mwaura et al. (2021), who showed that while the use of manure, crop rotations, mulching, and legume intercropping were all common in the central Kenya highlands, the proportion of land area under such practices was low—below 25%

in almost all cases. Therefore, although this measurement weakness was recognized decades ago, we have not made progress in overcoming it.

Finally, the same challenges of fragmented case studies, inadequate contextual description, variability in the use of explanatory variables, and modeling of NRM-dependent variables that characterized the state of the science around the turn of the century are still found in today's research. Fragmentation is shown by the dominance of case studies of modest numbers of farmers in limited geographies and the scope of NRM practices studied. It is often the case that a study aims to understand the use of a limited set of NRM practices. Where studies do cover a broader scope of NRM practices, there is much variation in how these are modeled, sometimes as independent practices, sometimes as interrelated binary decisions (Martey and Kuwornu 2021), and sometimes as combinations of practices (e.g., the number of practices or in multinomial logit regressions expressing different combinations in Horner and Wollni 2020). Furthermore, one would struggle to find two studies using the same sets of explanatory variables. And finally, while the majority of studies have focused on the household as a decision-maker, some recent work has looked at individual decision-making and thus, opened up exploration into the influence of gender (Bernier et al. 2015). These issues make it nearly impossible to synthesize findings—for example, to understand how household labor may constrain the use or adoption of various NRM practices in different contexts. Discussion of when certain specifications are preferred over others is needed.

11.3 The State of NRM in African Agriculture

Our information on the extent of adoption of NRM practices in Africa is imperfect, partly because of the measurement challenges noted above. Numerous cross-sectional studies note adoption rates of selected NRM practices, indicating a mixed picture of adoption depending on the location and NRM practice. For example, within the theme of agroforestry, there is evidence of widespread adoption of farmer-managed natural regeneration in the Sahel (Reij et al. 2009), where the parkland system has been practiced for many decades while planting of trees for soil improvement in Zambia is low (Stevenson and Vlek 2018). CA has long been disseminated in Africa, but in no country outside of South Africa is it commonly adopted (Corbeels et al. 2014). On the other hand, Kosmowski et al. (2020) analyzed recent national surveys in Ethiopia and found that soil and water conservation practices were widespread, practiced by 72% of households (over 9 million in total). Also, in Ethiopia, the use of CA was much lower, with about 10% of households using minimum tillage and about 5% practicing minimum tillage along with crop rotation and residue cover of soil. This highlights that adoption of full sets of recommended practices, such as CA or ISFM, is very low, even if some of their components are commonly used. For example, Sheahan and Barret (2017) found that the correlation between the use of organic nutrients and mineral fertilizer, both components of ISFM, was low in Niger, Tanzania, Uganda, and Malawi, and only significant in Nigeria and Ethiopia.

A few of the studies noted above drew upon the LSMS-ISA, and indeed the survey instrument has improved its ability to capture NRM practices in each round. To date, this seems an undermined source for analysis and ideally should be better utilized in the future.

11.4 Understanding Adoption of NRM in Agriculture in Africa

Decades ago, five broad hypotheses were formulated as to why the adoption of NRM practices could be lower than suggested by their technical performance in trials. These are:

- Technologies/practices are not well understood by farmers enough to evaluate or implement them
- Technologies/practices do not offer many technical advantages in any kind of time horizon
- Benefits from technologies/practices are too far in the future to be of interest
- There are critical constraints to the implementation of technologies/practices related to upfront costs that cannot be easily overcome
- Technologies/practices are not profitable or otherwise suitable for farmer conditions under existing economic/policy regimes, notably in comparison with alternative uses of labor/capital/land.

Perhaps as no surprise, studies on NRM adoption in recent literature came to the same conclusions as earlier literature—that all of these hypotheses appear to be valid for given NRM-location combinations. One key advancement in knowledge over the years has been on the interactions of gender with each of these hypotheses, which are discussed in the following sections.

11.4.1 Lack of Awareness or Understanding

A number of recent studies confirm that lack of awareness or knowledge remains a constraint to adopting certain NRM practices. Aker and Jack (2021) ran a randomized controlled trial (RCT) to test for information and capital constraints to investment in half-moon microcatchments for rainwater harvesting in Niger. They found that training was key to boosting adoption rates—additional cash transfers did not have an incremental effect. Martey and Kuwornu (2021) found that in a region in Ghana that hosted several projects, including the Alliance for a Green Revolution in Africa's (AGRA) soil health program, the adoption of soil fertility management practices was common, with nearly half of farmers using three or more practices on their farms. Mango et al. (2017) collected data on farmer awareness and adoption of various soil and water management practices in the Chinyanja triangle of Malawi, Mozambique, and Zambia. They found a considerable variation in the awareness of individual practices. For example, only 2% and 4% had knowledge about mulching and rainwater harvesting, respectively, while 38% had knowledge about using contour ridges. Finally, a review of incentives for adopting sustainable land management practices found that access to extension is often a positive factor in uptake (Pineiro et al. 2020).

11.4.2 Lack of Technical Advantages

The likelihood that inappropriate NRM practices are vigorously disseminated has diminished in recent years due to the accumulated testing of practices in different contexts and a better understanding of which plant species grow better in certain soils, altitudes, and climates. This has led to geographical information system (GIS) databases of 'best' or 'good-fit' practices, such as conservation approaches and technologies (www.WOCAT.net) and agroforestry species (World Agroforestry Centre 2009). However, as noted earlier, increased attention has been paid to the need for integrated practices, which generates a more complicated challenge to what works best in different conditions. To give one example, Gram et al. (2020) examined the evidence in a metareview of how well fertilizer and organic nutrients separately or in combination relate to CSA principles of improved agronomic efficiency of nitrogen, reduced yield variability, and build-up of soil organic carbon. At low rates of nitrogen fertilizer, fertilizer alone does well, but combinations with organic sources are best when nitrogen fertilizer rates are higher. On the other hand, fertilizer is the worst option for yield variability and soil organic carbon, indicating tradeoffs. Giller et al. (2021) examined the evidence that regenerative agriculture can deliver on problems, such as poor soil health or low levels of agrobiodiversity, and found that the evidence is mixed.

11.4.3 Benefits Are Too Far in the Future

Many NRM practices require upfront investment costs, while benefits may not be realized until many years later. This will dissuade farmers with high discount rates from investing in such practices. Ngoma et al. (2018) found high risk aversion and impatience (short-term time horizons) among farmers in Zambia. Similarly, Bell et al. (2018a, b) found that subsidies or early payments for environmental services can increase the adoption of CA in Zambia. Regardless of the incentives offered, farmers who do not have secure long-term rights to land will not be interested in investing in long-term NRM practices. Indeed, one of the most consistent findings in the literature is that farmers operating on rented land are much less likely to adopt

NRM practices than owner-operators although they are equally or more avid users of inputs (Place et al. 2021). This seems to be an issue of growing importance as the prevalence of land renting is growing in many African countries (Jayne et al. 2021).

11.4.4 Constraints to Their Implementation

There has been significant investigation on the relationships between NRM adoption and land and labor factors of production and, to some extent, capital constraints. For labor, a general conclusion has been that household labor has either a positive or benign effect on the adoption of NRM practices—it is very rare to find a negative relationship. The case of farm size is more mixed—generally insignificant, but with some positive and negative relationships found. The pattern for wealth variables is similar to that for farm size.[1] The latter two results are encouraging because it suggests NRM practices are accessible and beneficial to households and farms at varying asset levels. Labor appears, therefore, to be a key constraint. Recent studies also reinforce this pattern (e.g., Mwaura et al. 2021 on labor effects in central Kenya) and have probed further to distinguish different cases. For example, Wordofa et al. (2020) found that farmers in Oromia, Ethiopia perceived that many introduced soil conservation measures required considerable establishment or maintenance labor costs even though their technical effectiveness was appreciated. Horner and Wollni (2020) analyzed over 6,000 maize, wheat, and teff plots in Ethiopia as part of a randomized soil fertility project. They found that ISFM adoption resulted in more than 50% more labor used on the three crops. Although this was compensated for on average by higher returns, households reduced labor to other crops or nonfarm activities in some regions, offsetting these gains.

11.4.5 Economic Returns/Profits Are Too Low

Compared to studies of NRM adoption, studies that compare costs and benefits and profits from NRM practices are relatively few. Such studies are challenging because costs and benefits are different at different stages of the practice and, thus, ideally require a multi-year assessment. In their review, Ngoma et al. (2021) noted that studies related to CA show mixed results. One of the positive cases is Tambo and Mockshell (2018), who analyzed data from farmers across nine African countries. They found that CA significantly increased household income. On the other hand, Horner and Wollni's (2020) study in Ethiopia found that returns to unpaid labor for organic nutrient additions are low in humid zones, unless improved seeds are also part of the package, but are relatively high in drier zones. This again points to the heterogeneity of findings that characterize these studies.

[1] From author's own analysis of 35 African NRM adoption studies between 2001 and 2017.

11.4.6 Constraints and Benefits Are Different for Men and Women

Almost all studies of the adoption of NRM practice are conducted at the household level, with scant attention to individual decision-makers. However, there are gender dimensions within each of the hypotheses above. For example, women have less access to information or labor than men. Bernier et al. (2015) found that women are much less informed than men about climate-smart practices in Kenya, and this affects their ability to invest in such practices; when they are informed, they adopt practices at the same rates as men. Mponela et al. (2021) found a more nuanced relationship depending on the NRM practice. A positive relationship was found between women's empowerment (participation in decision-making domains) and adoption of legumes, a negative relationship with manure, and a statistically insignificant relationship with mineral fertilizer. Meinzen-Dick et al. (2014) reviewed literature that contributes to an analysis of gender and sustainability. They found that several factors may motivate better or worse stewardship by women than men. On the positive side, women are interested in conserving natural resources for food, water, firewood, and medicinal products, which may traditionally be among her tasks to collect. On the other hand, rights to resources among women are often less secure than for men, providing less incentive for longer-term stewardship. More research is needed on gender and NRM in Africa, not least because of continuing transformation processes that create significant change in rural areas regarding household composition and decision-making.

11.5 Key Conclusions

Reflecting on the review above, eight concluding remarks emerge:

Studies on NRM adoption in African agriculture have continued since the early works decades ago. It, therefore, remains an important issue, perhaps even more so given the growing importance of climate change.

On the negative side, there has not been much improvement in the quality or insights from these new studies. We still have small case studies, cross-sectional studies, measurement using discrete variables, and challenges with analyses (e.g., endogeneity). Some of the early innovations (e.g., using remote sensing, integrating soils, and socioeconomic data from 2001 and 2011) have not expanded.

What has emerged is a proliferation of NRM terminology with many new integrated approaches—regenerative agriculture, organic farming, ISFM, CA, agroecology, CSA, and sustainable intensification—all being the subject of analysis. Each of these methods is complex and lends itself to disaggregation and analysis, and has increased the complexity of this area of inquiry.

There remains some debate about the severity of resource degradation and the extent of adoption of NRM in African agriculture due to measurement challenges and, in some cases, lack of investment in research.

The major reasons for why adoption may be low or limited in Africa are still the same as espoused many years ago. Some new evidence supports each of these, suggesting that they remain important in different situations. There have been attempts to understand the best fits for different situations, but this remains elusive due to challenges in synthesizing fragmented literature.

We are not advanced in our overall understanding of what key constraints are binding in different contexts, nor what types of incentives or other interventions could cost-effectively spur adoption. There is a sense that multiple interventions are necessary, including human capital investments in education and training. But we are far from understanding this well.

Moving forward on the research side, two avenues seem to be warranted. The first is to make better use of improved coverage of NRM in the LSMS-ISA datasets. A second approach would be to undertake a large, coordinated study of NRM adoption (and impact), ideally building on the LSMS-ISA datasets, to advance our understanding of what factors are most constraining to different NRM practices, as well as what NRM practices are likely to be good fits in different situations. This would require a blending of methods (qualitative/quantitative/GIS/soils sampling). As for good-fit NRM practices, it may be more important for research to identify principles and characteristics of promising practices for different situations, given the heterogeneity of conditions. Where best fits are identified, more RCTs on interventions to strengthen NRM uptake are a second recommendation.

On the development side, a great deal of literature would suggest that scaling specific NRM practices (as opposed to principles) will have mixed success in NRM. On the other hand, place-based approaches, in which community-based field staff work with communities over long periods, seem to better translate NRM principles into functional practices within extension or development programming. A critical need is to enhance the skills in NRM of public extension officers (Jayne et al. 2019) as there is no other viable mechanism for improving NRM knowledge among farmers—there is little private sector incentive in labor-intensive practices and NGOs have broad agendas.

Recollections of Professor Keijiro Otsuka

Peter Hazell connected Kei with me in the mid-1990s while Kei was at IFPRI for several years and I was at the World Agroforestry Centre (ICRAF) in Nairobi. Kei was leading a global study on tenure and NRM, and I became his collaborator for studies in eastern and southern Africa. That proved to be exciting in many ways, and what I will remember the most was the initial diagnostic fieldwork—traversing large parts of Uganda and Malawi to collect insights on the dynamics taking place in many different contexts. Every day when we would come back from the field to our hotel, Kei would spend some time in his room organizing what he heard into an economic framework, and we would discuss this over dinner. This was such an important step in the process of identifying hypotheses, developing study designs, and ultimately in writing papers. We did have success in that collaboration, and I am grateful to have worked with and kept up a friendship with Kei ever since.

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