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A review of the literature on gender and chemical fertiliser use in maize production in sub-Saharan Africa

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Abstract

Are there differences in men's and women's access to and use of fertiliser in sub-Saharan Africa? This article explores the issue through a systematic review of the extant literature on gender and fertiliser use in maize production. The findings show that indeed a gender gap in the use of fertiliser exists. More than a decade after the World Bank identified a gender gap in fertiliser use, there are no systematic national or global data sets comparing fertiliser use by gender. While farm input subsidies can improve women farmer's access to fertiliser and have a positive effect on agricultural productivity for both men and women farmers, this approach has little effect on reducing the gender gap in agricultural productivity. The challenges associated with gender and fertiliser access and use are complex and there is no silver bullet intervention that can address the problem, particularly in relation to intra-household dynamics and social norms. Thus solving the noted problem, will require a holistic approach rather than "simple" sectoral interventions. Over time, suboptimal fertiliser use depletes soils. Nutrient use efficiencies worsen under soil nutrient mining and degradation, thus economic incentives for fertiliser investments are also eroded in such situations, resulting in a vicious cycle. The development of nutrient use efficient maize seed technologies could be an intermediate step towards closing the gender gap in fertiliser use.

Keywords: Inorganic fertiliser, gender, agricultural yield, staple food, *Zea mays*

1 Introduction

Africa urgently needs a massive transformation of the agricultural sector, starting with increasing agricultural productivity, to address the mounting challenges of population growth, unemployment, food insecurity, climate change and declining soil fertility (Alliance for a Green Revolution in Africa, 2013; African Development Bank, 2016; NEPAD, 2016). Since researchers estimate that about 50 % of the productivity gains experienced by Asian farmers during the Green Revolution can be attributed to the increased use of chemical fertiliser alone (Hopper, 1993; Tomich *et al.*, 1995), increased use of chemical fertiliser is recognised as one of the central drivers of agricultural productivity. Average inorganic fertiliser use in sub-Saharan Africa (SSA) has been estimated at 14 kg ha^{-1}, as opposed to 141 and 175 kg ha^{-1} in South Asia and Latin America, respectively (Asfaw & Adamassie, 2004). A recent study by Sheahan & Barrett (2017), based on data from the Living Standard Measurement Study Integrated Surveys on Agriculture Initiative (LSMS-ISA) covering 22,565 households from six SSA countries, namely Niger, Nigeria, Ethiopia, Malawi, Tanzania, and Uganda, found that the application of inorganic fertiliser may be low in aggregate, but is not uniformly low across these six countries.

Crop production in rural SSA is faced with the challenge of declining soil fertility (De Groote *et al.*, 2018) that compounds the problem of underproduction of food in the region. The primary cause of soil degradation in SSA is the expansion and intensification of agriculture in an effort to feed the region's growing population (Tully *et al.*, 2015). The article by Tully *et al.* (2015) goes on to note that certain soils in SSA are losing their ability to provide food and

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essential ecosystem services, and that soil fertility depletion is the primary cause of this. One of the ways to improve soil fertility is by the application of organic manure, a practice adopted more by women, or by the application of mineral or chemical fertiliser, adopted and purchased more by men (Nkonya & Moore, 2015).

However, in Africa, where women account for between 24 % (in Niger) and 56 % (in Uganda) of agricultural labour (Palacios-Lopez *et al.*, 2017), the widely documented gender gap in agricultural productivity, estimated to be between 20 % and 40 % globally, presents a sobering picture (Mukasa & Salami, 2015; FAO, 2011). According to FAO (2011), if women and men had the same access to productive resources, women's yields would increase by 20-30 %, which would raise total agricultural output in developing countries by 2.5–4 % and lead to a 12–17 % decline in the number of undernourished people. Moreover, the low use of fertiliser reduces food and nutrition security and also reduces the uptake and availability of other key nutrients for plant and human nutrition (Pasley *et al.*, 2019 and 2020). For instance, low fertiliser application reduces the Provitamin A maize content of biofortified maize (Ortiz-Covarrubias *et al.*, 2019). Against this background, more attention needs to be paid to assessing and addressing gender gaps in the use of chemical fertiliser.

This review explores chemical fertiliser use in maize production by men and women smallholder farmers in SSA. While the literature on gender, agricultural productivity and chemical fertiliser use is not crop specific, focusing on a single crop or group of crops allows for a more in-depth analysis of causal factors. Maize provides an ideal crop for examining gender differences in fertiliser use for several reasons: firstly, maize is grown by both men and women, and in most African societies is not considered either as "a man's crop" or as "a woman's crop"; secondly, hybrid maize optimally requires the use of chemical fertilisers and quality seed; thirdly, maize is the most important food crop in SSA, particularly in eastern and southern Africa, and receives much attention from governments in terms of production and policy support; and fourthly, in most of cases women tend to grow maize for subsistence needs, while men grow the crop for commercial purposes.

This paper is organised as follows: following the section on methodology, the second session of the paper provides the findings from the review. Specifically, in the first part (3.1), the paper summarizes the discussion on gender and agricultural productivity and examines how input use contributes to the gender gap in agricultural productivity. Part two of results section (3.2), explores the literature on gender and fertiliser use in maize production to address the following questions: Are there differences in men's and women's access to and use of fertiliser in SSA? What factors are responsible for gender differences in fertiliser access and use? What barriers and challenges do women maize producers face in accessing and using fertiliser? Part 4, discusses the strategies and approaches being used to improve women's access to and use of chemical fertiliser. The last section, section 5, is the conclusion.

2 Methodology

The literature on gender and fertiliser use in maize production in SSA was identified through an internet search to find referenced journal articles, reports, policy briefs and grey literature on the topic. Articles were also identified from electronic databases (Web of Science, African Journal Online, Science Direct, Taylor and Francis), using primary search terms and keywords 'gender AND fertiliser AND sub-Saharan Africa'; 'gender gap'; 'fertiliser'; 'adoption of fertiliser'; 'agricultural productivity'; 'access to credit'; and 'maize production'.

The literature search yielded 86 sources pertaining to input use in SSA and 37 publications specifically pertaining to fertiliser use in maize production in SSA. About 10 other articles were found that related to fertiliser, but not necessarily to maize production. The majority of the publications were articles in peer-reviewed journals and official reports.

3 Results

3.1 Gender and agricultural productivity

An extensive literature dating from the 1970s addresses the questions "are there differences in male and female agricultural productivity or technical efficiency?" and "do women have the potential to be as productive as men if they have the same access to productive resources" (see Doss, 2015 for a review of this literature). According to the UN, the annual cost of the gender gap in agricultural productivity is huge: US$105 million in Tanzania, US$100 million in Malawi, and US$67 million in Uganda (UN Women *et al.*, 2015). While results have in general been mixed, studies that apply production or profit functions find no significant differences in male and female agricultural productivity or technical efficiency after controlling for access to inputs and for characteristics of plots, households and farmers (Moock, 1976 on maize; Adesina & Djato, 1997 on rice; Tiruneh *et al.*, 2001 on wheat; Adeleke *et al.*, 2008 on maize). These studies generally conclude that gender differences in productivity are due to differences in access to resources.

Other studies, however, find that productivity differentials are driven by crop differences between men and women (Peterman *et al.*, 2011; Githinji *et al.*, 2014) and country specific conditions (Mukasa & Salami, 2015). Similarly, studies that examine technology adoption generally conclude that although male farmers tend to adopt technologies faster than women farmers, gender per se is not statistically significant in explaining adoption (Peterman *et al.*, 2010; Jagger & Pender, 2006; Doss & Morris, 2001). Factors commonly recognised as enabling technology adoption and found to be statistically significant include education, size of plot, fertiliser use, and access to extension services, agricultural information and credit, which all tend to be statistically correlated to the gender of the farmer or household head (Doss & Morris, 2001; Smale, 2011; Fisher & Kandiwa, 2014; Fisher & Carr, 2015). Policy recommendations based on this empirical evidence support improving women's access to resources and services including fertiliser, other agricultural inputs, and credit.

The literature concerning gender and agricultural productivity has come under recent criticism with regard to data sources, methodology and analytical approaches. The majority of the data on gender and agricultural productivity derives from case studies based on non-nationally representative samples and methodological differences that make it difficult to compare findings and arrive at externally valid results. Doss (2015) argues that the debate about gender and agricultural productivity is in itself flawed due to problems with defining and measuring women's "productivity", and challenges in conceptualizing the gendered structure of agriculture and food systems. A case in point is the assumption made in some studies that inputs or choice of crops are exogenously determined, which may not necessarily be true when gender is taken into account (Doss, 2015). Comparing the productivity of men and women farmers who may grow different crops based on their gender and have different access to land and other productive resources calls for analyses and statistics that consider these complexities. While researchers use several different ways to measure agricultural productivity, the two most popular being output per unit of labour or land. However, most approaches are not designed to measure separately the productivity of men and women farmers. Finally, a key but often overlooked conceptual issue in the discussion around gender and agricultural productivity relates to who is defined as a farmer and which farms/plots are being compared. The majority of studies compare agricultural productivity between male- and female-headed households (FHHs), which is problematic because such analyses compare two different types of household structures and overlook production by women farmers in male-headed households (MHHs), which constitutes the majority of women in SSA (Peterman *et al.*, 2011; Doss, 2015; Ali *et al.*, 2016) and often ignore differences between single women heads of households (widows, divorcees) and married women who head households in the absence of their husbands.

Recent studies have tried to address these issues using more sophisticated methodological approaches and modes of analysis. For example, a number of studies assess technology adoption and agricultural productivity by individual male and female farmers living in the same household (defined variously as the owner of the plot, the manager of the plot, or the person providing the day-to-day labour for the plot or crop) (Smale & Mason, 2012; Fisher & Kandiwa, 2014; Fisher & Carr, 2015; Ali *et al.*, 2016). However, researchers continue to grapple methodologically with the challenges of measuring the productivity of individual farmers who contribute to farms jointly managed by husbands and wives, and the contribution of women to men's farms and vice versa (Doss, 2015). Decomposition techniques such as the Oaxaca-Blinder decomposition allow researchers to identify how much of the productivity gap is due to gender differences in access to inputs (endowment effect) and how much is due to gender differences in returns to these inputs (structural effects) (see Doss 2015 for a review). Studies that use Oaxaca-Blinder decomposition analysis find that in some countries, even when women have access to the same amount of inputs as men, a gender gap in agricultural productivity still exists.

The earlier mentioned 2014 World Bank study on gender and agricultural productivity in six SSA countries (Ethiopia, Tanzania, Malawi, Uganda, Niger and Nigeria) provides an example of the kind of in-depth analysis generated by Oaxaca-Blinder decomposition analysis (O'Sullivan *et al.*, 2014). The study found that controlling for plot size and geographic factors significantly increased the gender agricultural productivity gap observed from a simple comparison of average male and female productivity from, for example, 13 % in Uganda to 25 % in Malawi, to 23 % in Tanzania and 66 % in Niger. Notably, Ethiopian women farm managers experienced smaller improvements in yields relative to men when they applied the same amount of fertiliser and used oxen for farm activities (O'Sullivan *et al.*, 2014). While access to advisory services was not associated with the gender productivity gap in Ethiopia, access to these services generated better returns for male than for female farmers. The authors suggest that these findings may be due to gender differences in knowledge of appropriate farming techniques due to unequal access to extension services and other sources of information, or to timing of use. On the other hand, women's

lower use of inputs (e.g. improved seed, chemical fertilisers) in Malawi accounted for more than 80 % of the gender gap in agricultural productivity. Other factors that contributed to the gender gap in agricultural productivity in the target countries included quantity and efficiency of farm labour (Niger, northern Nigeria), land ownership, quality and access (Ethiopia, Niger) and the burden of domestic and childcare responsibilities (Ethiopia, Malawi, Niger).

Findings based on nationally representative data on the adoption of hybrid maize in Malawi (often used as a proxy for gender productivity difference) also highlight the complexity of factors contributing to gender-differentiated agricultural productivity (Fisher & Kandiwa, 2014). In contrast with smaller sample surveys, which found that gender differences in adoption of hybrid maize in Malawi disappeared after controlling for access to key resources and services (land, labour, capital, extension services, and markets), this study shows that gender significantly influenced the decision to grow hybrid maize after controlling for those factors. After controlling for resource-related factors, female household heads had an 11 % lower probability, and wives in MHHs had a 12 % lower probability of growing hybrid maize than male household heads. Access to complementary inputs such as fertiliser was among several reasons for lower female adoption rates; other possible explanations were that women did not appreciate the traits of the maize varieties distributed and were more risk averse than men.

Despite methodological, conceptual and measurement challenges, this brief review of the literature on gender gaps in agricultural productivity shows that women farmers in Africa experience disadvantages that often result in lower productivity and inefficiencies.

3.2 Gender and fertiliser use in SSA

While fertiliser demand in SSA is projected to grow annually, at 3 % of global fertiliser consumption, the total volume of fertiliser in SSA is expected to remain low relative to other parts of the world (AGRA, 2016). Analysts have advanced several explanations for low fertiliser use in SSA including the following: limited and untimely supply of fertiliser; high costs; liquidity and credit constraints; lack of knowledge and skill in using fertiliser; uncertainty about returns from fertiliser use due to risks such as price volatility, pests and diseases; climate change; and limited access to output markets to ensure a return to investing in fertiliser (Morris, 2007; AGRA, 2016). Use of chemical fertiliser varies considerably across and within countries and by crop. For example, Ethiopia and Malawi are above the SSA average reported by FAOSTAT, while Niger, Nigeria, Tanzania, and Uganda all fall below (Sheahan & Barrett, 2014).

There is strong evidence of a significant gender gap in the use of chemical fertiliser in SSA where women play a significant role in crop production (Peterman *et al.*, 2010; Chirwa *et al.*, 2011; Sheahan & Barrett, 2014; Lambrecht *et al.*, 2016). For example, 55 % and 89 % of MHHs, compared to 26 % and 74 % of FHHs in a sample of maize-producing households in western Kenya applied urea and di-ammonium phosphate (DAP), respectively (Sheremenko & Magnan, 2015). In Uganda, 2 % of male plot managers compared to 0.4 % of female plot managers applied fertiliser (Ali *et al.*, 2016). Another study in Uganda found that male heads of household were between 49 % and 70 % more likely to adopt inorganic fertiliser than female heads of household (Diiro *et al.*, 2015). A 2017 endline survey in a longitudinal study found that 63 % of male maize farmers in Malawi used chemical fertiliser compared with 54 % of female farmers (Djurfeldt *et al.*, 2019). On the other hand, based on descriptive statistics, studies in Kenya and Ethiopia found no significant differences in the percentage of plots managed by individual men and women and jointly managed where fertiliser was used (Aguilara *et al.*, 2015; Ndiritu *et al.*, 2014).

A decade after the World Bank identified a gender gap in fertiliser use (World Bank, 2009), no systematic national or global data sets comparing fertiliser use by gender exist. As a result, much of the literature that explores the gender dimensions of fertiliser use derives from country-specific case studies, particularly from major maize-producing countries in eastern and southern Africa, notably Malawi, Kenya and Tanzania (Alene *et al.*, 2008; Chirwa *et al.*, 2011; Mapila *et al.*, 2012; Ndiritu, *et al.*, 2014; Gine *et al.*, 2015; Kilic *et al.*, 2015; Djurfeldt *et al.*, 2019) with a smaller number of studies on Ethiopia, Uganda and South Africa (Essa & Nieuwoudt, 2001; Aguilara *et al.*, 2015; Ali *et al.*, 2016). Researchers have also examined gender differences in fertiliser use in West Africa (Beaman *et al.*, 2013; Thériault, *et al.*, 2017; Tankari, 2018).

Sheahan & Barrett (2014) found that in all six SSA countries (Niger, Nigeria, Ethiopia, Malawi, Tanzania, Uganda) MHHs were significantly more likely than FHHs to use chemical fertiliser and other modern inputs. Exceptionally, Machina and colleagues observed higher female than male use of chemical fertiliser among participants in an input support program in Zambia (Machina *et al.*, 2019), in contrast with an earlier study showing that gender of the household head was the most significant factor influencing fertiliser use among Zambian farmers, with MHHs more likely than FHHs to use fertiliser (Mapila *et al.*, 2012).

Like the literature on gender and agricultural productivity, discussions about gender and fertiliser use grapple with conceptual issues regarding the unit of analysis and which

farmers are being compared. While most, especially older studies, compare MHHs and FHHs, some studies provide a more detailed categorization of female farmers by collecting data on fertiliser use by women farmers in MHHs, and distinguishing between households headed by single women and households headed by married women with an absentee husband (Ohlsson *et al.*, 1998; Uttaro, 2002; Chirwa *et al.*, 2011; Aguilara *et al.*, 2015; Ali *et al.*, 2016; Machina *et al.*, 2019).

Determinants of fertiliser demand and use by farmers in SSA fall into four types of groups: economic (price, access to credit/cash); knowledge and information; access; and perception. Socio-cultural factors constitute a fifth set of characteristics rarely discussed in the literature. Aside from gender, studies also control for household- or plot-manager characteristics such as age, literacy/education level, off-farm employment, labour availability, membership of producer organisations, as well as farm characteristics such as land size. These factors have an important gender dimension which influences men and women farmers' willingness and ability to purchase fertiliser and use it. We discuss below the gender dimensions related to economics, knowledge, access, perception, and socio-cultural factors that influence fertiliser access and use in SSA.

3.2.1 Economic factors

The high cost of fertiliser in SSA (on average USD 800-1200/MT at the farm gate) (Jayne *et al.*, 2013; Jain & Jha, 2015) and lack of cash or credit to purchase agricultural inputs are important constraints to fertiliser use by smallholder farmers. Because women have fewer income-generating opportunities than men, less time to engage in such activities, and generally earn less than men from off-farm employment, they often have less money for purchasing fertiliser and other agricultural inputs (O'Sullivan *et al.*, 2014; Rodgers & Akram-Lodhi, 2019). The importance of financial constraints to fertiliser adoption was highlighted in an experiment that resulted in Malian women increasing the amount of fertiliser and complementary inputs used on their rice plots when provided with fertiliser grants (Beaman *et al.*, 2013). The higher use of fertiliser by de facto female household heads in western Kenya compared with single female heads of households may be due to the former group's access to cash from their husbands (Ohlsson *et al.*, 1998). Women may also face gender-related barriers to accessing credit as they are less likely than men to belong to membership-based organisations, particularly formal organisations such as producer organisations that facilitate access to credit, fertiliser and other inputs and services (Tanwir and Safdar, 2013; Kaaria *et al.*, 2016). Furthermore, in some societies, access to credit is influenced by a woman's marital status, with married women having less access to credit than female heads of household (Fisher & Carr, 2015).

3.2.2 Knowledge and information

Evidence showing how women's more limited access to advisory services contributes to their lower use of fertiliser is supported by an extensive literature on gender differences in access to extension services (Meinzen-Dick *et al.*, 2011; Ragasa *et al.*, 2013; see Petrics *et al.*, 2015 for a review). Contact with and frequency of extension contact, which enhances knowledge, information and training on fertiliser and market linkages, is positively associated with fertiliser use through its effect on the increased productivity of available inputs, and indirectly through increased use of fertiliser and other resources (Alene *et al.*, 2008). In Malawi, participation in training and study tours significantly increased fertiliser use by a factor of 3.3 (Mapila *et al.*, 2012). Data from Ethiopia and Malawi showing the contribution of gender differences in returns to fertiliser use, to the gap in agricultural productivity suggest that women farmers in these countries may be applying fertiliser incorrectly or at the wrong time and/or be using inferior quality fertiliser (O'Sullivan *et al.*, 2014). A study carried out in Uganda attributed lower maize productivity and fertiliser use by female heads of household to more limited contact with extension and less market integration (Larson *et al.*, 2015). Limited access to extension services was also a factor explaining lower adoption of fertiliser by FHHs in KwaZulu-Natal, South Africa (Essa & Nieuwoudt, 2001). Evidence suggests that unless specific efforts are made to involve women, they are less likely than men to participate in events that promote and provide training on fertiliser (e.g. agricultural shows, field days, demonstrations) due to time and mobility constraints and restrictions, childcare responsibilities and limited access to transportation (Manfre *et al.*, 2013).

3.2.3 Access

Fertiliser supply channels include extension services, commercial suppliers e.g. agro-dealers, producer organisations and farmer groups. Constraints related to accessing fertiliser include late delivery, poor quality of fertiliser, difficulty in reaching the distribution/sale point due to long distance, poor roads, lack of transportation, packaging quantities etc. Empirical evidence shows that women face greater constraints than men in accessing fertiliser (Peterman *et al.*, 2010). Due to their heavy agricultural and domestic workloads, in addition to cultural restrictions on their mobility in some societies, women farmers are often less able than men to travel to purchase fertiliser and other agricultural inputs

from commercial sources and may lack funds for transportation (CIMMYT, 2014; David, 2015; Njuguna *et al.*, 2016). Women farmers also have gender-related needs that tend to be overlooked by fertiliser suppliers. Female farmers, who typically manage smaller plots and have less cash than male farmers, may find it more economical to purchase fertiliser packaged in smaller quantities (Okello *et al.*, 2016). Lower female literacy rates may make it difficult for women to get information about agricultural inputs including fertilisers and to read instructions on fertiliser packages, particularly if they are written in the official language (Quisumbing *et al.*, 1995).

3.2.4 Perception

As with other agricultural technologies, farmers' willingness to purchase and use fertiliser is determined by their perception of fertiliser, their evaluation of the potential gains from using it, and access to information and training on fertilisers. Attitudes and perceptions partly explain the correlation found in some studies between educational level and fertiliser use (Marenya *et al.*, 2015), with gender differences being important in some cases. For example, more than 30 % of surveyed farmers in Mozambique, Malawi and Tanzania, 55 % of whom were women, believed that fertiliser was bad for the soil (Mapila *et al.*, 2012). The researchers attribute the higher proportion of women holding this misconception to their lower levels of education and limited exposure to training on fertiliser.

3.2.5 Socio-cultural factors

Socio-cultural factors may influence fertiliser use by men and women. Some studies show that, where households cultivate a mix of individual- and household-managed plots, fertiliser application rates may vary by plot due to intra-household and gender dynamics (Thériault *et al.*, 2016). In situations in which agricultural decisions are jointly made by spouses, and cash and credit are scarce, women may depend on their husbands to access fertiliser (Lambrecht *et al.*, 2016). A study in the DRC that found higher adoption of fertiliser when both spouses participated in a fertiliser extension program, compared to adoption rates for women who participated alone, suggests that in some contexts, gender and intra-household dynamics should be taken into consideration when targeting farmers for increased fertiliser use (Lambrecht *et al.*, 2016). Recommendations from this study include the need for fertiliser programs to identify which household members are involved in decision making about fertiliser use, even where women are the principal plot managers, and the need to target all relevant household members (see O Campos *et al.*, 2016 for a discussion of how the choice of gender variable matters in the analysis of agricultural productivity). In some societies, land inheritance customs affect fertiliser use. A Zambian study found that in villages where widows were prohibited from inheriting land, couples applied 13–18 % less fertiliser, and were less likely to leave land fallow and to use intensive tillage techniques (Dillon & Voena, 2017). Researchers concluded that the possibility of land expropriation upon widowhood discourages households from investing in fertiliser and other land- and soil-improvement techniques even when husbands are alive.

4 Discussion

Improving women's access to and use of inorganic fertiliser requires a two-pronged strategy: addressing gender barriers related to women's education, land rights, market access, participation in producer organisations, access to labour-saving tools and equipment, child care facilities etc.; and approaches focusing on improving fertiliser access and use. While both strategies are necessary to address gender gaps in fertiliser use, it is beyond the scope of this paper to assess what impact efforts to address gender barriers have had on women's fertiliser use. Thus, the following discussion examines two approaches that aim to address gender inequalities in fertiliser access: farmer input support programs and strengthening the capacity of agro-dealers.

4.1 Input subsidy programs

The high cost of fertiliser and smallholders' lack of cash or credit to purchase agricultural inputs are the rationale for the farmer input support programs (FISP) that have been carried out in several SSA countries since the 1970s. Some input subsidy programs specifically target FHHs (e.g. Malawi) in an effort to boost food security among the poorest farmers, while some programs require recipients to co-pay some of the costs of the technology package (Chirwa *et al.*, 2011; Gine *et al.*, 2015).

There is mixed evidence on the impact of input support programs on women's access to and use of fertiliser and on outcomes of agricultural productivity and income (see Jayne *et al.*, 2018 for a review). Assessing the gendered impacts of FISP on fertiliser is further complicated by exogenous factors that affect voucher and fertiliser use, such as lack of knowledge about how to use fertiliser (Carter *et al.*, 2013) and the practice of selling vouchers (Gine *et al.*, 2015). Researchers in Tanzania found that fertiliser use increased significantly among FHHs in some villages where vouchers were distributed, but not among male farmers, presumably because men were more likely to have used fertiliser before the voucher program began (Gine *et al.*, 2015).

However, many female heads did not participate in the program because they could not afford the top-up to cover the remaining 50 % of the fertiliser cost. Studies in Malawi found that while FHHs were just as likely to receive a fertiliser voucher as MHHs, the average number of fertiliser vouchers received and redeemed was statistically lower for FHHs than for MHH (Karamba & Winters, 2015; Kilic *et al.*, 2015). By contrast, a study in Zambia reported that a higher proportion of female than male plot-mangers accessed fertiliser from the farmer input support program and commercial sources, and that higher quantities of basal and top-dressing fertilisers were applied by female managers (Machina *et al.*, 2019). Access to FISP, however, did not proportionately raise crop productivity for female-managed plots, implying that female farmers faced other non-input constraints to increased productivity. Based on similar findings in Malawi, Karamba & Winters (2015) warn that if persistent gender-related inefficiencies in agriculture are not addressed, input programs "could exacerbate the gender gap and make female farmers worse off as compared to their male counterparts" (p. 370). A study in Malawi suggests that subsidized fertiliser programs that target food security may increase fertiliser use on women-controlled plots and encourage greater female involvement in decisions about the allocation of fertiliser. Chirwa & Dorward (2013) found that while plots controlled by women in both FHHs and MHHs were less likely to use fertiliser compared with male-controlled plots, fertiliser use was to some extent determined by where households obtained fertiliser – from the subsidized program alone, from commercial sources alone, or from both sources. In purely subsidized programmes, the application of fertiliser did not differ by gender of the plot manager, which implies that the allocation of subsidized fertilisers in such households was efficient. The researchers attribute this finding to the involvement of both spouses in making decisions about the use of subsidized fertiliser, which could be a response to the program's focus on subsistence maize production, a responsibility that lies in women's domain. The availability of commercial fertiliser also increased the likelihood of fertiliser use on plots controlled by women. An important conclusion from studies on the gendered impacts of fertiliser subsidy programs (Gine *et al.*, 2015; Kilic *et al.*, 2015; Karamba and Winters, 2015; Machina *et al.*, 2019) is that while such programs can improve women's access to fertiliser and have a positive effect on agricultural productivity for both men and women farmers, they have little effect on reducing the gender gap in agricultural productivity.

4.2 Strengthening the capacity of agro-dealers

Several organisations, including the Alliance for a Green Revolution in Africa (AGRA), the International Fertiliser Development Center (IFDC) and the International Maize and Wheat Improvement Center (CIMMYT) support the professionalization and development of African agro-dealers as part of a supply side approach to increase fertiliser use. The African Fertiliser and Agribusiness Partnership (AFAP) established in 2012 by AGRA and IFDC works to provide development support for the fertiliser market and build the capacity of agro-dealers in thirteen SSA countries (www.afappartnership.org). While AFAP does not specifically address gender-related constraints in accessing fertiliser, its approaches have been instrumental in reducing the price of fertiliser and improving farmer access – key constraints faced by women farmers. Hallmarks of the AFAP program include "the hub and spoke system" that links larger agro-dealers with more remote providers, constructs larger storage facilities, and provides supporting credit and grants for agro-dealers (AGRA, 2016).

CIMMYT has invested in building the capacity of agro-dealers to be responsive to gender differences in fertiliser demand, through a training program that encourages agro-dealers to recognise men and women farmers as customers that may have different needs, and to address women's specific needs. A manual developed specifically for agro-dealers provides suggestions on how to take gender into consideration in promoting agro-dealer businesses specifically in the seed sector, but the manual can also be used for addressing gender gaps in other farm inputs, for example, by reducing fertiliser packaging size, using local language and pictures on fertiliser packages, providing information verbally on how to apply fertilisers, finding ways to make fertiliser more affordable for women, involving more women in demonstrations and field days by setting gender targets, and providing childcare (Adam *et al.*, 2019). To date, the impact of efforts to strengthen the capacity of fertiliser suppliers more broadly and to improve their responsiveness to gender gaps in access to fertiliser have not been assessed.

5 Conclusion

The literature reviewed indicates that female farmers are disproportionately disadvantaged compared to male farmers in terms of access to fertiliser, improved maize seed, credit, and prime agricultural land, among other social factors. In terms of data and conceptual matters of gender and fertiliser use, we observe the need to establish systematic national and global data sets comparing fertiliser use by gender. This

review also concludes that the provision of farm input subsidies is not a panacea for addressing the fertiliser gender gap.

The challenges to reduce the gender gap in chemical fertiliser use in SSA are complex and solutions need to take a holistic approach rather than introducing simple sectoral interventions. The problem of use of fertiliser is further compounded by the fact that nutrient use efficiencies (NUE) for planted maize worsen under low fertiliser use, which in turn lowers economic incentives for fertiliser investment (Cairns *et al.*, 2021). The development and deployment of maize seed enhanced ability to take up or utilize nitrogen fertiliser could be an important intermediate step (De Groote *et al.*, 2018). Breeding specifically for low input conditions has allowed the development of new maize varieties with a 20 % increase in yields compared to commercial varieties (Das *et al.*, 2018). A male sterility system to reduce the cost of production of maize seed also has potential to increase yields under low N conditions (Fox *et al.*, 2017). These technologies will increase both yields and the return on investment in low fertiliser conditions. However, it is important to note that they will increase yield in the short term, however unless higher levels of fertiliser are applied in the long term they will further deplete the soil of inorganic N (Pasley *et al.*, 2020). Public and private sector actors seeking to increase fertiliser uptake in SSA should take a broader approach to addressing gender gaps in this area by introducing interventions that empower women farmers economically as a way of boosting their purchasing power as opposed to relying on subsidy programs which tend not to cover full cost of inputs. Gender mainstreaming approaches should seek to diversity women's income generating activities beyond farming by, for example, providing opportunities for women to operate rural enterprises and own livestock. However, efforts to empower women economically need to be complemented by gender transformative approaches that are designed to change gendered social norms and barriers that prevent women from benefitting from any means of livelihoods they are involved in and increasing chemical fertiliser use on their farms.

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Conflict of interest

All authors declared that they have no conflict of interest.

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