Norwegian University of Life Sciences
Faculty of Landscape and Society
Department of International Environment and Development Studies

Philosophiae Doctor (PhD)
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Towards Feminist Crops: A Feminist Technoscience Study of Gender-Responsive and Transformative Crop Breeding

Feministiske plantesorter: En feministisk teknovitenskapelig studie av kjønnet planteforedling

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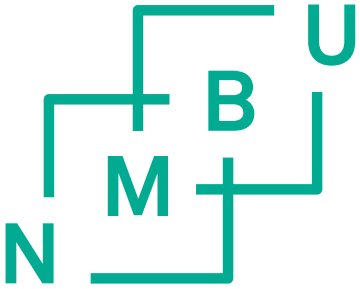

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Summary

Crop breeding is essential for adapting our crops to continuously changing climatic and societal conditions. At the same time, the practices of plant breeding, including priority-setting and varietal design, are highly political, power laden and value driven. The principal selection criteria of crop breeders have most commonly included agronomic traits for increased productivity, such as yield and abiotic and biotic stress tolerance. However, these may not fully capture the preferences and needs of diverse users and user groups in agriculture, including those of many women whose knowledges of and preferences for traits associated with food and nutrition security, processing, food preparation and consumption have often been overlooked. Failing to account for the needs of women not only violates their equal rights and status but is further believed to contribute to low levels of adoption and impact of improved crop varieties. Thus, there is a need to enhance our understanding of how crop breeding can be rendered more responsive to gender and other social factors.

Situated at the intersection of feminist technoscience studies, critical plant studies and political agronomy, the thesis investigates the knowledge politics, practices and tools through which African-based crop breeding programmes of the international agricultural research and innovation system CGIAR are developing gender-responsive and transformative crop varieties. It does so by homing in on the stage of varietal design through an ethnographic case study of the Gender+ Tools developed by the CGIAR Gender and Breeding Initiative. These comprise a set of digital tools that help breeding teams collate and organise sex-disaggregated data to support gender-responsive priority-setting and decision-making. The case study is situated within the historical and institutional context of plant breeding for development, including the market-led turn currently dominating within and beyond the CGIAR. Particular attention is paid to the agenda-setting and decision-making power that crop breeders and private sector donors hold.

The thesis is based on data collected both physically (fieldwork in Kenya and Tanzania) and virtually. This included participant observations during one physical workshop and eight online meetings as part of the piloting of the Gender+ Tools, as well as semi-structured and open-ended interviews conducted both physically and online with CGIAR scientists and national partners, donors, governmental representatives and non-governmental organisations. Additionally, document analysis of resources produced by the relevant actors was carried out.

Through three articles, I demonstrate how gender, crops and crop breeding become co-constructed through the knowledge politics, practices and tools of gender-responsive crop breeding in ways that

may both constrain and support gender equality and women's empowerment. In the first article, I show how the Gender+ Tools take on several performative roles through which farmers and other user groups and their crops, as well inter and intradisciplinary relations, become constructed and negotiated in gendered ways. In the second, co-authored article, we situate gender-responsive crop breeding in the market-led turn. We find that, in its conflated relationship with gender, the market is understood and used as an effective socioeconomic institution for soliciting demand, but also as a normative agenda. Across the continuum from socioeconomic institution to its normative meaning, the market constitutes an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded differential value.

Finally, in the third article, I develop the concept of the 'feminist crop', which helps capture the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. The concept contributes to an investigation of how intersectional gender identities, roles and relations are embedded not only in human systems, but also in plants and more specifically plant–people entanglements. This challenges conventional dichotomies that disassociate nature from culture and the material from the social. Grounded in the feminist crop concept, I explore how plant breeding, including plant genome editing using CRISPR-Cas, can be used as a means for feminist intervention and politics.

Guided by the overarching research question "how can crops and crop breeding be feminist?", the findings are discussed according to four, interrelated realms through which feminist action and politics can be advanced: 'sociomaterial design', the 'sociomaterial system', the 'metaphysical' and the 'imaginary'. Sociomaterial design refers to the ways gender, crops and crop breeding become co-constructed in specific ways through varietal design, and the opportunities it offers to promote feminist design of new plant varieties. The sociomaterial system refers to a larger set of social and material factors of which plant breeding is part, and which can both prevent and promote feminist interventions and outcomes. The metaphysical realm and imagination extend further by challenging the ethical, ontological and epistemological groundings of plant breeding and by using imagination to think of how plant breeding can be done differently and contribute to changes in gendered relationships between people and plants. Thus, the thesis contributes to a re-envisioning of the thinking and practices of crop breeders and gender specialists as a co-construction of gender, crops and crop breeding, with the aim of transforming values and power relations to advance gender equality in agriculture and society.

Sammendrag

Planteforedling er grunnleggende for å tilpasse matplantene våre til stadig endrede miljø- og samfunnsforhold. Samtidig er planteforedling en praksis preget av makt, politikk og verdier. Kriteriene for å velge ut nye plantesorter har konvensjonelt vært høyere avlinger og bedre toleranse for biotisk og abiotisk stress med mål om økt produktivitet. Disse kriteriene reflekter imidlertid ikke nødvendigvis behovene og preferansene til alle de ulike gruppene som benytter foredlede sorter i forskjellige deler av produksjons- og matsystemene. Dette gjelder særlig mange kvinner, hvis preferanser og kunnskap om planteegenskaper knyttet til matsikkerhet, ernæring, prosessering og matlaging ofte har blitt oversett. Dette neglisjerer ikke bare deres rettigheter og likeverd, men det fører også til at nye plantesorter ikke blir tatt i bruk. Det er derfor behov for teoretisk og praktisk kunnskap om hvordan planteforedling kan ta hensyn til kjønn og andre sosiale forhold på en bedre måte.

Denne avhandlingen befinner seg i skjæringspunktet mellom feltene kjent som feministiske teknovitenskapelige studier, kritiske plantestudier og politisk agronomi. Den undersøker hvordan afrikanske planteforedlings-programmer innenfor det internasjonale landbruksforskning-nettverket CGIAR arbeider med å utvikle sorter som er bedre tilpasset kvinnelige bønder og andre brukergrupper i matsystemene. Dette gjøres gjennom en etnografisk studie av de såkalte «Gender+»-verktøyene som er utviklet av CGIARs «Gender and Breeding Initiative». Verktøyene benyttes til å samle og organisere kunnskap om kjønnsforskjeller i landbruket og skal dermed gjøre foredlingsprogrammet bedre i stand til å ivareta både kvinner og menns behov og preferanser. Studien settes inn i en historisk og institusjonell kontekst, spesielt ved å analysere markedsdiskursen som for tiden dominerer innenfor og utenfor CGIAR-systemet. Den belyser spesielt ulike former for makt som private donorer og planteforedlere har som agenda-settere og beslutningstakere.

Avhandlingen bygger på data innhentet gjennom feltarbeid i Kenya og Tanzania, samt virtuell kommunikasjon. Dette omfatter deltakelse i fysiske og virtuelle møter som ble avholdt for å utvikle og teste «Gender+»-verktøyene. Videre ble det gjennomført intervjuer med forskere fra CGIAR, nasjonale samarbeidspartnere, donor-organisasjoner og sivilsamfunn. Det ble også gjort analyse av dokumenter og andre ressurser som aktørene benyttet i prosessen.

I tre artikler viser jeg hvordan kjønn, planteforedling og nye plantesorter blir samkonstruert på måter som både begrenser og fremmer likestilling mellom kjønnene. I den første artikkelen viser jeg hvordan

«Gender+»-verktøyene spiller ulike roller som bidrar til å konstruere bønder og andre brukergrupper og deres kulturplanter, samt tverrfaglige og intradisiplinære relasjoner, på en kjønnet måte. I den andre artikkelen setter vi kjønnet planteforedling i sammenheng med den større markedsdiskursen. Vi viser hvordan markedet, i tett tilknytning til kjønn, blir forstått og brukt som en effektiv sosioøkonomisk institusjon for å avdekke etterspørsel, men samtidig også som en normativ agenda. Slik blir markedet et økonomisk og ideologisk rammeverk der mennesker, kulturplanter og planteprodukter og -egenskaper gis forskjellig verdi.

I den tredje og siste artikkelen utvikler jeg et nytt og radikalt begrep, «the feminist crop», eller den 'feministiske plantesorten', som beskriver relasjonene mellom planter og kvinners roller, kunnskap, evner og makt. Begrepet bidrar til en undersøkelse av hvordan kjønnsidentitet, kjønnsroller og kjønnsrelasjoner ikke bare formes i rent menneskelige systemer, men også i komplekse samspill mellom mennesker og planter. Dette utfordrer konvensjonelle dikotomier som skiller mellom kultur og natur og det sosiale og materielle. Med utgangspunkt i den feministiske plantesorten undersøker jeg hvordan foredling av planter, herunder gen-redigering ved hjelp av CRISPR-Cas-verktøyet, kan brukes som et middel for feministisk politikk og handling.

Med utgangspunkt i et overordnet forskningsspørsmål om «hvordan plantesorter og planteforedling kan være eller bli feministisk?», diskuterer jeg funnene langs fire virkeområder for feministisk politikk og praksis: 'sosiomateriell design', 'sosiomaterielle systemer', det 'metafysiske' og 'forestillingsevne'. Sosiomateriell design dreier seg om at arbeidet med å skape nye plantesorter samkonstruerer kjønn, foredling og kulturplanter på bestemte måter, og de muligheter det gir for å fremme feministisk design av nye plantesorter. Det sosiomaterielle systemet viser til større sett av sosiale og materielle faktorer som planteforedling inngår i, og som både kan hindre og fremme feministiske tiltak og resultater. Den metafysiske dimensjonen og forestillingsevne strekker seg lengre ved å utfordre det etiske, ontologiske og epistemologiske grunnlaget for planteforedling og ved å skape et nytt forestillingsrom for hvordan planteforedling kan gjøres annerledes og bidra til endringer i kjønnede relasjoner mellom planter og mennesker. Avhandlingen bidrar dermed til en nytenkning av hvordan planteforedlere og kjønnsspesialister sammen kan skape og praktisere kjønn, planteforedling og nye sorter i prosesser som fremmer endrede verdier og maktforhold, samt likestilling i landbruk og samfunn.

[A] seed contains inside its coat the history of practices such as collecting, breeding, marketing, taxonomizing, patenting, biochemically analyzing, advertising, eating, cultivating, harvesting, celebrating, and starving. A seed produced in the biotechnological institutions now spread around the world contains the specifications for labor systems, planting calendars, pest-control procedures, marketing, land holding, and beliefs about hunger and well-being (Haraway, 1997, p. 129).

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Article 3

Tarjem, I. A. (2022). Feminist crops: A more-than-human concept for advancing feminist crop breeding for development. *Catalyst: Feminism, Theory, Technoscience.* [Accepted for publication in the fall of 2022]

Acronyms and abbreviations

AGGRi: Accelerated Genetic Gain in Rice (AGGRi) Alliance

AGRA: Alliance for a Green Revolution in Africa

AGRF: African Green Revolution Forum

APBA: African Plant Breeders Association

AUC: African Union Commission

AWARD: African Women in Agricultural Research and Development

BecA: Biosciences Eastern and Central Africa

CGIAR: Consultative Group on International Agricultural Research

CIAT: International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)

CIMMYT: International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maíz y Trigo)

CIP: International Potato Center (Centro Internacional de la Papa)

CRISPR-Cas: Clustered Regularly Interspaced Short Palindromic Repeats – CRISPR Associated Protein

CRP: CGIAR Research Program

EiB: Excellence in Breeding Platform

FAO: Food and Agriculture Organization of the United Nations

GBI: Gender and Breeding Initiative

GENDER: Generating Evidence and New Directions for Equitable Results

GREAT: Gender-Responsive Researchers Equipped for Agricultural Transformations

ICIPE: International Centre of Insect Physiology and Ecology

ICRAF: International Council for Research in Agroforestry (World Agroforestry Centre)

ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

IDRC: International Development Research Centre (Canada)

IFAD: International Fund for Agricultural Development

IITA: International Institute of Tropical Agriculture

ILRI: International Livestock Research Institute

IRRI: International Rice Research Institute

JKUAT: Jomo Kenyatta University of Agriculture and Technology

KALRO: Kenya Agricultural & Livestock Research Organization

KILIMO: Ministry of Agriculture, Livestock, Fisheries and Co-operatives of Kenya

NACOSTI: National Commission for Science, Technology and Innovation of Kenya

NARS: National Agricultural Research System

NBA: National Biosafety Authority of Kenya

NRF: National Research Foundation of Kenya

OWSD: Organisation for Women in Science for the Developing World

PPP: Product Profile Proposal

RTB: CGIAR Research Program on Roots, Tubers and Bananas

SDG: Sustainable Development Goals of the United Nations

SSA: Sub-Saharan Africa

SSG: Seed Systems Group

STS: Science and Technology Studies

TALENs: Transcription Activator-Like Effector Nucleases

TARI: Tanzania Agricultural Research Institute

UoN: University of Nairobi

ZFNs: Zinc Finger Nucleases

Prologue

It was not until I reluctantly found myself in a plant sciences laboratory in the final year of my BSc in Biology that my love for plants started to bloom (no pun intended). Up until then, I had not shown much interest in these seemingly sedentary, inert and passive organisms. However, when I was asked to investigate ways in which the model plant species *Arabidopsis thaliana* communicates, I started to realise that there was more to these organisms than first meets the eye. Since then, I have become completely fascinated by the ways in which people and plants mutually shaped one another, including through the practices of crop breeding. Thanks to my interaction with women and men farmers during my fieldwork in Kenya as part of my MSc in Biotechnology, I have become particularly captivated by the ways in which plants, seeds, food and their associated cultures and practices are mutually shaped with our identity, belonginess, meaning-making, roles and relations, including in gendered ways. This thesis is a labour of that love and fascination.

Part I: Introductory essay

1. Introduction

Humans first started manipulating the genetic potential and phenotypic characteristics of plants around ten thousand years ago (Schlegel, 2018). Since then, crop breeding has come to contribute substantially to food and nutrition security globally (e.g., Borlaug, 1983; Evans, 1998). The importance of crops bred for specific traits will continue to grow as climatic and environmental change, population growth and socioeconomic changes significantly alter our food and cropping systems (e.g., Abu et al., 2021; Ortiz, 2019; Stamm et al., 2011; Zsögön et al., 2022). Breeding objectives and criteria are typically defined according to agroecological zones and mega-environments, which is "a group of environments that share the same best cultivar(s)" (Yan, 2021, p. 2), and oriented towards an analysis of abiotic and biotic constraints (e.g., Braun et al., 1996; Gauch Jr. & Zobel, 1997; González-Barrios et al., 2019; Wagaw et al., 2021; Yan, 2021). This has led to a prioritisation of agronomic traits for increased productivity, such as yield, disease resistance and climatic tolerance.

However, such selection and evaluation criteria may not fully capture and meet the interests and needs of diverse users and user groups in the food and cropping system, including those of many women whose preferences for plant traits and characteristics associated with food and nutrition security, processing, food preparation and consumption have often been overlooked (e.g., Weltzien et al., 2019).[1] This may result in disinterest and lack of adoption of improved crop varieties or lead to negative impacts on women, such as by imposing increased drudgery, displacing income-generating opportunities and giving rise to gender conflict (e.g., Bentley et al., 2017; Bergman-Lodin et al., 2012; Jha et al., 1991; Mulatu & Belete, 2001; Sanya et al., 2018).

Since its establishment in 1971, the CGIAR Consortium of International Agricultural Research Centers (formerly known as the Consultative Group on International Agricultural Research) has become the world's largest agricultural research and innovation network consisting of fifteen independent research centres.[2] As part of the global development nexus, gender equality has become a top priority

[1] I distinguish between plant traits and characteristics. As explained by Polar et al. (2021): "For breeders, a trait is a distinguishing, genetically and environmentally determined feature or quality of the variety that can be measured and prioritized as a target for breeding (e.g., growth habit, level of resistance to a disease, shelf-life, yield, starch, gluten or protein content). When people express varietal preferences, they often refer to characteristics of the crop, some of which are known traits, others of which require research to discover whether the preferred characteristic is associated with a heritable trait" (p. 2).

[2] The fifteen research centres include Africa Rice Center (AfricaRice); Bioversity International; Center for International Forestry Research (CIFOR); International Center for Agricultural Research in the Dry Areas (ICARDA); International Center for Tropical Agriculture (CIAT); International Crops Research Institute for the Semi-Arid

in the CGIAR, including within its breeding programmes (e.g., Kholová et al., 2021; van der Burg, 2019; Voss et al., 2021). This follows in the wake of a long history of, and commitments to, gender in international development (e.g., Benería & Sen, 1981; Bill and Melinda Gates Foundation, 2012; Boserup, 1970; Momsen, 2019; United Nations & World Conference on Women, 1995), as well as findings demonstrating the important role of gender in agriculture (e.g., FAO, 2011; Peterman et al., 2014; Quisumbing et al., 2014; Raney et al., 2011; World Bank et al., 2009).

However, the integration of gender in crop breeding is far from straight-forward: it involves the need to challenge deep-seated and black boxed ideologies, norms and values and interdisciplinary and organisational power dynamics, as well as requiring novel conceptual and methodological frameworks and tools. In 2016, commissioned by the CGIAR System Management Office (Polar et al., 2022), a group of crop breeders, geneticists, economists and gender specialists from and beyond the CGIAR met in Nairobi, Kenya, to discuss the intersection of crop breeding and gender (CGIAR Gender and Breeding Initiative, n.d.).[3] The group convened again the following year, this time officially known as the Gender and Breeding Initiative (GBI), hosted and coordinated by the CGIAR Research Program (CRP) on Roots, Tubers and Bananas (RTB) and the International Potato Center (CIP). The group set out to "help catalyze a deliberate shift towards gender-responsive breeding in the CGIAR" (CGIAR Gender and Breeding Initiative, 2017, p. 1). Gender-responsive crop breeding is meant to ensure that "the perceptions, interests, needs and priorities of women and men (which differ because of their different roles and responsibilities in farming) will be considered in planning and decision-making" (Ashby & Polar, 2021, p. 2).

Most recently, the work of the GBI has culminated in the creation of a digital toolbox, the Gender+ (G+) Tools, which includes the G+ Customer Profile Tool and the G+ Product Profile Query Tool (Ashby & Polar, 2021a; Ashby & Polar, 2021b; Orr et al., 2021; Polar & Ashby, 2021). The G+ Tools provide step-by-step instructions on how to collate and organise existing data on gender differences in rights, roles, responsibilities and trait and varietal preferences to support gender-responsive priority-setting and decision-making in crop breeding. Using the G+ Tools, the breeding team gains an improved

Tropics (ICRISAT); International Food Policy Research Institute (IFPRI); International Institute of Tropical Agriculture (IITA); International Livestock Research Institute (ILRI); International Maize and Wheat Improvement Center (CIMMYT); International Potato Center (CIP); International Rice Research Institute (IRRI); International Water Management Institute (IWMI); World Agroforestry (ICRAF); and WorldFish.

[3] The CGIAR System Management Office is responsible for the day-to-day operations of the CGIAR System Organization which together with the CGIAR System Council provide governance to the CGIAR System.

understanding of who they are breeding for, including what their challenges, needs and preferences are, and how different plant traits may impact social groups of men and women differently.

Notably, the G+ Tools draw on several market-based concepts and frameworks adapted from commercial crop breeding, including the use of market segmentation and product profiles. A product profile describes "the full set of targeted attributes (…) that a new plant variety or animal breed is expected to meet to successfully be released onto a market segment" (Ashby & Polar, 2021, p. 2), with the market segment defined as "a geographic area or a group of people having a relatively homogeneous demand for a commodity" (Ragot et al., 2018, p. 5). The argument goes that, by starting the breeding process with a clearly defined market or customer segment(s) upon which the product profile(s) is designed, crop breeding programmes will be better equipped at understanding and responding to the needs and preferences of different customers from across the agricultural value chain.[4]

The use of market-based approaches to support gender-responsive crop breeding can be seen in relation to a market-led turn currently dominating within and beyond the CGIAR.[5] In 2016, as part of a larger modernisation agenda of CGIAR breeding programmes (CGIAR System Council, 2018), the Bill and Melinda Gates Foundation (hereafter the Gates Foundation), the biggest private foundation in the world and the second largest funder of the CGIAR (CGIAR, n.d.-a), commissioned an assessment of several CGIAR breeding programmes (CGIAR System Management Office, 2018). The assessment identified the need for the "systematic use of product profiles, based on continually updated market intelligence and stakeholder consultations, to ensure that new varieties are designed to meet the requirements and preferences of women and men farmers, consumers, traders, processes and others along the value chain" (CGIAR System Council, 2018, p. 7).

Established in 2017, the CGIAR Excellence in Breeding Platform (EiB) was tasked with coordinating and overseeing the modernisation process, with its module 1 on product design and management responsible for institutionalising the market-based product profile development framework

[4] The GBI uses the concept customer segment, defined as "[a] group of users who have both a common set of constraints and a common, unique and relatively homogenous need (demand) for a breeding program product" (Orr et al., 2021, p. 19). The customer is defined as "the growers who use the breeding product (crop varieties or animal breeds), and the other value chain actors, like traders, processors, or consumers who use one or more of the end-products" (Orr et al., 2021, p. 5). The value chain refers to "all the processes involved in the production, processing, and marketing of a product from its inception to its final use" (Pyburn & Kruijssen, 2021, p. 32).

[5] Market-based or market-led crop breeding are sometimes used interchangeably with demand-led crop breeding in the literature and by interlocutors. For analytical clarity, I conceive of market-based approaches as a way to contribute to demand-led and gender-responsive crop breeding. I address this at greater length in the second article.

(Excellence in Breeding Platform, n.d.). However, to meet donor requirements, the EiB also needed to ensure that market segmentation and product profiling were responsive to gender. Thus, in 2020, the EiB financially supported the piloting of the G+ Tools in several African-based breeding programmes of the CGIAR, with the intention of refining and adapting the G+ Tools to the EiB product profile development framework.

Many questions remain about who stands to benefit as market-based and gender-responsive approaches become increasingly intertwined. Feminist scholars and activists have produced important critiques of the relationship between, on the one hand, gender equality and empowerment and, on the other, market logics and neoliberal-capitalism, including the increasing role that private sector donors play in driving and shaping the 'gender agenda' (e.g., Calkin, 2017; Cornwall et al., 2008; Eisenstein, 2017; Esquivel, 2017; Gregoratti et al., 2018; Lewis, 2001; Moeller, 2018; Prügl, 2015; Roberts & Soederberg, 2012; Walters, 2021; Wilson, K., 2015).

Guided by the overarching research question "how can crops and crop breeding be feminist?", I aim to contribute to an improved understanding of the knowledge politics, practices and tools through which CGIAR breeding programmes are developing gender-responsive and transformative crop varieties, and how gender, crops and crop breeding become co-constructed in the process. I further develop novel ethico-onto-epistemological understandings and concepts through which feminist crop breeding can be advanced.[6] This includes an exploration of how plant genome editing may be wielded as a tool for feminist intervention and politics in and through crop breeding. In the broader sense, feminist interventions and politics are those that promote gender and social equity and equality. More specifically, I align with the feminist political aim articulated by Laura Foster (2017): "to contest binary modes of thinking, make connections across sites of inequality, think across multiple ways of knowing and being, dismantle hierarchies of knowledge production, contest the differential valuing of matter, and imagine alternative modes of belonging" (p. 11).

In my analysis, I combine perspectives from feminist technoscience studies, critical plant studies and political agronomy. A central theoretical premise of these fields, and indeed of this thesis, is the idiom of co-construction, which I use to conceptualise and analyse the mutually shaped relationships that exist between gender, crops and crop breeding. The thesis builds on ethnographic fieldwork conducted in Kenya and Tanzania, as well as online. This includes participant observations made during one

[6] Karen Barad (2007) coined the term 'ethico-onto-epistemology' to "mark the inseparability of ontology, epistemology, and ethics" (p. 409).

physical workshop and eight online meetings as part of the piloting of the G+ Tools, as well as semi-structured and open-ended interviews conducted both physically and digitally with CGIAR scientists and national partners, donors, governmental representatives and non-governmental organisations. Additionally, I carry out document analysis of resources produced by the relevant actors.

The research resulted in three articles that together provide a triple investigation of gender-responsive crop breeding upon which the thesis is based. In the first article, *Tools in the making: The co-construction of gender, crops, and crop breeding in African agriculture,* I explore the performative roles of the G+ Tools as they emerge in interaction with the crop breeding teams, attending to how gender, crops and crop breeding become co-produced in the process. The article is based on an institutional ethnography and uses theoretical insights from feminist technoscience studies. The findings serve as a starting point for discussing 'sociomaterial design'.

The second article, "*Whose demand?": The co-construction of markets, demand and gender in development-oriented crop breeding,* is co-authored together with Ola Westengen, Poul Wisborg and Katharina Glaab. We combine perspectives from political agronomy and feminist technoscience studies to unpack the market, demand and gender and their co-construction, with the aim of contributing to the understanding of how gender-responsive demand is constructed in development-oriented crop breeding. The article provides a background against which to discuss the broader 'sociomaterial system' in which gender-responsive crop breeding operates.

In the third and final article, *Feminist crops: A more-than-human concept for advancing feminist crop breeding for development,* I use insights from feminist technoscience studies and critical plant studies to develop the concept of the 'feminist crop', which captures the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. Informed by the new imaginaries and ethical commitments that the feminist crop engenders, I explore how plant breeding, including the use of plant genome editing, may help advance feminist interventions and politics. I use the concept to further address the 'metaphysical' and the 'imaginative' realms in the discussion of the thesis.

1.1. Background

I start this chapter by discussing the role of gender in food and cropping systems more broadly and in the history of the CGIAR. Subsequently, I introduce the GBI and the G+ Tools, followed by the overarching aim, relevance and structure of the thesis.

1.1.1. Gender, food and cropping systems and agricultural research and development

Gender refers to socially constructed and historically and culturally situated "ideas about maleness and femaleness and the shifting boundaries between them" (Lerman et al., 1997, p. 2). This includes both individually practiced gender identities and collective, institutional and structural gender norms and relations. Importantly, as first articulated by queer Black poetics and later conceptualised by Black feminist scholars (Lamoureaux & Rottenburg, 2021), gender intersects with other social factors such as race, ethnicity, ableness, age and class to produce multiple intersecting oppressions and dominations (Collins, 2000; Collins, 2015; Crenshaw, 1989; Nash, 2019). Thus, there are numerous masculinities and femininities (e.g., Connell, 1987; Connell, 1995; Dharani et al., 2021; Hamilton et al., 2019; Moolman, 2013; Morrell, 1998; Morrell, 2001; Ratele, 2021), some of which are constructed in relation to agricultural practices and technologies (e.g., Annes et al., 2021; Avakian & Harper, 2005; Brandth, 1995; Brandth, 2006; Bryant, 2003; Counihan & Kaplan, 1998; Ferrell, 2012; Liepins, 2000; Little, 2002; Peter et al., 2000; Pini, 2004; Saugeres, 2002; Shisler & Sbicca, 2019). As will be further explored, a fundamental premise of this thesis is that intersectional gender identities and relations are performed through distributed interactions with both humans and nonhumans, such as crops and research and marketing tools and concepts.

Gendered power relations are ubiquitous across all levels of the food system, defined as "the growing, harvesting, processing, packaging, transporting, marketing, consumption and disposing of food" (Ashby & Polar, 2019, p. 11). Globally, women (and men) of various backgrounds fulfil diverse, multifaceted, dynamic and essential roles in agriculture, including that of consumers, producers, processors, marketers, traders, entrepreneurs, seed custodians and managers of crop diversity (e.g., Quisumbing et al., 2014; Raney et al., 2011). Similarly, the food system plays an important role in the lives of many women. For instance, it has been estimated that agriculture represents the primary activity for almost half of the world's economically active women (FAO, 2011; Palacios-Lopez et al., 2017).

Still, evidence gathered over several decades continues to demonstrate that women in agriculture face inequalities across all institutional levels (from the household and community level to state and regional policies) and how food and cropping systems are underperforming as a result (e.g., FAO, 2011; Kilic et al., 2015; Quisumbing et al., 2014; Raney et al., 2011). Intersectional gender differences in rights, status, roles and responsibilities mean that men and women often engage in agriculture under very different economic, social, technical and agroecological conditions. Consequently, men and women may develop different knowledges, skills, interests, goals and strategies, also as it relates to the types of crops and crop traits and characteristics they need and desire (e.g., Marimo et al., 2020; Weltzien et al., 2019).

The CGIAR has a relatively long, albeit slow and patchy, history of dealing with gender perspectives and integration in research, with the social sciences and gender research being afforded less resources compared to the biophysical sciences (Ashby et al., 2013; Cernea & Kassam, 2006; CGIAR-IEA, 2017; Jiggins, 1986; Karlsson & Russell, 2017; MOPAN, 2020; van der Burg, 2019). Until recently, CGIAR breeding programmes most commonly included gender as a variable in participatory approaches to plant breeding (e.g., Dorward et al., 2007; Farnworth & Jiggins, 2003; vom Brocke et al., 2010; Weltzien et al., 1998; Worku et al., 2020). However, while such studies have often consulted both men and women farmers, few have been designed with explicit gender objectives in mind (e.g., Voss et al., 2021; Weltzien et al., 2019; but do see, e.g., Defoer et al., 1997; Galiè, 2013; Galiè et al., 2017; Tegbaru et al., 2020). Additionally, social scientists have commonly been engaged in the aftermath of varietal design, such as during adoption studies and impact assessments, with little influence and decision- making power in priority-setting and trait selection. Failure to engage meaningfully with gender (and, thus, gender research and researchers) is believed to be one of the factors explaining the low levels of adoption and development impacts of improved crop varieties in Africa (e.g., Acevedo et al., 2020; Fisher & Carr, 2015; Smale et al., 2018; Thiele et al., 2021).

This history has led to the argument that breeding objectives and varietal design should be more strongly based on social targeting and (market) demand analysis relative to an analysis of the mega-environment and agroecological context (e.g., Forsythe et al., 2021; Orr et al., 2018; Persley & Anthony, 2017; Ragot et al., 2018; Tufan et al., 2018). A practical challenge, however, is "how to systematize relevant information about gender differences, especially men's and women's trait preferences, in a way that breeders can factor it into their trait prioritization and product profiles" (Ashby & Polar, 2019, p. 13). Indeed, the crop breeding process is complex, costly and lengthy, where a range of genetic, biophysical, technical, economic, political and regulatory factors determine what crops and traits can or should be bred for (e.g., Kholová et al., 2021; Shimelis & Laing, 2012; Voss et al., 2021; Weih, 2003).

Consequently, trait selection is highly selective and involves several trade-offs. Moreover, priority-setting and decision-making in breeding are shaped by deep-seated, taken-for-granted and black boxed norms, beliefs and values, along with interdisciplinary and organisational power relations, where often senior and male crop breeders and private sector donors have substantial definitional, agenda-setting and decision-making power.

1.1.2. The Gender and Breeding Initiative and the Gender+ Tools

The GBI has pioneered the development of conceptualisation and tools, methods and practices of gender-responsive breeding.[7] These include: (i) must-have features of gender-responsive breeding (Mascarenhas, 2016); (ii) four principles, a flowchart of critical decision points and a decision checklist for gender-responsive crop breeding (Ashby et al., 2018; CGIAR RTB, 2018); (iii) the working paper *From market demand to breeding decisions: A framework* (Ragot et al., 2018); (iv) the working paper *Gender and social targeting in plant breeding* (Orr et al., 2018); and (v) the working paper *State of knowledge for gender in breeding: Case studies for practitioners* (Tufan et al., 2018). All of these have informed the design and development of the G+ Tools to some extent. However, to better understand where and how the G+ Tools are to be used in the breeding cycle, I will elaborate on the flowchart onto which the Tools can be mapped.

The flowchart provides breeding teams with an improved understanding of when and how gender can be integrated across the breeding cycle (Fig. 1). In the flowchart, seven critical decisions are identified for operationalising gender-responsiveness (amber boxes in Fig. 1) that occur at key stages in the breeding process (orange diamonds in Fig. 1) (Ashby et al., 2018; CGIAR RTB, 2018). Integrating gender at these decision points results in five gender-responsive outcomes (green ovals in Fig. 1): (i) a customer profile with a gender dimension for each segment the programme decides to target; (ii) breeding objectives with a gender dimension included; (iii) a product profile with a gender dimension;

[7] The Feed the Future Innovation Lab for Crop Improvement at Cornell University in the United States is currently developing the Impact Centered Varietal Design Framework which "takes a human-centric approach to help National Agricultural Research Institutes (NARIs) assess their breeding priorities, challenge their assumptions, perform engaged research and ultimately prioritize the impact they want to make through crop improvement" (Innovation Lab, 2021). The team behind the framework "encourage[s] plant scientists and social scientists to work together to confront common barriers and ask critical questions: Whose voices are being heard? Who is making the decisions? What assumptions are being made? Who is growing, processing and consuming the crop, and how can ***they*** benefit from crop improvement?" (Innovation Lab, 2021, italics and bold in original). Many of the same questions arise throughout this thesis.

(iv) breeding products (varieties) with traits useful to women and men; and (v) a gender-responsive delivery strategy (Ashby et al., 2018).

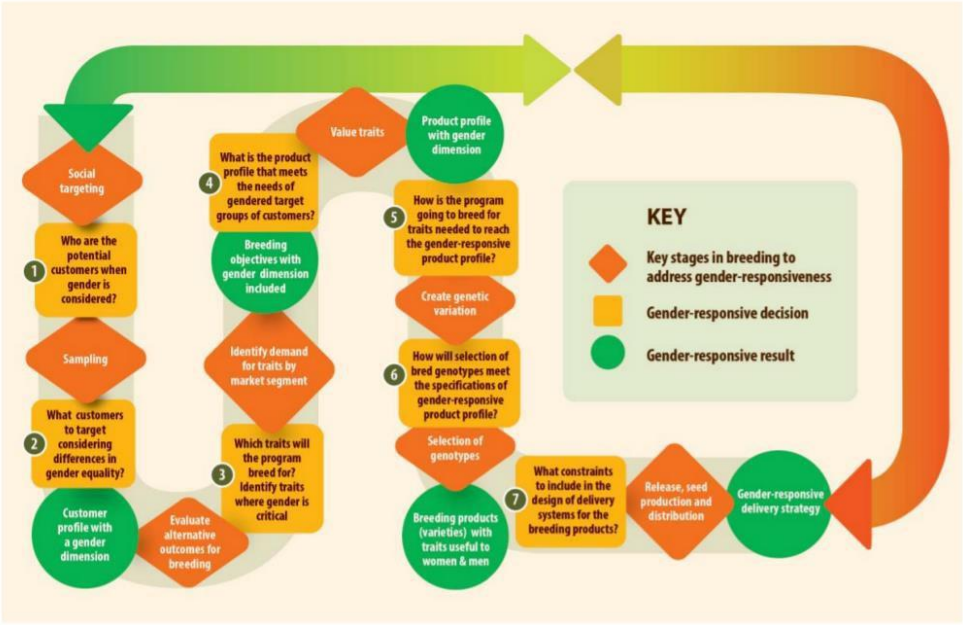

Figure 1. Flowchart of critical decision points for gender-responsive breeding. *The arrow is double headed to indicate that the gender-responsive breeding process is cyclical and entails learning. Source: Ashby et al. (2018). Used with permission from Jacqueline Ashby and Vivian Polar.*

The G+ Customer Profile Tool helps answer the first and second question of the flowchart by combining "geographic, gender and other social variables to segment, target, and profile the customers for a breeding program" (Orr et al., 2021, p. 1). Ultimately, a customer profile with a gender dimension is generated (i.e., the first green oval in Fig. 1; Appendix 1). Accordingly, the G+ Customer Profile Tool "help[s] the breeding program prioritize its customers in terms of their numbers, geographic location, socio-economic characteristics, product preferences, and the reasons for these preferences. (…) The G+ Customer Profile is therefore a tool for gender and social targeting" (Orr et al., 2021, p. 1).

The G+ Product Profile Query Tool, in turn, informs trait prioritisation by scoring each trait on the product profile according to whether it is expected to have a positive, neutral or negative impact on women, men or another specific intersectional group (Ashby & Polar, 2021a). As explained by Polar et al. (2022): "Scoring is similar to the nominal index that breeders often use to assign a value for disease tolerance to a variety" (p. 488). Scores are generated using "do no harm" and "positive benefits"

analyses (Fig. 2; Appendix 2), which are based on information about "four well-researched causes of gender inequity in agriculture that can be widened or reduced by introducing new plant varieties or animal breeds" (Ashby & Polar, 2021a, p. 1): the effects of the proposed trait on women's unpaid labour, on on-farm or off-farm activities for own income generation, on control over production inputs and control over production outputs (Appendix 2). Additionally, a comparison of how a trait is assessed for both men and women should be made "to clarify where there is common ground between men and women producers as well as potential trade-offs involved in targeting men and women producers differently" (Ashby & Polar, 2019, p. 19).

A trait that does not pass the "do no harm" analysis should either be omitted from the product profile or 'amended', such as by introducing the crop variety alongside complementary measures (for instance, if a trait increases threshing for women, it could be introduced together with small-scale threshers). Traits that pass the "do no harm" test will either be classified as gender neutral – meaning "neither beneficial nor harmful to women differently from men" (Ashby & Polar, 2019, p. 19) – or beneficial to women, depending on how the trait scores during the "positive benefit" analysis (Fig. 2; Appendix 2). Using the G+ Product Profile Query Tool may also reveal additional traits that should be included in the product profile from a gender perspective.

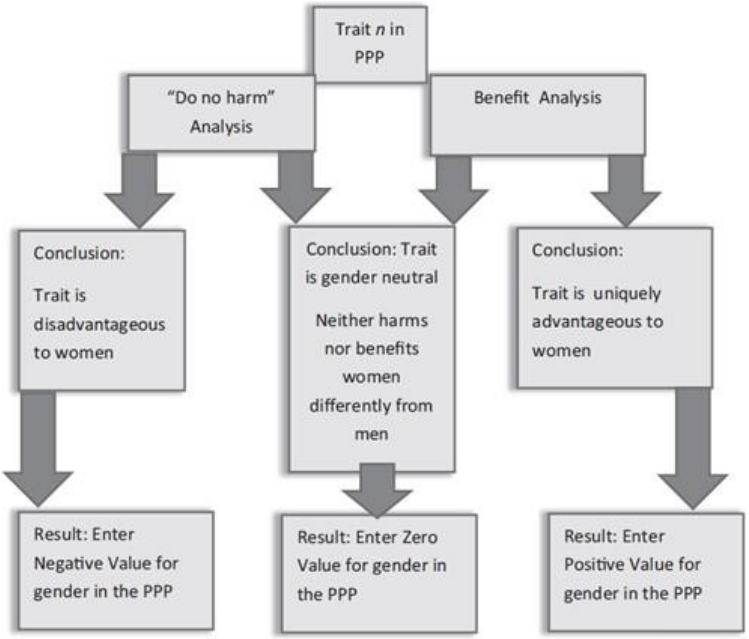

Figure 2. Decision tree for gender screening a trait in a product profile proposal (PPP). *Source: Ashby and Polar (2019). Used with permission from the authors.*

Thus, the G+ Product Profile Query Tool helps answer the third and fourth question of the flowchart (Fig. 1), resulting in a product profile with a gender dimension (i.e., the third green oval in Fig. 1). Ultimately, the goal is not to "produce a case for the development of specifically 'women's' varieties, but [to] inform key breeding decisions to make it more likely that breeding will include traits important for women" (Ashby & Polar, 2019, p. 29). Ashby and Polar (2019) further argue that the "[u]se of gender screening creates the opportunity for a breeding project to opt for including a highly beneficial, 'game changing' trait in design of a new breeding product that is potentially transformative" (p. 19).

The GBI has also discussed how genomics may present novel opportunities and entry points for integrating gender more effectively in the breeding cycle (CGIAR Gender and Breeding Initiative, n.d.). While these discussions have mostly centred on genomic selection (e.g., Ashby & Polar, 2019; Mascarenhas & Ashby, 2017; Olaosebikan et al., 2018; Polar et al., 2021), I address how genome editing using the clustered regularly interspaced short palindromic repeats (CRISPR) and CRISPR-associated protein (Cas) system (CRISPR-Cas) can help advance gender-responsive and transformative crop breeding. CRISPR-Cas is an adaptive immune system in many bacteria and archaea which can be programmed to introduce, in contrast to conventional gene modification, sequence-specific mutations in the genome of more or less any organism (Jinek et al., 2012). The genomics tool has become touted as key in achieving a sustainable and food secure future (e.g., Karavolias et al., 2021; Karembu, 2021; Qaim, 2020; Tripathi et al., 2019; Wada et al., 2020; Zaidi et al., 2020; Zhu et al., 2020), albeit subject to extensive political, regulatory, economic and ethical debates (e.g., Bartkowski et al., 2018; Helliwell et al., 2019; Rock & Schurman, 2020; Schmidt et al., 2020; Zhang et al., 2020).

1.2. Overarching aim, relevance and structure of thesis

With this thesis, I aim to contribute to an improved understanding of the knowledge politics, practices and tools through which African-based CGIAR breeding programmes are developing gender-responsive and transformative crop varieties, and how gender, crops and crop breeding become co-constructed in the process. I do so by homing in on the stage of varietal design through an ethnographic case study of the G+ Tools, using a combination of perspectives from feminist technoscience studies, critical plant studies and political agronomy. The case study is situated within the historical and institutional context of plant breeding for development, including the market-led turn currently dominating within and beyond the CGIAR. Particular attention is paid to the agenda-setting and decision-making power that crop breeders and private sector donors hold. The thesis further explores how feminist crop breeding

may be advanced through conversations between feminist technoscience, critical plant studies and molecular crop breeding, including the use of the genome editing tool CRISPR-Cas.

The research is particularly timely given the renewed and growing attention and commitments to gender not only in plant breeding, but also in agricultural research for development more broadly, including in relation to the rapidly advancing field of plant genome editing and the institutionalisation of market-based approaches in and beyond the CGIAR. If we come to better understand the relationship between gender, crops and crop breeding, we can use this knowledge to support and improve gender-responsive and transformative crop breeding. Ultimately, I hope the research will contribute to the advancement of women's rights, opportunities and wellbeing in agriculture and society. Gender equality and women's empowerment have value in and of themselves, as well as sharing close, interrelated ties to food, nutrition and climate security. Thus, as we are falling off track in achieving the Sustainable Development Goals (SDGs) by 2030 (Roser & Ortiz-Ospina, 2018; United Nations, 2020), including SDG2 on Zero hunger, SDG5 on Gender equality and SDG13 on Climate action, this is not only an opportune but a critical time to champion feminist crop breeding and feminist varieties.

The introductory essay consists of seven chapters. In the first chapter, I introduced the research topic and the overarching aim, relevance and structure of the thesis. In the second chapter, I outline the theoretical framework and the philosophy of science, which provide the necessary background for introducing the aims, research questions and research and knowledge contributions in the third chapter. Chapter four addresses the methodology, which includes a description of the case study approach, ethnographic fieldwork, data analysis and research ethics. In chapter five, I provide a summary of the three articles, followed by a discussion of the findings in chapter six. I structure the discussion according to the four realms of sociomaterial design, the sociomaterial system, the metaphysical and the imaginative. In the conclusion, I circle back to the guiding question of the thesis: How can crops and crop breeding be feminist? Additionally, the reference list, the full-length articles and the appendices can be found attached at the end of the introductory essay.

2. Theoretical framework

I start this chapter by introducing the idiom of co-construction (which I use interchangeably with co-production, co-constitution and mutual shaping) which forms the theoretical foundation of the thesis, and which helps unite feminist technoscience studies, critical plant studies and political agronomy. I chose these scholarly streams as they provide unique and complementary perspectives on the co-construction of gender, crops and crop breeding: feminist technoscience studies provide insights into the mutual shaping of gender and crop breeding tools and practices, including the performative role of the G+ Tools; critical plant studies emphasise the agential capacity of crops, including in the co-construction of gender and crop breeding; while political agronomy provides a lens through which to understand the historical, political and institutional arrangements implicated in the co-constitution of gender, crops and crop breeding. After having presented the three disciplines and how they inform the research, I situate the theoretical framework in the philosophy of science and note the challenges I faced in doing so.

2.1. Introducing the theoretical framework: The idiom of co-construction

The co-construction of gender, crops and crop breeding is at the heart of this thesis. I conceive of and use co-construction in three main, interrelated ways: in a broad ontological and analytical sense; in a narrower analytical sense; and in an applied sense. In the broad ontological and analytical sense of the word, I understand co-construction as referring to the mutually shaped relationships that exist between human and nonhuman actors or 'actants' (e.g., plants, animals, microorganisms, technology and inorganic compounds).[8] Fundamentally, such an understanding rests on a relational ontology where "things come into existence as a result of the set of relations of which they are a part" (Asdal et al., 2007, p. 29). In informing this conception of co-construction (as well as my philosophy of science, as addressed later), I have drawn a lot of inspiration from Karen Barad's agential realism.

Building on the work of Niels Bohr on quantum indeterminacy, Karen Barad (2007) introduced the ethico-onto-epistemological framework of agential realism, which takes phenomena, defined as the "ontological inseparability of agentially intra-acting components" (Barad, 2007, p. 33), to be the primary ontological unit. In contrast to interaction, where entities and agency pre-exist relations, 'intra-action' holds that the ability to act and materialise emerges from within relationships among things (not outside of them). Thus, agency becomes conceptualised as "a matter of intra-acting; it is

[8] Latour (1996) defined an 'actant' as anything "provided it is granted to be the source of action" (p. 373).

an enactment, *not something that someone or something has*" (Barad, 2007, p. 178, italics in original). Indeed, agency is not constrained to the human realm: Barad take a posthuman approach, which they describe as "the crucial recognition that nonhumans play an important role in naturalcultural practices, including everyday social practices, scientific practices, and practices that do not include humans" (Barad, 2007, p. 32; for other key texts on posthumanism, see, e.g., Braidotti, 2006; Braidotti, 2019; Hassan, 1977).

Thus, with such an understanding comes a heightened appreciation of the agential capacity and liveliness of nonhumans and matter (also see, e.g., Alaimo & Hekman, 2008; Bennett, 2009; DeLanda, 2015), which I refer to as nonhuman or more-than-human agency. Barad (2003) define matter not as "an inherent, fixed property of abstract, independently existing objects; rather, 'matter' refers to phenomena in their ongoing materialization" (p. 151). Such a conceptualisation shares strong parallels with postcolonial theory and some African philosophies, such as African animist materialism (e.g., Garuba, 2003) and other Indigenous cosmologies and knowledge systems which have acknowledged the vitality of matter and nonhumans as sentient beings for centuries (also see section 2.3).

Thus, taking nonhumans and their agency seriously and using the notion of posthuman performativity allow me to broaden my understanding of gender performance to include crops and crop breeding practices, tools and concepts, notably the G+ Tools. Judith Butler, whose work on gender performativity is seminal (also see West & Zimmerman, 1987), defined performativity as "the discursive practice that enacts or produces what it names" (Butler, 1993, p. 10). Butler addresses materiality, but largely with respect to how discourses come to bodily matter (e.g., Butler, 1993; Butler, 2004). Thus, posthuman performativity moves beyond the conception of (gender) performance as a largely discursive practice to consider the "material and discursive, social and scientific, human and nonhuman, and natural and cultural factors" of performativity (Barad, 2003, p. 808; also see, e.g., Frost, 2011; Grosz, 1994; Haraway, 2008; Mol, 2003; Wilson, E. A., 2015). Barad further note how "[c]rucial to understanding the workings of power is an understanding of the nature of power in the fullness of its materiality" (Barad, 2003, p. 810). Such a conception of power is evident in my argument that a more complete understanding of (gender) power relations in agriculture and crop breeding needs to take plants and other nonhumans and their materiality into account.

In their agential realist framework, Barad further explain that it is through 'apparatuses', which they define as "material-discursive practices (they are not merely laboratory setups that embody human concepts and take measurements)" (Barad, 2007, p. 146), that 'agential cuts' are enacted, which "produce differences that matter—they are boundary-making practices that are formative of matter

and meaning, productive of, and part of, the phenomena produced" (Barad, 2007, p. 146). Thus, according to Barad, matter and meaning are ontologically inseparable. As I explore at greater length in the second article, I conceive of the G+ Tools and other research and marketing tools as Baradian apparatuses which, through agential cuts, bring certain (gendered) beings and (gendered) ways of being into existence, while excluding others. Indeed, apparatuses enact exclusionary boundaries (Barad, 2003).

I also use the idiom of co-production in a somewhat narrower analytical sense to conceive of the relationship between society on the one hand, and 'technoscience' on the other, as co-constructed, which scholars of science and technology studies (STS) and related fields have conceptualised and investigated empirically (e.g., Bijker et al., 1987; Callon, 1986; Hughes, 1994; Jasanoff, 2004; Latour, 1987; Law, 1987; Pinch & Bijker, 1984). The term technoscience is used to "convey that scientific knowledge and technological worlds are active constructions of entangled material, social, and historical agents" (Hamraie, 2015, p. 307). More specifically, I am interested in how agricultural knowledge production and technical innovation (notably plant sciences and crop breeding) are co-produced with society, in particular gender relations and capitalism, but also racial politics, indigeneity and colonialism (e.g., Andersson & Sumberg, 2017; Bonneuil, 2000; Brockway, 1979; Carney, 2001; Carney & Rosomoff, 2009; Davidson, 2012; Eddens, 2019; McCann, 2007; McCusker & Carr, 2006; Mintz, 1985; Ross, 2014; Schiebinger, 2004; Subramaniam, 2014).

For instance, while most of the research centres of the CGIAR are headquartered in, and/or have several offices and research stations located across, the 'Global South', the CGIAR has from its very inception been governed and influenced by donors and development agencies from the 'Global North' (Byerlee & Lynam, 2020).[9] Indeed, the CGIAR and its breeding programmes are steeped in colonial histories and postcolonial settings. For instance, Byerlee and Lynam (2020) note how the first CGIAR centres established in Africa were "[b]uilt soon after the transition from colonial rule to independence, (…) [and] in different ways reflected a colonial legacy, both organizationally and scientifically" (p. 9) (also see, e.g., Eddens, 2019).

[9] While there does not exist a single, agreed-upon definition of the terms 'Global South' and 'Global North', I adhere to the definition by Martins (2020): "the global South refers broadly to a grouping of countries and people that experience economic marginalisation within the global system and have elements of a shared history of colonisation and exploitation. This is the same grouping within which are most often the net receivers of foreign aid, although many Southern donors also exist. The global North refers to countries and people traditionally referred to as 'the West', who tend to be foreign aid donors to the South" (p. 151).

While I do not carry out a postcolonial or decolonial analysis, it is still important to recognise this history for the contextualisation of the thesis. Furthermore, I do draw attention to power relations between donor agencies headquartered in the Global North (notably the Gates Foundation in the United States) and breeding programmes located in different African countries. Indeed, the construction and use of the G+ Tools do not take place in a vacuum: the G+ Tools are mutually shaped, more or less explicitly, together with human actors – such as crop breeders, gender specialists, agricultural economists, management, donors, farmers and other user groups – with diverging values, interests and goals that may further embody capitalist, colonialist and patriarchal ideologies.[10]

In contrast to the ontological and analytical meanings of co-production, the more applied sense refers to studies on how knowledge is co-produced in collaborative, multi-stakeholder and interdisciplinary processes (e.g., Akpo et al., 2015; Bell et al., 2012; Chambers et al., 2021; Crane, 2014; Harvey et al., 2019; Norström et al., 2020; Pohl et al., 2010; Voorberg et al., 2015; Zarei et al., 2020). I did not explicitly carry out such a study, which included "a detailed account of the group dynamics to understand the social process" involved in the co-production of knowledge (Akpo et al., 2015, p. 1). However, the applied meaning of co-construction is still present in my research, as I did address some of the opportunities and challenges faced by multidisciplinary breeding teams in using the G+ Tools and in crop breeding more broadly. Given the centrality of multi and interdisciplinarity in the new gender-responsive and market-based approaches to crop breeding, this represents an intriguing area for future research.

2.2. Feminist technoscience studies

The goal of feminist technoscience studies or feminist science and technology studies (feminist STS) is to advance our understanding of knowledge production and technological innovation with a commitment to social justice and gender equality. Similarly, my own research goal is to get an improved understanding of the knowledge politics, tools and practices of crop breeding with the intention of promoting gender equality and women's empowerment. Feminist technoscience studies "emerged out of decades of feminist critiques of the ways in which gender in its intersections with other sociocultural power differentials and identity markers is entangled in natural, medical and technical sciences as well as in sociotechnical networks and practices of a globalized world" (Åsberg &

[10] I employ the term user group to refer to any user of a variety, such as producers, consumers, processors, marketers, traders and so forth.

Lykke, 2010, p. 299).[11] Among others, scholars of feminist technoscience have challenged what they perceive to be an Eurocentric, racist and masculine ideology and philosophy of science which promote a mechanistic worldview, control over nature and distance between the observer and the observed (e.g., Keller, 1985; Merchant, 1980), and that acknowledge white, heteronormative, well-educated men as being the only legitimate knowing subject (e.g., Haraway, 1997).

In turn, feminist scholars have developed feminist philosophies, epistemologies and methodologies of science (e.g., Bleier, 1986; Harding, 1986; Longino, 1999; Tuana, 1986; Tuana, 1995). Along with strong objectivity, feminist empiricism and feminist standpoint theory (Harding, 1991; Harding, 1992; Harding, 1998; Harding, 2015; Hartsock, 1983; Longino, 1994), Donna Haraway's concept of 'situated knowledges' has become particularly influential in and beyond feminist STS (Haraway, 1988). Haraway (1988) argues that all knowledges and knowledge systems are the product of historically and culturally situated social activities and that all knowing subjects hold only a partial perspective. Accordingly, an argument is made in favour of "a politics and epistemology of location, position, and situation, where partiality and feminist standpoints, and not universality, are the precondition for knowledge-making politics" (Mascarenhas, 2018, p. 158).

Such an understanding is a far cry away from positivist ideas of science as being universal and objective, which are commonly held beliefs in agronomy and plant sciences (e.g., Cleveland, 2001; Song & Vernooy, 2010; Taylor et al., 2021). As apparent in the third article, I use situated knowledges to consider how the positionality and social embeddedness of scientists and donors involved in plant breeding shape knowledge production and varietal design, including how crop varieties become imbued with power and political qualities (e.g., Berg & Lie, 1995; MacKenzie & Wajcman, 1999; Winner, 1980). Situated knowledges has also been important in informing my understanding of my own positionality and research practice (see section 4.4.2).

However, many feminist writers of technoscience have emphasised not only how human actors and societal factors (such as gender) shape science and technology, but how science and technology shape the social and society at large. Indeed, the relationship between gender and technoscience is understood as mutually shaped, contingent, flexible and malleable (e.g., Bray, 1997; Cockburn & Ormrod, 1993; Faulkner, 2001; Gill & Grint, 1995; Lohan, 2000; Pujol & Montenegro, 2015; Wajcman, 1991; Wajcman, 2004; Wajcman, 2010; Webster, 1996). Thus, a major focus of feminist technoscience

[11] Feminist STS also emerged out of a reaction to the gender blindness of 'mainstream' STS (e.g., Berg & Lie, 1995; Corrigan & Mills, 2012; Haraway, 1994; Hunter & Swan, 2007; Lagesen, 2012; Lohan, 2000; Star, 1991; Whelan, 2001).

studies, as explained by Deborah Johnson (2010), "has been directed at understanding how a system of gender relations becomes inscribed in a technology and, vice versa, how technology reinforces, embodies, or disrupts gender ideas and relationships" (p. 36). In other words, artefacts, objects and technologies (such as crop varieties) can both be a source and consequence of gender identities and relations. Importantly, this further implies "the possibility of design – feminist design – as a new strategy for feminist goals" (Johnson, 2010, p. 40), which is a major topic in the discussion of this thesis.

The concept of 'gender scripts' describes how scientists, technologists, designers and engineers – often based on their own social embeddedness and situated knowledges – incorporate (most commonly unconsciously) gender ideologies, norms and values into the material and symbolic design of technical artefacts (e.g., Akrich, 1992; Bardini & Horvath, 2006; Comunello et al., 2021; Friz & Gehl, 2016; Hardon, 2006; Offenberger & Nentwich, 2013; Oudshoorn et al., 2004; Rommes, 2002; Shade, 2007; van Kammen, 1999; van Oost, 2003). In turn, such scripts may shape the agency and behaviours of users by delegating specific statuses, motives, competencies, skills, interests, roles and responsibilities. Accordingly, the concept of gender scripts can help capture two different but related processes through which gender and technology become co-constituted: one, the process through which technologies become gendered at the hands of designers and, two, how such gender scripted technologies may shape the agency and behaviours of men and women users. In the first article, I employ gender scripts to conceive of how, using the G+ Tools, crop breeding teams anticipate the behaviours, interests, skills and preferences of women and men farmers and other user groups, which down the line may become inscribed in the crop varieties themselves.

Feminist technoscience studies have also been important in highlighting the role that users play in shaping and co-designing technologies and technological trajectories (e.g., Cowan, 1987; Oudshoorn & Pinch, 2005). The STS concepts of 'interpretative flexibility' and 'de-scription' describe how users interpret, appropriate, modify or even reject technologies and their (gender) scripts (e.g., Akrich, 1992; Lie & Sørensen, 1996; Pinch & Bijker, 1984). In the first article, I use interpretative flexibility and de-scription to conceptualise how researchers and breeding teams interpret and appropriate the G+ Tools differently, sometimes resulting in rejection. I also use the concepts to argue that women and men farmers and other user groups may exercise interpretative flexibility and de-script an improved crop variety so that it takes on a new meaning and function than what was intended by the crop breeders (for instance, a variety bred for subsistence farming is appropriated as a source of animal feed). Indeed, while my data do not include farmers and other user groups, it is important to keep in mind their agency, which is a point I return to in section 4.1.

An important and noteworthy point of criticism of co-construction studies is the tendency towards treating technology as malleable and describing the processes through which technology become gendered, while gender is treated as static, fixed and binary. Accordingly, men and women are often depicted as relating to technology in ways that reflect heteronormative ideas of masculinity and femininity (Landström, 2007; Lohan, 2000). Interestingly, it appears more challenging for people to envision the mutability of gender as compared to the mutability of technology (e.g., Gil-Juárez et al., 2018). Moving forward, then, feminist technoscience studies should pay more attention to the construction of gender in the process of developing and using technology (Landström, 2007; Lohan, 2000). A fundamental argument of this thesis is that to better understand how gender is performed in and through agriculture and crop breeding, there is a need to pay attention to the agential and mediating role of plants. To do so, however, we need to transgress the nature/culture and social/material dualisms, which feminist technoscience studies and, as considered next, critical plant studies can help us do.

2.3. Critical plant studies

A central pillar of feminist technoscience studies (and feminism more broadly) as well as critical plant studies is the interrogation and disruption of dualisms upon which Western science and philosophy are generally based and from which power, domination and exclusion are perceived to flow (e.g., Descola, 2013; Fausto-Sterling, 2003; Foster, 2019; Haila, 2000; Latimer & Miele, 2013; Latour, 1991 [1993]; Mathews, 2017; Plumwood, 1993). In this section, I draw particular attention to the dominant metaphysics which disassociate nature from culture, as well as the material from the social. In her *Companion species manifesto*, Haraway (2003) coins the term 'natureculture' to signify nature and culture as mutually shaped and the world as an ever-changing entanglement of matter, discourse and semiotics (also see Strathern, 1980). Related to the broader ontological and analytical meaning of co-construction (see section 2.1), a naturecultural ontology allows us to go beyond the misconception of plants as passive beings to an understanding of "how plants *act upon* us, contributing to the co-generation of our cultural practices, values, perceptions, relations, artifacts, and all else" (Ryan, 2012, p. 104, italics in original).

Critical plant studies is an inter and transdisciplinary field that draws on environmental humanities, arts, philosophy, ethics and plant sciences to provide "a broad framework for re-evaluating plants, their representations and human-plant interactions" (Lawrence, 2021, p. 2; also see, e.g., Gibson & Brist, 2018; Hall, 2009; Hall, 2011; Head et al., 2012; Karlsson, 2022; Marder, 2013; Ryan, 2012; Scott,

2009; Scott, 2017; Tsing, 2015; Woodward & Lemmer, 2019). Critical plant studies is rooted in Indigenous cosmologies and knowledge systems which for centuries have recognised plants as agential and sentient beings and as kin (e.g., Dev, 2018; Geniusz, 2015; Kimmerer, 2003; Kimmerer, 2013; Kohn, 2013; Kwek, 2018; Miller, 2019; ojalehto et al., 2017; Shepard, 2018; TallBear, 2011; Wright & Taylor, 2009).

When discussing the feminist vegetal turn, Catriona Sandilands argues that we should attend to "the specific, material ways in which particular people have relations with particular plants in particular moments, both as these relations may serve the interests of heteropatriarchal capitalism and as they might offer sites of resistance" (Cielemęcka & Szczygielska, 2019, p. 9). Among others, Augusto (2007), Foster (2017), Ives (2017) and Osseo-Asare (2014) have produced important contributions to our understanding of the relationship between plants, knowledge production, indigeneity, race, gender, coloniality, capitalism and belonging in parts of Africa (especially South Africa). I am myself particularly interested in the ways in which plants and people are mutually shaped in constellations of knowledge, matter and intersectional gender identities and power relations. I address this most notably in the third article using banana, yam and cassava as examples.

To investigate this further, I use the idiom of 'entanglements' – which conjures up mental images of the entangled system of roots, shoots and branches of plants – to describe the various ways and forms in which humans and nonhumans, and more specifically plants, get caught up with and depend on each other (Barton & Denham, 2018; Hodder, 2011; Nally & Kearns, 2020; van der Veen, 2014), including in gendered ways. I further find the concept of 'plant agency', along with the concept of 'plantiness' (Head et al., 2012), useful in better understanding how plants are or become implicated in the construction and reproduction of intersectional gender identities and relations in African agriculture. Plantiness refers to the unique biological-material properties of plants and provides insights into "the specifics of plant agency – how it comes out of certain material capacities – and how that prefigures relations with people" (Head et al., 2012, p. 29).

The concept of plantiness provides me with an improved understanding of the agential capacity of crops in shaping knowledge production and technological innovation in crop breeding (banana) and in shaping gender identities, relations and (dis)empowerment pathways (yam and cassava). Relatedly, I also employ 'affordances' to conceive of how, in this case cassava, may "stimulate or foreclose various kinds of social actions" (Nally & Kearns, 2020; also see Berg, 2009; Gibson, 1979; Greeno, 1994; Sigaut, 1996). As described by Glover et al. (2019): "Affordances arise from the material properties of an object or environment and the characteristics of the people interacting with it, including their mental and

biophysical capacities (e.g. their knowledge, intelligence, creativity, strength and dexterity) and their resource endowments (of money, energy, land, labour, etc.), conditioned by timeliness (in relation to seasonality, sequences or conjunctions of events, and stages of life) and shaped by the social and cultural norms and rules that govern appropriate behaviour" (p. 174). Thus, affordances do not only take plantiness into consideration, but also capture a particular moment of the encounter between plants and people, which can also be gendered (as noted by Glover et al., 2019). Finally, I find Hannah Pitt's (2016) concept of 'planty knowledge' relevant, which refers to "a combination of what humans learn about plantiness, and that which plants themselves understand or sense of the world" (p. 92). In other words, planty knowledge, arising from gendered plant–people entanglements, is of critical importance in informing plant breeding, which I argue in the third article.

Thus far, through the lens of feminist technoscience studies and critical plant studies, we have mostly tended to smaller scale politics, practices and relations, including technological design, the role of users in shaping technological trajectories and the intimate and mutually shaped relationships that exist between plants and people. There is, however, a need to lift one's gaze to consider the broader historical and institutional context that shapes and is shaped by such micro-politics, practices and relations. While feminist technoscience studies and critical plant studies can be helpful also in this respect, I consider in the next section how political agronomy can complement such an analysis.

2.4. Political agronomy

In attending to 'knowledge politics' (i.e., the normative assumptions, political-institutional dimensions and agendas and the epistemological and technological logics), the field of political agronomy foregrounds the political and power-laden nature of agricultural knowledge production and technological innovation (Sumberg & Thompson, 2012; Sumberg et al., 2013). Thus, political agronomy provides me with a lens through which to better understand the knowledge politics, including the human actors, institutional settings and broader narratives and discourses, shaping the co-construction of gender, crops and crop breeding. In particular, I have found the 'contested agronomy argument' useful for contextualising and understanding this co-constructed relationship. The contested agronomy argument holds that, since around the mid-1970s, three interrelated developments have politicised, changed and contested agricultural research and development: the neoliberal project, the environmental agenda and the participation agenda.

The neoliberal project refers to the growing influence of the private sector in driving agrarian change (e.g., Akram-Lodhi, 2013; Friedmann & McMichael, 1989; Kherallah et al., 2002; Moseley et al., 2015). Among others, private funding agencies, also referred to as philanthrocapitalists, have come to play an increasingly important agenda-setting and decision-making role in agricultural research and development (e.g., Bishop & Green, 2015; Haydon et al., 2021; Morvaridi, 2012; Moseley et al., 2015; Mushita & Thompson, 2019; Thompson, 2018; Thompson, 2014; Wilson, 2014). For instance, as touched upon in the introductory chapter and elaborated on in the second article and in the discussion, the Gates Foundation has been instrumental in driving and shaping both the gender agenda and market-led turn (including their conflation) in and beyond the CGIAR (e.g., Farhall & Rickards, 2021; Polar et al., 2022).

The environmental agenda has drawn attention to the health and environmental impacts of industrialised farming (e.g., Carson, 1962; Loevinsohn, 1987; Newell & Taylor, 2018; Pimentel & Pimentel, 1990; Pingali & Rosegrant, 1994). In the context of this research, although this agenda is less visible, it is present in arguments that gender-responsive crop breeding can help increase the adoption of climate-resilient varieties. Finally, the participation agenda, in attending to the rights and emancipation of farmers as a goal in and of itself, as well as a way to achieve more efficient development management (Sumberg et al., 2012b), has called for a de-centralised, participatory and bottom-up approach to agricultural research and development. This has given rise to participatory approaches to plant breeding, such as participatory varietal selection (e.g., Chambers et al., 1989; Richards, 1985; Scoones & Thompson, 1994; Scoones & Thompson, 2009). Gender-responsive crop breeding, as noted in the second article, builds on this history and tradition.

In the second article, we use the concept of knowledge politics and the contested agronomy argument to contextualise and situate gender-responsive crop breeding, notably in relation to the market-led turn. However, as addressed at greater length later, to gain a fuller understanding of this dynamic relationship, we argue in favour of adding a fourth element to the contested agronomy argument: the gender agenda. Moreover, we complement the political agronomy analysis with perspectives from feminist STS, including the Baradian concepts of intra-action and apparatuses. This allows us to conceive of the market as an ongoing, relational performance consisting of intra-acting discourses, practices and human and nonhuman actors (for literature on the shaping and performativity of markets, see, e.g., Callon et al., 2002; Callon et al., 2007; Doganova & Eyquem-Renault, 2009; Doganova & Karnøe, 2015; Doganova & Muniesa, 2015; Kjellberg & Helgesson, 2007; MacKenzie et al., 2007; MacKenzie, 2009).

2.5. Philosophy of science

Our philosophical worldview shapes how we see and understand the world (i.e., ontology) and how knowledge about the world is generated (i.e., epistemology). Although philosophical and metaphysical questions are central in this thesis, one of my struggles and contestations as part of this PhD has been trying to situate my diverse theoretical approach within a broader conception of the philosophy of science or even a philosophical worldview. In particular, I have found aspects of both agential realism and critical realism informative, albeit at times contradictory. As apparent in the introductory section to this chapter, agential realism aligns with several of the theoretical concepts and analytical tools that I use, including my understanding of relationality, agency, performativity, matter/materiality, natureculture and sociomateriality, as well as the relationship between ethics, ontology and epistemology which I address at greater length in the discussion of the thesis.

It is further worth noting how agential realism shifts our understanding of causality and responsibility, which is also relevant when considering the implications of my research. In contrast to a singular, linear, unidirectional and deterministic model of causality, agential realism conceives of causality as enacted through intra-actions, which "effect the rich topology of connective causal relations that are iteratively performed and reconfigured" (Barad, 2007, p. 393). This means that there "are no singular causes. And there are no individual agents of change" (Barad, 2007, p. 394). Consequently, explanations and generalisations generated by research entail "a simplification of the causal field" (Frost, 2011, p. 79). Thus, there is a need to come to terms with "the impossibility of full and definitive knowledge and a corollary surrender of the teleological assumption that we might possibly, at some future point, achieve full mastery over ourselves and the world around us" (Frost, 2011, p. 79). In other words, it is impossible for me to acquire complete knowledge of the complex, heterogeneous, dynamic and co-constructed relationship between gender, crops and crop breeding nor to ascertain that my research will contribute towards gender equality and women's empowerment.

Moreover, as expressed by Frost (2011): "To shift our understanding or model of causation in this way represents a huge challenge: feminists will have to retool their theories of explanation and political critique so that they encompass both an awareness of the ways in which power is discursively naturalized and an appreciation of the distinctive and effective agency of organisms, ecosystems, and matter. This in turn will demand that feminists rethink how to apportion responsibility for injustice and assess the possibilities for and paths toward social and political transformation" (p. 73). This and related arguments has, however, given rise to some criticism, in which relational and agency-based accounts have been accused of dissolving human responsibility and accountability, as well as for being

ahistorical and apolitical by ignoring structure (e.g., Amsterdamska, 1990; Bloor, 1999; Collins & Yearley, 1992; Jasanoff & Kim, 2015; Vandenberghe, 2002). Indeed, if plants have agency in shaping gender relations, does that mean that they should bear some of the responsibility if an improved crop variety comes to disadvantage women? Should we blame the G+ Tools if their use contributes to the reproduction of stereotypical gender roles and responsibilities?

I argue, alongside Barad, that acknowledging that there are other active beings besides humans does not "[deflect] our responsibility onto others" (Barad, 2007, p. 391). Rather, taking into consideration the role that the G+ Tools (and other research and marketing tools and concepts) and crops play in the construction of gender helps broaden our understanding of (but never fully predicts) how social and political transformation can both the constrained and promoted. Furthermore, as evident from my use of political agronomy, I do not wish to deny the existence of historical, political and institutional structures and arrangements (e.g., capitalism, patriarchy, the market, etc.). However, rather than conceiving of these as pre-given 'explanations', a relational ontology and agency-based account consider these as "things that themselves need to be explained" (Fox & Alldred, 2018, p. 322; also see Latour, 2005). Thus, I am interested in the relations through which these structures are constantly made and remade and the different shapes and meanings they take on as a result. For example, Lohan (2000) argues that while gender should be "operationalized as an analytical category in order to be seen" (p. 901), we should not assume "a particular shape to gender dichotomy and hierarchy, or at least in predictable and traditionally-defined ways" (p. 905).

Still, while it is intriguing to use the weird and wonderful world of quantum physics to deconstruct ways of thinking about gender dualisms and the relationship between subject and object, nature and culture, the social and material, human and nonhuman and so forth, I am yet to be fully convinced by Barad's extrapolation of phenomena at the quantum to the sociological level. Indeed, I find it hard to rid myself of notions of scale, which agential realism appears to deny. Thus, critical realism seems to better support at least some aspects of my philosophical worldview, as well as with political agronomy's concern with historical, political and institutional developments and agendas in describing, in this case, what drives and shapes the co-construction of gender, crops and crop breeding.

Critical realism is a philosophical stance which holds that a reality exists beyond our knowledge or conscious experience of it (Bhaskar, 1998), meaning that "entities exist independently of being

perceived, or independently of our theories about them" (Phillips, 1987, p. 205).[12] In critical realism, reality is structured and stratified into three overlapping ontological domains – the empirical, actual and real – through which entities and structures emerge.[13] As explained by Danermark et al. (2002): "The empirical domain consists of what we experience, directly or indirectly. It is separated from the actual domain where events happen whether we experience them or not. (…) But this domain is in its turn separated from the real domain. In this domain there is also that which can produce events in the world, that which metaphorically can be called mechanisms" (p. 20). Thus, critical realists are interested in mechanisms that cause events (Danermark et al., 2002). Moreover, Roy Bhaskar (1998) argues that an universally recognised feature of social life is intentional agency, which draws upon social structure to produce outcomes. Thus, critical realists understand agency and causality very differently from agential realists.

However, a critical realist ontology would seem to violate several of the theoretical and analytical concepts that I use in my thesis, such as the inseparability of the social and the material, of nature and culture, of ontology and epistemology, and my understanding of agency and performativity. Thus, if I were to strictly follow critical realist claims (or agential realism for that matter), it would have restricted my empirical and theoretical investigative scope (Kemp, 2005). Perhaps where I get stuck is in trying to unite my natural sciences and social sciences ontologies. Indeed, there might be some truth to Kemp's (2005) argument that "realist claims about the ontology of the social world do not have as strong an epistemic warrant as the ontological claims realists derive from analyzing fundamental physics and chemistry" (p. 178), which may arguably also be the case for agential realism.

Thus, after several attempts at trying to arrive at one consistent metatheoretical framework, I have decided to rather delve in this uncertainty; to acknowledge that science, and indeed the world, is messy; to be honest and transparent about the inconsistencies I experience in my attempt to make sense of it all; and recognise that I am still on a journey in trying to figure out how I understand the world and the production of knowledge. Furthermore, what is perhaps more important than finding one neat, coherent framework is rather to ask, as Laura Foster does, "what and whose epistemologies, ontologies and ethics come to matter most" (Foster, 2017, p. 11)? These are questions I will touch upon in the discussion of the thesis.

[12] From an agential realist understanding, however, even quantum particles would be considered sociomaterial, which renders such an objective reality not simply material but indeed sociomaterial.
[13] Part of the reason why I am drawn to critical realism is that its three ontological domains seem to share some commonalities with the intriguing metaphysical framework developed by the mathematical physicist Roger Penrose, in which reality consists of the physical, the mental and the platonic world (Penrose, 1994).

3. Aims, research questions and research and knowledge contributions

In this chapter, I present the aims and research questions, followed by the research and knowledge contributions of the thesis.

3.1. Aims and research questions

In this PhD, I aim to (i) investigate the knowledge politics, practices and tools through which CGIAR crop breeding programmes are developing gender-responsive and transformative crop varieties; (ii) consider how gender, crops and crop breeding become co-produced in the process; and (iii) explore how feminist crop breeding can be advanced through conversations between feminist technoscience studies, critical plant studies and molecular breeding. To guide this investigation, I posit the following overarching research question: **How can crops and crop breeding be feminist?**

I further break the question down into three research questions that build on each other, each of which are addressed in the three respective articles (Table 1; Fig. 3).

1. ***How is gender-responsive crop breeding practiced and negotiated in ways that co-construct gender, crops and crop breeding?***

To analyse this empirical and theoretical question, I carry out an ethnographic case study where I follow the G+ Tools from their conception through to the aftermath of their piloting. This includes engagement with the Tools themselves and interviews with and observations of researchers involved in the construction and use of the G+ Tools, as well as with actors from the broader gender and breeding community. I explore the performative roles of the G+ Tools as they emerge in interaction with the crop breeding teams and consider how gender, crops and crop breeding become co-produced in the process. In doing so, I use concepts from feminist STS, including gender scripts, interpretative flexibility and de-scription (Table 1). I also pay close attention to the inter and intradisciplinary tensions and negotiations involved in the use of the G+ Tools.

2. ***What drives and shapes the co-construction of gender, crops and crop breeding, and with what effects?***

In this co-authored article, we explore this largely empirical question by situating gender-responsive crop breeding in the context of the market-led turn currently dominating within and beyond the CGIAR. We develop and use a novel feminist political agronomy lens to unpack the market, demand and gender and their co-construction. Political agronomy and its contested agronomy argument, along with the key concept of knowledge politics, foregrounds the human actors, institutional settings and broader narratives and discourses that drive and shape the co-construction of gender, crops and crop breeding (Table 1). Feminist STS, in turn, help draw materiality and nonhuman actors into the analytical frame through the use of the concepts of intra-action and apparatuses (Table 1). The article is based on an institutional ethnography that includes interviews with and observations of actors involved in the GBI, the EiB and other high-profile breeding initiatives and organisations, and document analysis of resources produced by the relevant actors.

3. ***How can feminist crop breeding be advanced through conversations between feminist technoscience studies, critical plant studies and molecular crop breeding?***

I address this question through a theoretical, albeit empirically grounded (based on past, personal experiences working in a molecular breeding lab, as well as observations of crop breeders and gender specialists), exploration that combines perspectives from feminist technoscience studies, critical plant studies and molecular plant breeding. Using a naturecultural and sociomaterial understanding of plants and people as mutually shaped and entangled, along with the concepts of plantiness, plant agency, affordances and planty knowledge (Table 1), I introduce the concept of the feminist crop. The concept helps capture the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. I illustrate some of the methodological and ethico-onto-epistemological implications of the concept, also as it relates to plant genome editing, using banana, yam and cassava as examples.

Table 1. Overview of articles, research questions, theoretical field(s) and key concepts

Article #	Research question	Theoretical field(s)	Key concepts
1	How is gender-responsive crop breeding practiced and negotiated in ways that co-construct gender, crops and crop breeding?	Feminist technoscience studies	• Gender scripts • Interpretative flexibility • De-scription
2	What drives and shapes the co-construction of gender, crops and crop breeding, and with what effects?	Political agronomy and feminist technoscience studies	• Knowledge politics • Intra-action • Apparatuses
3	How can feminist crop breeding be advanced through conversations between feminist technoscience studies, critical plant studies and molecular crop breeding?	Critical plant studies and feminist technoscience studies	• Natureculture • Sociomaterial • Entanglements • Plantiness • Plant agency • Affordances • Planty knowledge

The first question is a grounded, descriptive 'what'-type question which provides insights into what gender-responsive crop breeding entails in practice and how gender, crops and crop breeding become co-produced in the process. I consider this exploration as belonging to the realm of sociomaterial design (Fig. 3)**.** Leading on from this, the second question is an explanatory, 'why'-type question as it helps explain some of the observations made in the first article by asking why gender-responsive crop breeding is being done this way – in other words, what drives and shapes the co-construction of gender, crops and crop breeding, and with what effects. Accordingly, the question goes beyond the stage of design to consider the broader sociomaterial system of gender-responsive crop breeding (Fig. 3). Finally, the exploration into the 'what' and 'why' allows me to explore 'how' gender-responsive crop breeding can be done differently, where I venture into the metaphysical and imaginative realms (Fig. 3). In reality, however, the research questions and the realms to which they belong are intimately entangled and overlapping but are separated here for the sake of analysis.

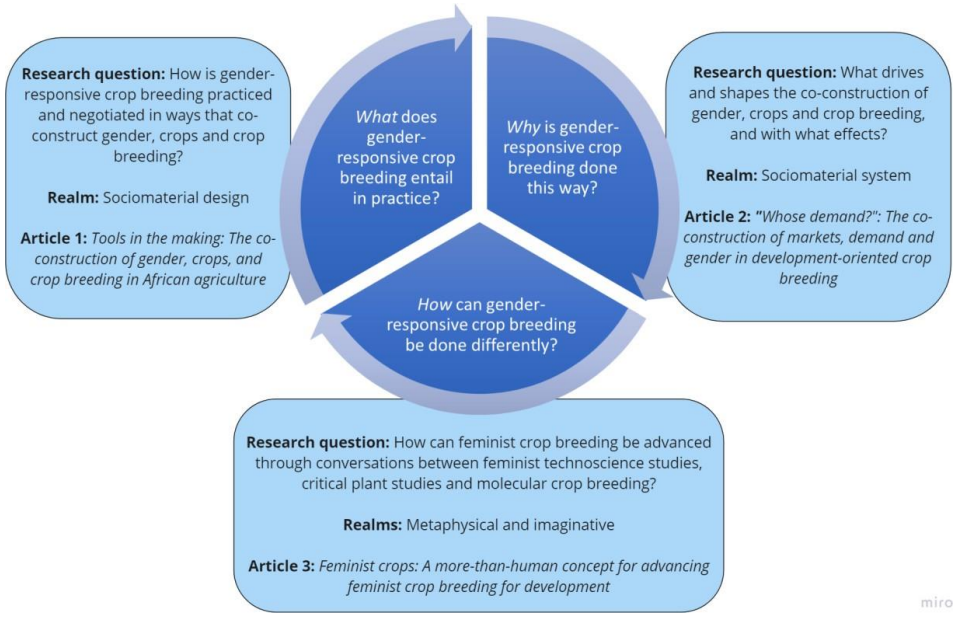

Figure 3. Overview of research questions, realms and articles

3.2. Research and knowledge contributions

Several studies have been published in recent years that address gender and crop breeding, including in relation to market-based approaches, most of which collect sex-disaggregated varietal and trait preference data (e.g., Cairns et al., 2021; Marenya et al., 2021; Mudege et al., 2021; Nanyonjo et al., 2021; Okello et al., 2021; Teeken et al., 2021a; Teeken et al., 2021b; Tegbaru et al., 2020). Some of the studies also suggest ways of better supporting gender-responsiveness in crop breeding. This includes the need to improve methods for capturing trait and varietal preferences and other operational challenges (e.g., Cairns et al., 2021; Voss et al., 2021), as well as the need to engage with other actors in promoting gender-responsive crop breeding, including policy departments (e.g., Marenya et al., 2021), food scientists and postharvest specialists (e.g., Tegbaru et al., 2020) and the private sector, including seed companies (e.g., Tegbaru et al., 2020; Voss et al., 2021).

In other words, most of these studies have been conducted at the level of farmers and other user groups along the value chain. However, few studies have investigated how gender-responsive crop breeding plays out in practice, including the knowledge politics through which gender-responsive crop breeding is negotiated. Of the studies that do, Hannah Ewell (2021) explores gender-responsive crop

breeding in the case of cassava in Nigeria through interviews with natural and social scientists in the CGIAR and the national research system. Ewell (2021) provides important empirical insights into perceptions and challenges of gender-responsive crop breeding, including interdisciplinary negotiations and the donor drive towards market-based approaches. Still, while the concept of product profile is mentioned, Ewell (2021) does not engage with the new tools and approaches to gender-responsive breeding, such as the G+ Tools.

Furthermore, the article by Ewell is grounded in the seminal empowerment theories of Sen (1990) and Kabeer (1999). Sen (1990) put forth the capability approach to development, where "[t]he foundational importance of human capabilities provides a firm basis for evaluating living standards and the quality of life" (p. 11). Kabeer (1999), in turn, defines empowerment as the "expansion in people's ability to make strategic life choices in a context where this ability was previously denied to them" (p. 437). Thus, many gender scholars envision women's empowerment as a dynamic process that address structural causes of gender inequalities, domination and oppression and through which the capabilities of women are improved (e.g., Batliwala, 1994; Rowlands, 1995). Consequently, my research expands on our empirical understanding of the new practices and tools of gender-responsive crop breeding and contributes new theoretical ways of understanding these. Among others, I explore how a more-than-human, naturecultural and sociomaterial ontology can provoke new ways of understanding agency, power relations and (dis)empowerment in agriculture, taking plants and plant agency into account. Due to the interdisciplinary nature of the research, I tap into and contribute to additional academic debates, as elaborated next.

The thesis is among the few studies in STS and feminist STS to explore the topic of plant breeding for development in Africa (but do see McGuire, 2008 and Eddens, 2019; for studies on crop breeding in the Global North, see Busch & Juska, 1997; Mendum, 2009a; Mendum, 2009b; Powell, 2016). More broadly, the research adds to a growing literature in STS and feminist STS conducted in the Global South (e.g., Kervran et al., 2018; Mascarenhas, 2018; Rajão et al., 2014), including studies that recognise the value of applying such and related perspectives to agricultural research and development (e.g., Almekinders et al., 2019; Crane, 2014; De Roo et al., 2019; Gengenbach et al., 2018; Glover et al., 2019; Goodman, 1999; Higgins, 2006; Rezvani, 2021; Verschoor, 1997; Voeten et al., 2015; Watts & Scales, 2015). More specifically, the thesis contributes to the comparably small literature on African (feminist) STS (e.g., Borenstein, 2021; Foster, 2012; Foster, 2016a; Foster, 2016b; Foster, 2016c; Henry et al., 2019; Lamoureaux & Rottenburg, 2021; Okune, 2020; Paxling, 2019;

Pollock, 2014; Rottenburg, 2009).[14] Some of the scholars writing under the umbrella of African STS have attended to plants and plant knowledge (e.g., Augusto, 2007; Bauchspies, 2009; Foster, 2017; Osseo-Asare, 2014), with a few addressing gender relations and drawing on feminist perspectives (see in particular Bauchspies, 2009 and Foster, 2017). However, the topic of gender and crop breeding has yet to be covered to a significant extent.

My literature review also revealed that the relationship between feminism, gender and plant genome editing remains underexplored in feminist technoscience studies, critical plant studies and political agronomy (conventional gene modification, in turn, has been well-covered). In investigating this relationship, I have been inspired by Deboleena Roy's book *Molecular feminisms: Biology, becomings, and life in the lab*, where she reconciles molecular biology practices (using the case of reproductive neuroendocrinology and cloning) with feminist ethical and political principles (Roy, 2018). I would also like to draw attention to articles by Bryant and Pini (2006) and Ezezika et al. (2013) (also see Shaw, 2020), although they do not explicitly address genome editing (which is likely to reflect the time of publication).[15] In recognising the lack of a feminist analysis of agricultural biotechnologies, Bryant and Pini (2006) used perspectives from ecofeminism and feminist STS to argue that "we need to question how the gendering of agricultural biotechnologies materially and discursively impact on decisions about what agricultural biotechnologies will be designed, who will design them and for whom and how they will be designed" (p. 267).

Similarly, in their article on gender-responsive priorities for effective development of agricultural biotechnology in Sub-Saharan Africa (SSA), Ezezika et al. (2013) found that "incorporating a gendered perspective is critical for the sustainable development of agricultural biotechnology" (p. 461). They contend that "[a]gricultural biotechnology initiatives provide avenues through which we can assess and re-negotiate the inequitable social structures and social relations at play in the agricultural sector in SSA and other developing regions" (p. 463). Thus, I am raising to the calls of both Bryant and Pini (2006) and Ezezika et al. (2013) by attending to several of the questions they pose, including through the development of novel theoretical concepts and approaches, such as the feminist crop.

[14] Tellingly, Africa was not "present in the institutional geography" of the latest edition of the *Handbook of science and technology studies* (Felt et al., 2017, p. 16). It is also noteworthy that several scholars of African STS are from, or work at academic and research organisations in, Europe and North America.

[15] While the discovery of CRISPR dates back to the late 1980s (Ishino et al., 2018; Mojica & Rodriguez-Valera, 2016), it was not until 2012, when it became operationalised as a biotechnological tool (Jinek et al., 2012), that the interest in and application of CRISPR skyrocketed. Note, however, that other genome editing tools have been (and still are) in use prior to CRISPR-Cas, including transcription activator-like effector nucleases (TALENs) and zinc finger nucleases (ZFNs).

In contrast to feminist STS, crop breeding is a well-covered topic in political agronomy (e.g., Brooks & Johnson-Beebout, 2012; Rao & Huggins, 2017; Sumberg et al., 2013; Taylor et al., 2021; Westengen et al., 2019; Whitfield, 2016). However, through my literature review, I found that political agronomy has yet to significantly engage with gender studies and feminist theories. In the edited volume by Sumberg and Thompson (2012) that helped define the field of political agronomy, Sumberg et al. (2012b) note that the participation agenda has highlighted women's role in agriculture and the need to empower women farmers, but the authors do not identify a separate gender agenda. When gender occurs elsewhere in the book, it is most commonly in passing (Erenstein, 2012, p. 58; Ramisch, 2012, p. 152; Sumberg et al., 2012a, p. 188; Woodhouse, 2012, p. 110). Similarly, while more recent contributions to political agronomy do address gender to some extent, they do not engage at depth with feminist scholarships nor develop a broader argument on gender (Rao & Huggins, 2017; Taylor et al., 2021; Westengen et al., 2018). Additionally, in its focus on human actors, institutional settings and broader historical and discursive developments, materiality and nonhumans often seem to recede into the background of analysis.

Thus, in the second article, we expand on the contested agronomy argument of political agronomy, arguing that the gender agenda must be recognised alongside the neoliberal project and environment and participation agendas that have shaped development-oriented agronomy and crop breeding over the last decades (see section 2.4). We further assert that political agronomy can benefit from taking feminist STS analysis of materiality and nonhumans seriously. Given the centrality of gender in the food system and agricultural knowledge production and technological innovation, the gender agenda and feminist analysis have the potential for broader applications in political agronomy. As such, the article contributes towards advancing a feminist political agronomy.

4. Methodology

In this chapter, I will present the methodology. I considered a qualitative case study approach using ethnographic sensibility and methods, including qualitative and semi-structured interviews and observations, appropriate for answering the research questions. Towards the end of the chapter, I also address research ethics, including privacy and informed consent and my own situated knowledge and positionality.

4.1. Case study approach

Ethnographic case studies are central in STS and feminist STS (Beaulieu et al., 2007), where they have featured everything from shavers and scallops to arteriosclerosis and eutrophication (Callon, 1986; Mol, 2003; van Oost, 2003; Waterton & Tsouvalis, 2015). While the definition of a case is highly ambiguous and contentious (Ragin, 1992), the case study is considered a comprehensive, in-depth research approach that covers "the logic of design, data collection techniques, and specific approaches to data analysis" (Yin, 2014, p. 14) in order to provide a thick description (Geertz, 1973) of a "contemporary phenomenon within its real-life context" (Yin, 2014, p. 13). The intention is not to generate statistical but rather analytical generalisations, where theories are developed, expanded and generalised (Yin, 2014). However, while cases are *"more or less* representative of some broader phenomenon" (Gerring, 2008, p. 675, italics in original), Lund (2014) notes how a case is "an edited chunk of empirical reality where certain features are marked out, emphasized, and privileged while others recede into the background. As such, a case is not 'natural,' but a mental, or analytical construct aimed at organizing knowledge about reality in a manageable way" (p. 224).

I considered a case study approach suitable for investigating the G+ Tools, which I conceive of as representing a case of the co-construction of gender, crops and crop breeding. My understanding of causality limits the extent to which I consider it possible to draw causal generalisations (see section 2.5). However, my case study investigation can be considered an attempt at generating analytical generalisations by expanding the theoretical scope of feminist STS, critical plant studies and political agronomy to the underexplored topic of gender-responsive crop breeding. I also develop novel theories, notably the feminist crop concept, which may be applicable in other cases where the co-construction of gender, crops and crop breeding is investigated. Some of my empirical findings, such as observations made of power relations and negotiations between donors, crop breeders and gender

specialists, may also be present in other breeding programmes beyond the ones investigated in this research (see, e.g., Ewell, 2021).

The choice of case study was a not a deliberate one. As described in the first article, my entry into the field was challenging, as I faced several obstacles in getting access to various breeding programmes. My access was secured through an agreement with Kenyatta University (appendices 3-5), facilitated by Dr. Richard Okoth Oduor who became part of the supervisory team. Before going into the field, I had little prior knowledge of the GBI and knew nothing of the G+ Tools. Thus, it was a stroke of luck that the G+ Tools were piloted simultaneously to my fieldwork (see, e.g., Fine & Deegan, 1996, for a discussion on the role of serendipity in qualitative research). In a sense, then, this is in line with the STS sensibility of foregrounding the empirical and not determining *a priori* what or who the most relevant actors are.

Receding into the background of this case, however, are the women and men farmers and other user groups that produce, process, cook, market, trade, exchange and consume crops, seeds and crop products. Still, the objective of my research was not to empirically investigate the gendered relationship between crop varieties and farmers and other user groups (as others have done; see section 3.2), but rather to explore how gender-responsiveness is conceptualised, practiced and negotiated by scientists and other 'formal experts'. However, as will become apparent, farmers and other user groups become constructed (including in gendered ways) through the practices of gender-responsive crop breeding. Thus, it is important not to lose sight of the men and women who eventually are meant to benefit from gender-responsive crop breeding, also from an ethical perspective (as addressed later in this chapter). Indeed, my hope is that the findings generated from this thesis can inform crop breeding in ways that will ultimately equally benefit women and men in agriculture.

4.2. Ethnographic fieldwork

I approached the case study using an ethnographic sensibility and ethnographic methods of data collection, including participant and non-participant observations, open-ended and semi-structured interviews and document analysis. "As a way of thinking," Van Tiem (2021) notes, "ethnography orients researchers and implementors to 'everyday' contexts, which includes the local and the lived experience, as well as the tacit and implied" (p. 2). In my own research, which can further be thought of as a form of institutional ethnography as it explores the dynamics between individual experiences and institutional relations (Smith, 2006), I attended to the lived experiences of scientists and other

formal experts (see below) involved in gender-responsive crop breeding; not only in their encounters with other humans but indeed nonhumans, most notably the G+ Tools.

While ethnographers from the very beginning have shown interest in the material culture and materiality of human life (e.g., Malinowski, 2002 [1922]), it is traditionally highly human-centric. STS, feminist STS and critical plant studies, however, include both human and nonhuman actors in their analytical frameworks and attend to how matter and people mutually shape one another, which can be referred to as sociomaterial ethnography or more-than-human ethnography (further discussed in section 6.3). While I argue in favour of the need to pay analytical attention to plants, plantiness and plant agency, a major limitation of this thesis was the lack of engagement with the crop plants themselves. Originally, the intention was to follow crop breeders as they worked with plants in the field and in the laboratory, and to investigate how gender entered plant–people entanglements constructed at the hands of crop breeders. Unfortunately, due to the circumstances, including the pandemic, I was unable to do this.

An ethnographic sensibility also entails a high degree of openness, flexibility and adaptability as puzzles and surprises arise in the field. Goldbart and Hustler (2005) note how "ethnography is a constant process of decision-making" (p. 18), where "openness to smaller or very large changes in research design is crucial" (p. 18). This flexibility allowed me the freedom to take on new opportunities as they presented themselves during the fieldwork, such as accepting an invitation to participate in a workshop in Tanzania and in the piloting of the G+ Tools (see section 4.2.3 for more information). Furthermore, as I gained more knowledge through readings, observations and conversations, I would progressively focus interviews and observations, and I would work iteratively between data collection and analysis throughout my fieldwork.

Hess (2001) further notes how fieldwork in STS often entails several points of exposure. The method of "following the actor" may result in a multi-sited ethnography "wherein observations are not tied to any specific location or particular village, in the sense of a traditional ethnography" (Powell, 2016, p. 54). As described in further detail below, my ethnographic fieldwork was multi-sited, particularly as I faced challenges imposed by the COVID-19 pandemic. I participated in several physical and virtual conferences, meetings and workshops; read and analysed various types of documents and literature; and conducted interviews both in-person and online. This also allowed for triangulation of data, defined by Stake (2005) as "a process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation" (p. 454). In other words, triangulation is important in cross-checking the data and increasing the validity and credibility of the findings.

The discussion on what counts as the field and immersion has existed in anthropology for decades (e.g., Gusterson, 1997; Nader, 1972), but has intensified as we have come to live in an increasingly globalised, interconnected and digitally mediated world (e.g., Ahlin & Fangfang, 2019; Beaulieu, 2004; Bluteau, 2021; Gupta & Ferguson, 1997; Hine, 2015; Marcus, 1995). Many of these discussions became particularly pertinent during the COVID-19 pandemic, as the pandemic significantly changed the way we did (and perhaps will continue to do) research (e.g., Howlett, 2021). The pandemic meant that I had to return from Kenya little over one month prior to my planned departure and thus move my remaining interviews online, while large parts of the piloting of the G+ Tools had to be conducted digitally.

Doing online research has its pros and cons. Among the biggest disadvantages is the lack of physical interaction with the research participants and the materiality of their surroundings. This is not only an important aspect of data collection and analysis, but also for building trust (meeting face to face is a very different experience compared to, for instance, email correspondence). Furthermore, other important social cues may get lost in translation in the digital world. Another disadvantage are technical issues, such as blackouts and unreliable internet connectivity, as well as time differences, which may cause a lot of frustration during interviews and other types of digital interactions and events.

Then again, online interviews using (decent quality) video allows close reading of facial expressions and, to some extent, the person's surroundings. In cases where just audio is used, a lot of information can be read off the soundscape: the tone of someone's voice, awkward silences, laughter, chuckles, sighs and sounds from the surroundings (animals, the weather, police sirens, cars honking, people conversing). In terms of building trust, participants may let their guard down more when they find themselves in the comfort of their own home as opposed to a work setting (however, it is far from a given that someone finds their home a comforting place to be, which may be particularly true for many women who bear the brunt of the reproductive and emotional labour or are more often victims of domestic abuse). Furthermore, as conversations usually started by talking about where in the world people were and how they and their loved ones were experiencing the pandemic, this often served as an entry point for sharing more personal information, which may have helped establish trust.

An advantage of doing online research is that it allows for other types of communication that people may (or may not) be more comfortable using as opposed to, for instance, speaking in more public fora, such as physical workshops and conferences. These may include virtual chats, pre-recorded

presentations and the use of emojis and animations. During the G+ Tools piloting project, the digital tool Conceptboard was used, where people worked on a digital concept board together. This helped foster cooperation and exchange of ideas and provided me with insight into the way people were thinking and working as they would type out, change or delete comments in real-time.

Another benefit of doing digital research is that it allowed me – and others who would normally have been prevented from travelling, for instance women scientists with primary responsibility for child and elderly care or for whom it may not be safe or culturally acceptable to travel – to join events I would otherwise not have had the resources or time to attend (e.g., the EiB Contributors Meetings and the APBA Conference 2021, as described in section 4.2.3). Thus, digital events may facilitate increased accessibility and transparency. The downside, however, is that participation is restricted to those with digital means and digital literacy, and virtual events may have entry fees that may exclude people living under certain socioeconomic conditions.

4.2.1. Field site

The main bulk of the data was collected during fieldwork in Nairobi, Kenya, in the period between August 2019 to March 2020, which included a short trip to Morogoro, Tanzania, from 12–19 October 2019. Nairobi was selected as the field site as the city hosts several CGIAR offices and research stations, including those located at the International Centre of Insect Physiology and Ecology (ICIPE) campus, the International Council for Research in Agroforestry (ICRAF) campus and the Biosciences Eastern and Central Africa–International Livestock Research Institute (BecA–ILRI) campus (Fig. 4). Additionally, research participants included scientists situated at other CGIAR offices in Ethiopia, Nigeria, Uganda and Zimbabwe, as well as some National Agricultural Research System (NARS) organisations. Following my return to Norway in March 2020, online interviews continued until the start of 2021, while digital observations continued until November of 2021. As such, while I did not carry out long-term observations in a single setting in the sense of traditional ethnography, my research extended over a period of about two years with varying degrees of ethnographic intensity.

Figure 4. The three main sites where interviews were conducted in Nairobi, Kenya. *ICIPE: International Centre of Insect Physiology and Ecology; ICRAF: International Council for Research in Agroforestry (World Agroforestry Centre); BecA–ILRI: Biosciences Eastern and Central Africa–International Livestock Research Institute.*

4.2.2. Qualitative interviews

As explained by Brinkmann and Kvale (2014), "[t]he qualitative research interview attempts to understand the world from the subjects' point of view, to unfold the meaning of their experiences, to uncover their lived world prior to scientific explanations" (p. 3). Brinkmann and Kvale (2014) further note how "knowledge is constructed in the inter-action between the interviewer and the interviewee. An interview is literally an inter-view, an inter-change of views between two persons conversing about a theme of mutual interest" (p. 4). What follows is an understanding of the interviewee as an active participant in the making of knowledge. The interviews conducted for this research were semi-structured and open-ended, which allowed me and the person being interviewed the freedom to explore several aspects of interest as they appeared in the conversation.

The content of the interviews varied according to the person being interviewed but generally revolved around the following topics: the role of gender in agriculture and crop breeding; historical perspectives on gender research in the CGIAR and beyond; factors influencing priority-setting and decision-making in crop breeding, including during varietal design; conceptualisation, methods and rationale of gender-responsive crop breeding, also in relation to market-based approaches; challenges and costs associated with gender-responsive crop breeding; the knowledge politics of (gender-responsive) crop

breeding, including interdisciplinary power relations and the role of donors; how to facilitate interdisciplinary communication and cooperation; the transformative potential of crops and crop breeding; and the opportunities and challenges of genetic engineering for gender-responsive and transformative crop breeding. Conversations also included questions about the background of the interviewee, how they became interested in the topic of gender and their professional experiences, goals and aspirations. Interviews with participants in the piloting of the G+ Tools and others previously or currently involved in the GBI focused more so on the GBI as an organisation and experiences in developing and using the G+ Tools and other resources produced by the GBI.

A total of 48 interviews were conducted with 42 people, meaning that some people were interviewed several times (Appendix 6), with interviews commonly lasting for about 45–60 minutes. Participants were chosen based on their professional experience with the topic. People were contacted using email, WhatsApp or phone, often via reference from other key persons. Thus, snowball sampling was used to select research participants and interview respondents (Goodman, 1961). Of the participants, 15 worked as crop breeders or other types of biophysical researchers, 10 were gender specialists, 5 were socioeconomists, 5 represented non-governmental organisations, 4 were governmental policy and decisionmakers and 3 represented donor organisations (Appendix 6). The small number of donor representatives was partly due to difficult access, as similarly experienced by other researchers working on philanthropy and donor agencies (e.g., Hay & Muller, 2012; Kohl-Arenas, 2017; Schurman, 2018). Thus, I was unable to represent the full range of donor perspectives in this study. This gap was supplemented through analysis of textual resources produced by donors, as well as observations of donors during conferences and other types of events where they participated.

The majority of participants were of African nationality (25 participants), followed by 8 participants from Europe, 7 participants from the Americas (most from North America) and 2 participants from Asia. Most participants worked in or as a partner to various CGIAR breeding programmes based in Africa, including those of the International Center for Tropical Agriculture (CIAT), the International Maize and Wheat Improvement Center (CIMMYT), the International Potato Center (CIP), the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI) and the International Rice Research Institute (IRRI). The NARS organisations consisted of Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya Agricultural & Livestock Research Organization (KALRO), National Biosafety Authority (NBA) and University of Nairobi (UoN) (Appendix 6).

The donor organisations included Bill and Melinda Gates Foundation (Gates Foundation) in the United States and the International Development Research Centre (IDRC) in Canada, while the governmental and non-governmental organisations comprised of the Alliance for a Green Revolution in Africa (AGRA), the African Women in Agricultural Research and Development (AWARD), the Ministry of Agriculture, Livestock, Fisheries and Co-operatives of Kenya (KILIMO), the National Commission for Science, Technology and Innovation of Kenya (NACOSTI), the National Research Foundation of Kenya (NRF) and the Seed Systems Group (SSG) (Appendix 6). While I did not ask participants about their gender identity, 23 presented as female, while 19 presented as male.

As evident above, most of the research participants were people in senior positions and positions of power relative to my own. However, rarely did I feel depreciated because of my age, gender or academic position as a PhD researcher; most people appeared open and willing to share. It would be naïve to think, however, that this openness would not at times be shaped by the socio-political contexts and considerations of the participants. These include my relative privilege as a white, well-educated cis woman of Norwegian nationality; it is also possible that a few of my informants considered me a potential link to Norwegian donors and other partners.

4.2.3. Participant and non-participant observations

"The methodology of participant observation", Jorgensen (1989) explains, "is exceptional for studying processes, relationships among people and events, the organization of people and events, continuities over time, and patterns, as well as the immediate sociocultural contexts in which human existence unfolds" (p. 12). The aim is "to generate practical and theoretical truths about human life grounded in the realities of daily existence" (Jorgensen, 1989, p. 14). We can further extend this definition to include the study of the relationship between people and nonhumans and 'truths' about human and nonhuman lives grounded in naturecultural and sociomaterial becoming. In contrast to participant observations, where the researcher takes active part in the phenomenon under study, non-participant observation refers to situations where the researcher does not actively participate (Cohen et al., 2017). I carried out both participant and non-participant observations, as further elaborated below.

The key observations informing this thesis were made during the piloting of the G+ Tools organised by the GBI with support from the EiB. Once the G+ Tools and their piloting was brought to my attention by a key contact, I was put in touch with the project organisers who were happy to have me attend the piloting workshops. Once I arrived at the first workshop in Nairobi (see below), I was approached by the project manager who asked whether I would be willing to assist with some practical tasks as part

of a consultancy for CIP (most notably writing workshop reports). The consultancy was a great networking opportunity and allowed insights into the piloting process and access to materials that I would normally not have had access to (I address the ethical implications of the consultancy in section 4.4.2).

The G+ Tools were initially piloted in three African-based breeding programmes, namely the IITA cassava breeding programme in Nigeria, the Alliance-Bioversity-CIAT bean breeding programme in Zimbabwe and the CIP sweetpotato breeding programme in Uganda (Fig. 5). A fourth case, the Alliance Bioversity–CIAT banana breeding programme in Uganda, was also part of the project, but the piloting did not move forward as planned (see Polar et al., 2022, p. 495). The G+ Tools have also been scaled in three additional breeding programmes: the Alliance Bioversity–CIAT bean breeding programme in Kenya, the CIP potato breeding programme in Uganda and the ICARDA lentils breeding programme in Ethiopia. The latter participated actively in the piloting project and was included in the data material for this thesis (Fig. 5).

Figure 5. Breeding programmes of the G+ Tools piloting that were included in the data collection

The piloting project was meant to consist of three main events: the Knowledge-Sharing and Planning Workshop in Nairobi (4–6 March 2020), the Evaluation and Learning Workshop in August 2020 and sharing of the results and final report during the EiB Contributors Meeting in November 2020. The Knowledge-Sharing and Planning Workshop was hosted as planned in Nairobi and is described in more

detail in the first article and in one of the workshop reports I co-authored (CGIAR Gender and Breeding Initiative, 2020). Following the workshop, each of the piloting teams (which consisted of at least one crop breeder, gender specialist and economist) returned to their research organisation to pilot the G+ Tools. However, due to the COVID-19 pandemic, the project was extended until the end of December 2020 and the Evaluation and Learning Workshop was replaced by eight digital meetings taking place from September to December 2020, all of which I participated in (CGIAR Gender and Breeding Initiative & CGIAR Excellence in Breeding Platform, 2020; also see Polar et al., 2022).

Extensive notes were taken during the meetings, which consisted of presentations by the project organisers and participants, lively discussions verbally and in the chat and brainstorming using the app Conceptboard. Furthermore, while I did not play an active role in most of the discussions taking place among the piloting participants, I interacted with the G+ Tools themselves. For instance, I filled the templates of the G+ Tools using hypothetical cases and I was also asked to provide feedback on the Tools. This hands-on experience allowed me a deeper appreciation of the materiality of the G+ Tools, which was beneficial in understanding their performative role, as well as allowing me to relate more closely to the experiences that the piloting participants themselves had when using the Tools.

In addition to the piloting project, the workshop in Tanzania informed my understanding of market-based approaches to gender-responsive crop breeding; observations which I drew most extensively on in the second article. The four-day long workshop Trait Prioritization and Evaluation in Rice was co-organised by the International Rice Research Institute (IRRI), the Tanzania Agricultural Research Institute (TARI) and the New Zealand-based private company AbacusBio. The workshop was part of a larger project called the Accelerated Genetic Gain in Rice (AGGRi) Alliance, funded by the Gates Foundation, where one of the primary outcomes is the development of "market- and gender-responsive data-driven product profiles" (Ibabao, 2019).

The outcome of the workshop provided the basis for creating a survey (based on the 1000Minds software) for collecting data on demographics and trait preferences among men and women stakeholders across the rice value chain in Tanzania. The results from the survey will be used by AbacusBio to create a decision-making tool for breeders based on economic weighting of traits (Abacusbio & IRRI, 2018; Balogun et al., 2022; also see Teeken et al., 2021a). During the workshop, the participants (myself included) got hands-on experience in using the survey tool, which helped reveal both the potential and limitations of the software. Trying to think of myself as a farmer, I found responding to the questions as part of the conjoint analysis of the survey tool really challenging (for instance, "would you rather earn 5 dollars more per bag of rice or have a reduction in disease

prevalence of 20%?"). This provided me with an even greater appreciation of the knowledge held by farmers and other user groups in agriculture.

Additionally, I made non-participant and, in a few cases, participant observations at several other events that provided additional insights into the context, knowledge politics, processes and practices of gender-responsive crop breeding. These included the launch of the One Planet Fellowship hosted by AWARD in Nairobi; the 1st year anniversary meeting for the Organisation for Women in Science for the Developing World (OWSD) Kenya National Chapter hosted in Nairobi; the workshop Gender Dynamics in Seed Systems in Sub-Saharan Africa and WorldWide–Lessons hosted by CIMMYT in Nairobi (Adam & Muindi, 2019); the digital 18th Gender Summit 2020 Africa; the digital 10th Annual Summit of the African Green Revolution Forum (AGRF), which included the launch of the new CGIAR Generating Evidence and New Directions for Equitable Results (GENDER) Platform; the digital Cultivate Africa Conference, including Track #7 on Women & Agriculture organised by the International Fund for Agricultural Development (IFAD), the African Union Commission (AUC) and the CGIAR GENDER Platform; the digital conference Cultivate Equality 2021: Advancing Gender Research in Agriculture and Food Systems; the digital African Plant Breeders Association (APBA) Conference 2021; and the digital EiB Contributors Meeting in 2020 and 2021.

4.2.4. Qualitative document analysis

Bowen (2009) describes document analysis as "a systematic procedure for reviewing or evaluating documents—both printed and electronic (computer-based and Internet-transmitted) material" (p. 27). During my research, I reviewed multiple types of grey and white documents and other types of peer-reviewed and popular literature and materials produced by the relevant actors. Most notably, these included resources produced by the GBI, including working papers, briefs, workshop materials and workshop reports; materials produced by the EiB, such as the product replacement strategy guide and annual reports; resources produced by the CGIAR and its research centres, including gender strategies, gender assessment studies, fact sheets, pamphlets and other website resources and dashboards; and resources produced by donors, most notably the Gates Foundation, including their gender equality strategy, global framework for advancing women's economic empowerment, gender equality toolbox, conceptual model for women and girl's development, gender impact strategy for agricultural development, gender checklist and the orientation document on creating gender-responsive agricultural development programmes. I also read Melinda Gates' book *The moment of lift: How empowering women changes the world* and watched *My next guest needs no introduction with David Letterman* featuring Melinda Gates and the documentary *Inside Bill's brain: Decoding Bill Gates*, both

on Netflix. While I did not systematically analyse these documents and resources using qualitative content and thematic analysis (described in the next section), the materials still contributed to "uncover meaning, develop understanding, and discover insights relevant to the research problem" (Merriam, 1988, p. 118).

4.3. Data analysis

I analysed the data, which mostly consisted of field notes, including detailed descriptions of the various meetings and workshops as part of the piloting project and other events described above, as well as electronically transcribed interviews, using qualitative content and thematic analysis. Qualitative content and thematic analysis describes research phenomena by coding the data, identifying patterns, classifying topics and articulating themes and thematic groups with illustrative citations (e.g., Gibbs, 2007; Merriam, 1988; Weber, 1990). Following an inductive, grounded and iterative approach (e.g., Charmaz, 2006; Glaser & Strauss, 1967), codes were manually derived directly from the raw data, and patterns, topics and themes were detected by working back-and-forth between data collection and analysis (e.g., Tashakkori & Teddlie, 2003).

4.4. Research ethics

In this section, I discuss two ethical considerations that have been of particular importance to my research: (i) privacy and informed consent, and (ii) my own situated knowledge and positionality, which include reflections on the ethical implications of my different roles during the research process.

4.4.1. Privacy and informed consent

As the research involved human subjects, and with several conversations touching upon sensitive topics such gendered, sexual and racial harassment, I had to take great care in protecting the privacy of the research participants through anonymity and data confidentiality. This included omitting any potential personal identifiers. Research participants received the information letter and consent form via email some days prior to the interview which contained information about use and storage of personal data, along with other steps taken to preserve anonymity. On the day of the interview, the key points of the consent form were read aloud before the start of the interview and the interviewee was given the chance to address any issues or questions before deciding whether to sign the consent

form and proceed with the interview. An ethical approval of the research was issued by the Norwegian Centre for Research Data (Appendix 7).

4.4.2. My situated knowledge and positionality

Feminist philosophy and epistemology of science have not only informed the way I understand knowledge production more broadly, but indeed my own positionality and practice as a researcher. In this section, I situate my own knowledge production and acknowledge my positionality through self-reflexivity. Self-reflexivity is "a self-conscious revelation of [one's] own relationship to the research – the impetus behind it, the personal values and theoretical allegiances framing it" (Fegan, 1999, p. 242). As Macleod (2002) further notes, rather than simply confessing one's emotional and discursive position, reflexivity more importantly addresses the relational power dynamics that shape the research.

While I have felt first-hand some of the challenges that being born a woman presents, I am nevertheless a young, white, Norwegian, able-bodied, well-educated and economically privileged cis woman. In other words, my historical and present reality differs from many of the research participants and not least the people for whom development-oriented plant breeding hopes to serve, particularly as it relates to questions of race, ethnicity, indigeneity and coloniality. There is thus both an ethics of distance and intimacy at play here, as coined by Ananya Roy (2010) in her study of poverty capital, in the sense that I talk of lives that are distant from my own, while I am simultaneously a part of the (technoscientific-political-economic-social) machinery that creates structures of domination and subordination. So how can I, given my positionality, generate valuable insights from and for lives that are not my own?

To do so, I must "educate myself about people of color, their struggles, and their cultures. I have to study my own ignorance as well (…). I have to study white exploitation, domination, oppression, and privilege" (Harding, 1991, p. 293; also see Collins, 1986; Frye, 1983). While this is a continuous and lifelong practice on which I have just been getting started, this has meant acknowledging my own white privilege, sharing transparent and sincere conversations about colonialism, race and gender with African men and women in and outside of my research and engaging with African feminist and womanist writers and African (feminist) art and film (e.g., *Pumzi* by Kenyan filmmaker Wanuri Kahiu and artwork by the Kenyan-American artist Wangechi Mutu).

Once I started to engage with African feminism, I quickly learned that there is a great deal of contention surrounding the term itself. Many African scholars and activists reject the label as it is considered yet another imperial imposition that does not reflect the realities and struggles of African women in all their complexities (e.g., Aidoo, 1997; Arndt, 2002; Hudson-Weems, 2019; Makaudze, 2016; Nfah-Abbenyi, 1997; Ogundipe-Leslie, 1994). Thus, in addition to the perhaps most widely applied theory of African womanism (Kolawole, 1997; Ogunyemi, 1985; Ogunyemi, 1996), other African alternatives include, among others, stiwanism (Ogundipe-Leslie, 1994) and motherism (Acholonu, 1995). Contrary, scholars such as Amina Mama argue that "changing the terminology doesn't solve the problem of global domination. I choose to stick with the original term, insist that my own reality inform my application of it" (Salo & Mama, 2001, p. 61). Njoki Wane (2011), in turn, are among those who "try to demystify the fallacy of feminism as a Western or borrowed ideology" (p. 17), arguing that "[i]n their struggle to overcome different oppressions, African women were the original feminists who sought to emancipate themselves from the bonds of servitude, inequality, and racial discrimination" (p. 9).

A major realisation that I have gained from reading such and related literature, is how my own understanding of feminism, gender, masculinity, femininity, gender equality and empowerment has been strongly shaped by Western philosophies and norms, feminist or otherwise, and thus can be very different (neither better nor worse necessarily, depending on the context in which they are applied) from African-derived understandings and conceptualisations (e.g., Amadiume, 1987; Ammann & Staudacher, 2021; Goredema, 2010; Kolawole, 1997; Makaudze, 2016; Mfecane, 2018; Nfah-Abbenyi, 1997; Oyěwùmí, 1997; Oyěwùmí, 2002; Steady, 1987; Tamale, 2014; Tavenner & Crane, 2019; Wane, 2011). Indeed, the ways in which gender is theorised as an African concept is highly debated (see, e.g., Lamoureaux & Rottenburg, 2021), and the Nigerian academic Bibi Bakare-Yusuf (2002) argues that "[t]o commit oneself to the assumption of gender is to remain unquestioningly embedded within a specific western intellectual tradition of critique" (p. 3).

Admittedly, however, I started to engage with African feminist and womanist writers, as well as African STS, later in my PhD journey, which is reflected in my articles: while the first and second articles do not engage much with this literature and do indeed apply Western-derived concepts (which I still hope can be of some value), the third article is more highly situated in relation to African scholarships. In the future, I hope to contribute to bringing African feminist and womanist scholarships into closer conversation with plant breeding, including plant genome editing, noting how this conversation needs to be led by my African feminist and womanist peers and colleagues.

Closer readings and engagement with African feminist and womanist scholarships, together with decolonial and postcolonial literature, could have helped bring out other aspects in addition and in relation to gender, including race, ethnicity, indigeneity and coloniality. Decolonial and postcolonial theories and studies have been essential in making visible and challenging the different ways in which coloniality continues to shape postcolonial contexts, including the tendency of Western science and modernity and Western feminism to essentialise marginalised subject positions, including women and people of colour in the Global South (e.g., Anderson, 2002; Asher, 2013; Benjamin, 2009; Bhambra, 2014; Harding, 2009; Lorde, 1984; Lyons et al., 2017; McNeil, 2005; Minh-Ha, 1989; Mohanty, 1988; Pollock & Subramaniam, 2016; Spivak, 1988). Such analyses could help highlight, for instance, how race and coloniality shape and are shaped by crop breeding and plant–people entanglements (Eddens, 2019).

Another important aspect of my situated knowledge and positionality is my background as a natural scientist and my enthusiasm for science and technology in general and for genome editing in particular. This has influenced my philosophical, theoretical and empirical interests, choices and arguments. For instance, my natural sciences background has informed my thinking around the philosophy of science, as well as my appreciation for hybridity, materiality and nonhuman agency (I can thank my interest in biology to Lynn Margulis who developed the endosymbiosis theory of evolution, which centres on sympoiesis). It has also triggered particular conceptual and empirical questions, including questions surrounding the intersection of feminism, gender and genome editing. My natural sciences background has also given rise to a scepticism towards (essentialist) scholarships that perceive technoscience as inherently patriarchal and harmful (as similarly argued by, e.g., van Zoonen, 1992; Wajcman, 2004), which include much ecofeminist thinking (e.g., Sachs, 1992; Shiva & Mies, 1993; Shiva, 2000). This is likely, however, to have caused me to overlook some important insights and critical perspectives. I further acknowledge that my "attribution of (…) transformative power to new technologies reflects a very American fascination with technological progress", as Judy Wajcman (2004, pp. 98-99) reflects on the work of Donna Haraway.

Finally, I would like to comment on my dual role as a researcher and consultant. As previously described, taking on the role as a consultant for CIP allowed me unique insights into what became my main empirical case, meaning the G+ Tools and their piloting. However, it did have ethical implications, most notably in terms of how to maintain analytical integrity while also filling a practical and paid function, and in making sure that my presence as a PhD researcher did not interfere with the piloting process (such as by making the piloting participants uncomfortable). The ethical implications were discussed within the supervisor team and with the department/faculty, upon which it was decided that

the ethical aspects were of a manageable nature. Indeed, while it was at times challenging to navigate how to perform such a role while also critically investigating the work of people whom I developed collegial relationships and even friendships with, it was helpful knowing that the gender and breeding community expressed an appreciation of constructive and critical feedback. Accordingly, my research and consultancy allowed me to, in a sense, give back by establishing a mutually reciprocal working relationship. To borrow a phrase from Laura Foster (2017), we became "colleagues who share knowledge, challenge each other, learn from one another" (pp. 21-22).

5. Summary of articles

In this chapter, I provide a summary of the three articles.

5.1. Article 1. Tools in the making: The co-construction of gender, crops, and crop breeding in African agriculture

Author: Ida Arff Tarjem

The article follows the G+ Tools, a set of gender-responsive crop breeding tools developed by the CGIAR Gender and Breeding Initiative (GBI), through their construction to the aftermath of their piloting. The article is based on ethnographic fieldwork where I depict my encounter with the gender and breeding community, along with observations and interviews made during the piloting of the G+ Tools, which included several African-based CGIAR breeding programmes. I explore the performative roles of the Tools as they emerge in interaction with the piloting teams, paying particular attention to how gender, crops and crop breeding become co-produced in the process. In better understanding this co-constructed relationship, I draw on perspectives from feminist STS, including the concepts of gender scripts, interpretative flexibility and de-scription.

The G+ Tools are described as a decision support tool and can, fundamentally, be considered an ideological and political tool working towards social justice, gender equality, women's empowerment and other developmental outcomes in agriculture. Beyond these intended functions, the findings reveal that the G+ Tools take on additional, interrelated performative roles, subject to interpretative flexibility exercised by the users of the Tools: as a diagnostic and screening tool, as a communication and marketing tool and as a management tool.

As a diagnostic and screening tool, the G+ Tools diagnose what is or needs to be known about men and women farmers and other user groups, including their gendered status, rights and roles, and screen crop traits according to their social impact. Importantly, the G+ Tools help foreground women as essential customers of crop breeding programmes and the importance of taking their knowledges, needs and preferences into account. However, in their reliance on existing data, which are sometimes outdated and unrepresentative, the G+ Tools stand in danger of scripting men and women users, including their relationships with crops, according to binary and heteronormative gender stereotypes. Furthermore, the use of the Tools renders men and women as passive bystanders from which researchers can extract sex-disaggregated preference data. This is at odds with an understanding of gender as contingent, dynamic and constantly negotiated in relation to both human and nonhuman

actors (including plants), and of women and men as active participants and co-producers of knowledge and innovation.

Through standardisation and the use of ordinal values, as well marketing concepts, the G+ Tools also act as a communication device by presenting gender data in ways that adhere to the quantitative values and practices of crop breeders as well as funding agencies. While this can be a strategically important way of making gender more tangible in a highly biophysical and donor-driven organisation such as the CGIAR, the turn to a market logic may result in the perception that the G+ Tools are a type of marketing tool. In their role as a marketing tool, the G+ Tools may script men and in particular women as 'untapped markets' and 'valuable investments'.

Finally, through the G+ Tools, organisational and interdisciplinary power relations and negotiations are attempted managed by strengthening the influence and decision-making power of gender specialists relative to crop breeders. Indeed, the G+ Tools are themselves scripted in ways that shape the agency, behaviours and relations of the users of the Tools. While some of the gender specialists reported that the G+ Tools helped initiate productive conversations with crop breeders, others told of struggles in engaging with crop breeders as well as agricultural economists. Additionally, as a management tool, I suggest that the G+ Tools may end up failing to manage intradisciplinary negotiations. The analysis revealed how the gender research community consists of different schools of thought that diverge in, among others, their perspectives on the nature of gender research, which in some cases result in description and rejection of the G+ Tools.

In conclusion, the article helps demonstrate how the practices and negotiations of gender-responsive crop breeding, as epitomised by the performative roles of the G+ Tools, do not simply describe but co-produce gender, crops and crop breeding. The article is novel in expanding the scope of feminist technoscience studies to the underexplored topic of development-oriented crop breeding in Africa.

5.2. Article 2. "Whose demand?": The co-construction of markets, demand and gender in development-oriented crop breeding

Authors: Ida Arff Tarjem, Ola Tveitereid Westengen, Poul Wisborg, Katharina Glaab

In the article, we unpack the market, demand and gender and their co-production, with the aim of contributing to the understanding of how gender-responsive demand is constructed in development-oriented crop breeding. The article is based on an institutional ethnography that includes qualitative interviews with, and observations of, crop breeders, agricultural economists, gender specialists,

donors and other actors involved in formulating and implementing market-based approaches to gender-responsive crop breeding, along with document analysis of relevant resources. In particular, we engage with actors involved in, and materials produced by, the CGIAR Excellence in Breeding Platform (EiB) and the CGIAR Gender and Breeding Initiative (GBI).

We conceptualise the market as an ongoing, relational performance consisting of intra-acting discourses, practices and human and nonhuman actors. This enables an understanding of how the market, demand and gender take on different shapes, meanings and outcomes in co-constructed ways. In the analysis, we use perspectives from political agronomy to foreground the performative role of human actors, institutional settings and broader narratives and discourses, while insights from feminist science and technology studies (STS) draw materiality and nonhuman actors into the analytical frame.

We find that the market is understood and used as an effective socioeconomic institution for soliciting demand, but also as a normative agenda. When applying the market as a socioeconomic institution, gender tends to become reduced to a variable used to delineate and describe market or customer segments and demand. Including gender as a variable or component represents a politically strategic way of rendering gender research and data more tangible, which can help support gender objectives in and through crop breeding. However, such an integrative component approach may mask the complexity, relationality and institutional and structural dimensions of gender and thus limit our understanding of what constitutes demand. Furthermore, in being one variable among many according to which markets and demands are defined and targeted, and where crop breeders and in particular donors hold much of the decision-making power, gender appears to take a backseat.

As a normative agenda, the market represents a way to transform 'traditional', subsistence-based livelihoods of resource-poor, small-scale farmers in ways that are considered fair, equitable and sustainable. Gender and demand are framed in neoliberal agential terms, with women constructed as competitive, business savvy, entrepreneurial, responsible and efficient, which in many ways casts women and their agency in more empowering ways. However, there is currently little evidence supporting market-based approaches to gender equality and women's empowerment in agriculture. Contrary, intersectional gender norms and power relations often shape access to markets and information, as well as bargaining and buying power, in ways that disadvantage women. Furthermore, defining agency and empowerment in terms of individualism, efficiency and market access may undermine, as above, the relational, collective and structural dimensions of agency and gender and strengthen rather than challenge patriarchal and capitalist interests and values.

Across the continuum from socioeconomic institution to its normative meaning, we found that the market is pivotal in the creation of an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded value. The analysis revealed how humans and nonhumans that do not readily fall within the confines of such a framework may stand in danger of being excluded. We further identify a form of 'trait fetishism', where the crop trait itself becomes the source of value, with some traits rendered less visible. Thus, the market creates insiders and outsider, inclusions and exclusions, which are considerations that should be emphasised as market-based approaches are being developed and promoted.

The article contributes to political agronomy and feminist STS by empirically investigating the underexplored topic of the co-construction of markets, demand and gender in development-oriented crop breeding. Additionally, we expand on the contested agronomy argument of political agronomy by adding a fourth gender agenda, arguing that this allows us to better contextualise and evaluate the new market-based approaches to gender-responsive crop breeding. We further assert that political agronomy can benefit from taking feminist STS analysis of materiality and nonhumans seriously. Given the centrality of gender in food and cropping systems and agricultural knowledge production and technological innovation, we assert that the gender agenda and feminist analysis have broader applications in political agronomy. Accordingly, this article calls for and contributes towards a feminist political agronomy.

5.3. Article 3. Feminist crops: A more-than-human concept for advancing feminist crop breeding for development

Author: Ida Arff Tarjem

Drawing on feminist technoscience studies and critical plant studies, in this article I introduce the concept of the feminist crop which is meant to capture the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. The concept contributes to an investigation of how intersectional gender identities and relations are embedded in plant–people entanglements, which (re)shapes and shifts the thinking and practices of both crop breeders and gender specialists. By bringing together the material and natural on the one hand, and the social and cultural on the other, the feminist crop provides a common ground on which the two disciplines can engage. The feminist crop further advances a decision-making process guided more explicitly by an ethics of mattering and exclusion, which ask scientists and their organisations to take responsibility for what comes to matter and what becomes excluded in plant–people entanglements**.**

The article demonstrates some of the methodological and ethico-onto-epistemological implications of the concept, also as it relates to plant genome editing, using examples from banana, yam and cassava. I argue that plant genome editing informed by the new imaginaries and ethical commitments that the feminist crop engenders, and developed using participatory action research and transformative learning, may represent one way of engaging more profoundly with plantiness, plant agency and planty knowledge to advance feminist crop breeding.

The article contributes to the small but growing field of African feminist STS. The article is also novel in being among the first of its kind to put plant genome editing into conversation with feminist scholarships. Given the centrality of agriculture in the lives of many African women and men, I contend that agricultural knowledge and (bio)technological innovation represent important vantage points from which to study and develop African-derived theories about gender, subjectivity, agency, power, philosophy, ontology, epistemology and ethics, all of which are at the heart of feminist technoscience studies and critical plant studies.

6. Discussion

The overarching research question guiding this thesis is: How can crops and crop breeding be feminist? I subsequently broke the question down into three research questions, each of which are addressed in the three respective articles and broadly categorised according to the interrelated realms of sociomaterial design, the sociomaterial system, the metaphysical and the imaginative (see section 3.1).[16] In the discussion that follows, I summarise and expand on the main empirical findings and theoretical insights of the articles according to the four realms and identify some possible directions for future research along the way. Before I do so, however, it is worth pausing to reflect on the very question itself. As Deborah Johnson (2010) argues when discussing whether technology can be feminist, the question of how crops and crop breeding can be feminist is highly ambiguous and may stand in danger of falling "into the trap of essentialism both about women and about feminism" (p. 36) (and, we might add, technology, in this case crop varieties). Consequently, we need to "continually question the meaning of the question" itself (Johnson, 2010, p. 36).

Indeed, given the plurality of feminisms and, in an African context, African womanism and other African alternatives (see section 4.4.2), along with the whole plethora of intersectional realities and conditions that African women and men experience, what would it mean for crops and crop breeding to be feminist? What kind of feminist or womanist social relations would these have to advance? Would feminist or womanist crop varieties be those that are good for women, favour women, that constitute gender equitable social relations or social relations *more* equitable than the status quo (Johnson, 2010)? Would they have to empower most or all women? "What if", to borrow a phrase from Linda Layne (2010), a crop variety "empowers some women and disempowers others?" (p. 3). How are we to even set criteria for what constitutes a feminist crop variety knowing that gender is negotiated and performed in an entangled and constantly changing dance with humans and nonhumans? How would crop breeding programmes and practices have to change to enable feminist crop breeding? And even if we were to design a seemingly feminist variety, there is no guarantee that women will start using it (perhaps because of gender differences in rights, access, resources and decision-making power) or use it for the purpose intended by the crop breeding team.

[16] This framework, where feminist crop breeding is discussed according to the four realms of sociomaterial design, the sociomaterial system, the metaphysical and the imaginative, could potentially be applied to other technologies in and beyond agriculture, such as livestock breeding (which could further benefit from insights from critical animal studies in place of critical plant studies), irrigation technology, mechanised processing equipment and so forth.

These are but a few of the considerations we need to bear in mind as we delve deeper into the question of how crops and crop breeding can be feminist. For now, suffice it to say that the important thing is that crops and crop breeding stay "in the sight of the feminist social movement and that feminists call for sociotechnical systems that are good for women, gender equitable, sometimes favor women, and are always an improvement over prior gender-inequitable social relations" (Johnson, 2010, p. 52).[17] Johnson (2010) further argues that "it makes good sense in this historical period to think of feminist technologies as those that move in the right direction even if not achieving full gender equity. (…) A plausible account of feminist technology could, then, refer to new artifacts and changes to the built environment that create the possibility for more equitable gender relations, including artifacts that favor women" (p. 49).

6.1. Sociomaterial design: Towards feminist crop varieties

The first research question asks how gender-responsive crop breeding is practiced and negotiated in ways that co-construct gender, crops and crop breeding, which I address in the first article. Through a case study of the G+ Tools, I find that the current practices and negotiations of gender-responsive crop breeding centre on the initial stages of the breeding process, including varietal design, where decision are made about who (i.e., the people) and what (i.e., the crops and crop traits) to breed for. Using the G+ Tools, gender is integrated into this priority-setting and decision-making process by including gender as a variable to understand the challenges, needs and preferences of the customer and the potential social impacts of crop traits. Gender-responsive varietal design should, at the very least, avoid traits with harmful effects on groups of women and, at best, include potentially transformative traits. These priority-setting and decision-making processes, however, entail both inter and intradisciplinary negotiations.

Using the concepts of gender scripts, interpretative flexibility and de-scription, I further demonstrate how gender, crops and crop breeding become co-constructed through the practices and negotiations of gender-responsive crop breeding, i.e., through the many performative roles of the G+ Tools as they emerge in intra-action with the breeding teams: as a diagnostic and screening tool, a communication and marketing tool and a management tool. For the purpose of discussing sociomaterial design, I explain below how the G+ Tools, as a diagnostic and screening tool, construct farmers and other user

[17] Johnson (2010) uses the term sociotechnical system, which she defines as "networks of social arrangements, practices, and relationships *together with* artifacts" (p. 40, italics in original). I prefer using sociomaterial system as material seems to better capture entities beyond those commonly considered technical, such as plants, animals, microbes, inorganic compounds and so forth.

groups in gendered ways; and, as a management tool, I suggest that the G+ Tools may end up failing to manage intradisciplinary negotiations, some of which arise in response to the way the Tools promote gender research (I address interdisciplinary negotiations in the next section). Towards the end of the section, I go beyond the findings of the article to discuss some potential design principles and methods that could help advance feminist sociomaterial design.

As a diagnostic and screening tool, the G+ Tools do not simply help collate and organise sex-disaggregated data to describe and target customer segments, taking gender into account; in intra-action with the breeding teams, they also construct particular types of gendered users, including their gender roles, responsibilities, challenges, needs and preferences, thus creating a form of gender script. Once materialised or 'emplanted' (van der Veen, 2014) in a crop variety, these scripts may come to shape the agency of such users, meaning the farmer, processors, marketers, traders and consumers, albeit subject to interpretative flexibility and de-scription.[18] Thus, the concept of gender scripts allows us to better understand how crop varieties become political, value laden and gendered, including how crops may enact particular social statuses, rights and labour relations.

Importantly, the G+ Tools draw attention to women's multiple roles and knowledges, portraying them as essential customers of breeding programmes, and the need to include gender and gender-related traits in breeding objectives and product profiles (Polar et al., 2022). Encouragingly, findings following the piloting project demonstrate that the use of the G+ Tools resulted in adjustments to trait prioritisation and customer and product profiles in some of the breeding programmes (Polar et al., 2022). However, reflecting broader methodological challenges of gender-responsive crop breeding (e.g., Ashby & Polar, 2019; Polar et al., 2021; Voss et al., 2021; Weltzien et al., 2019; but do see Teeken et al., 2021b), by relying on existing data that were at times outdated and unrepresentative, the G+ Tools may script men and women users, including their relationships with crops, according to binary and heteronormative gender stereotypes.

Rommes (2014) argues that there may be some benefits of designing from stereotypes, as it may "strengthen and give value to skills and preferences considered feminine (Cassell & Jenkins, 1998), and it is a way of creating a wider diversity of (gender specific) products with different target audiences" (pp. 47-48). However, this type of design may also "run the risk of reinforcing and re inscribing perceived gender differences rather than challenging gender inequalities through efforts at

[18] Marijke van der Veen (2014) uses the concept of 'emplantment' (in contrast to embodiment) when referring to the marks left in the physical makeup of a plant due to interactions between humans and plants, most notably through agricultural practices and plant breeding.

transforming gender as a normative (social) construction" (Rommes, 2014, p. 48). Johnson (2010), in turn, argues that technology that addresses women or women's needs does not constitute a feminist but rather a feminine technology.

For instance, by constructing women as users who prefer culinary and cooking traits, one might end up addressing women's practical as opposed to strategic needs, as well as sending a signal that cooking should remain a responsibility of women. Practical needs are associated with traditional gender roles and immediate perceived necessity, while strategic needs are related to the position of women in relation to men, such as with respect to decision-making power and control over inputs and outputs, which thus can help challenge existing gender roles and relations (Moser, 1989; also see Orr et al., 2021). Accordingly, feminist varietal design should not (necessarily or only) be equated with breeding for 'women's traits' or 'women's crops', particularly as such language may reinforce heteronormative and essentialising assumptions that can have real sociomaterial implications, for instance by restricting access to and control over more lucrative income-generating opportunities for women (Polar et al., 2021).

The G+ Tools also represent and perform a particular way of doing gender research, where gender is integrated as a variable or component in biophysical research and innovation. In contrast to such an integrated or gender accommodating approach, a gender strategic approach aims to understand gender norms, agency, identities and relations in agrarian communities and their implications for agricultural innovation and sustainability (e.g., Badstue et al., 2018). A systemic approach, in turn, seeks to address and challenge engrained gender structures and is central to gender transformative approaches which are increasingly promoted in the CGIAR and beyond (e.g., CGIAR, n.d.-b; CGIAR Research Program on Aquatic Agricultural Systems, 2012; Escobar et al., 2017; FAO et al., 2020; Kantor et al., 2015; van der Burg, 2019; Wong et al., 2019).

Through an integrated or accommodating approach, gender research may be seen as having tangible benefits to biophysical researchers. Indeed, a material and technical integration of gender, such as through the use of the G+ Tools, may render principles and practices of gender-responsive crop breeding more 'durable' (Latour, 1990). However, by reducing gender to one or a few variables, such an approach also stands in danger of turning gender into a box ticking exercise (with gender potentially swamped by other variables, as addressed in the next section), which Ewell (2021) also observed. In such an exercise, gender may be reduced to knowledge extracted from passive research participants

about sex-disaggregated preferences and (market) demands.[19] Thus, van der Burg (2019) argues that gender accommodating approaches may "risk reinforcing gender inequalities" (p. 51).

Scientists and activists who apply a strategic or systemic approach, however, may stand in danger of being labelled irrelevant to biophysical and technological practices. Thus, they "risk encountering much resistance and consequently to be frustrated, marginalized or even stopped" (van der Burg, 2019, p. 51; also see Tegbaru et al., 2015). Accordingly, an integrative approach may be more politically tactical and strategic. Indeed, to borrow a phrase from Eva Giraud (2019), gender specialists and feminist scholars and activists have "to work tactically within and against the assemblages they are opposing, and have to constantly negotiate the constraints imposed by the existing material-semiotics arrangements, even as they experiment with alternative ways of doing things" (p. 77).[20] However, the different approaches to gender research are not mutually exclusive but rather complementary: we need both smaller-scale feminist action and change, such as at the level of feminist sociomaterial (varietal) design, and larger-scale feminist action and change, such as at the level of feminist sociomaterial systems, as addressed in the next section (and, sometimes, small changes may yield big impacts, while big changes may yield small impacts).

However, when addressing the management role of the G+ Tools in the first article, I show how gender scientists may diverge in their perspectives on gender research, which in some cases result in resistance and de-scription of the G+ Tools. Differences in perspectives could possibly reflect different feminist groundings and convictions, which may give rise to contention about the feminist potential of the G+ Tools. In expanding the varietal choices that women farmers have, some might argue that the G+ Tools represent a liberal feminist technology or even a marketing tool, as addressed in the first and second articles. Others might argue that it is a radical feminist technology as it attempts to challenge organisational power relations by strengthening the voice and influence of (women) gender specialists. A socialist feminist may appreciate the Tools' emphasis on women's paid and unpaid labour and drudgery; while an African feminist or womanist might argue that the G+ Tools need to pay closer attention to African women's and men's unique conditions and relations by reflecting gender in its

[19] Importantly, trait preferences do not always reflect meaningful choices and may in several cases represent "a self-subordinating adaptation to a restricted choice, to accommodate (…) inferior access to labor, capital, farm equipment, seed, fertilizers, pest control products and market access" (Polar et al., 2021, p. 4). Moreover, expressed preferences may not fully reflect or predict adoption and buying behaviour (Cairns et al., 2021).

[20] 'Material-semiotic' refers to entities that are "simultaneously semiotic (because they are relational, and/or they carry meanings) and material (because they are about the physical stuff caught up and shaped in those relations.)" (Law, 2019, p. 1). The concept of 'assemblage' is used with meanings that are roughly similar to idioms such as actor-networks, ensembles, entanglements, hybrid networks and so forth (for a comparison between actor-networks and assemblage theory, see, e.g., Müller, 2015; Müller & Schurr, 2016).

intersections with race, ethnicity, indigeneity, coloniality, polygamy, humanitarian interventions, religious fundamentalism and so forth (e.g., Arndt, 2000; Ogunyemi, 1997). Finally, some may argue that the G+ Tools are not feminist at all and that they (and perhaps gender-responsive breeding more broadly) essentialise the needs of farmers and other user groups along gender lines.

In other words, the G+ Tools help reveal differences and contentions within gender research and feminism. This is not a bad thing, however. As Aengst and Layne (2010) argue: "It is by struggling to take into account these differences, that we can make headway in defining, recognizing, calling for, and creating feminist technologies" (p. 78). Similarly, Bronet and Layne (2010) assert that "generating more, sustained, multivoiced debate about feminist or antifeminist attributes of existing or emerging technologies will be of great benefit to the goals of improving women's lives" (p. 179). Layne (2010) further suggests that technologies can be placed on a continuum of feminist achievement, which includes minimally, moderately and radically or truly feminist technologies. Could such a ranking system be used in crop breeding programmes? If so, perhaps a variety that serves women's practical needs would constitute a minimally feminist variety; one that addresses women's strategic needs comprises a moderately feminist variety; while a crop variety containing a transformative trait(s), and introduced alongside systemic measures that challenge gender norms and relations, would be ranked a radical feminist technology?

For the remainder of this section, I reflect on some possible design principles and practices developed by feminist scholars of technoscience that could help advance feminist sociomaterial (varietal) design. I note, however, that the studies I draw on address computer science and software engineering in the Global North. Needless to say, these are very different contexts from development-oriented crop breeding in African countries. Thus, while I believe constructive conversations can be had across such topics and contexts, which I hope can be explored in future research, I approach these dialogues with a sense of caution and an understanding that such approaches may not be readily transposable to other geopolitical, socioeconomic and cultural contexts.

Corinna Bath (2014) argues that "[a] deeper understanding of the mechanisms that are at work when technological artefacts are gendered (…) is a crucial prerequisite for making suggestions for an alternative design that may be called feminist" (p. 58). Thus, further research is needed to gain an improved understanding of the mechanisms through which crop varieties become gendered, including empirical investigations of the processes of defining breeding objectives and priorities, designing product profiles and decision-making during product advancement meetings, in the lab and in the

field.[21] Such explorations may benefit from paying analytical attention to the values of crop breeders and crop breeding teams.[22] But how are we to expose and challenge the values as well as the norms and biases of crop breeding, ranging from the primacy afforded to optimalisation, efficiency and productivity at the organisational and disciplinary level, to the values and beliefs of individual researchers related to questions of gender, race, ethnicity, age and other social factors?

To expose black boxed values and biases and create space for unlearning and relearning to promote more socially constructive values, I find 'mind scripting' intriguing (Allhutter, 2011; also see Allhutter & Hanappi-Egger, 2005; Allhutter & Hofmann, 2010). Drawing on concepts such as situated knowledges and gender scripts, mind scripting is a deconstructive design technique that helps analyse "processes of the co-materialization of gender and technology and [works] as a tool to support cooperative, reflective work practices" (Allhutter, 2011, p. 684). The method unveils unconscious sense and meaning-making and enables the deconstruction and negotiation of value systems, assumptions and established ways of doing that shape design and development practices and processes, not only with respect to gender but also other social factors such as race and sexuality. Ideally, this should initiate a "learning process within development teams that enhances their knowledge on the entanglement of societal hegemonies and sociotechnological processes" (Allhutter, 2011, p. 686). Thus, could mind scripting be used not only as a method to research crop breeding values, but also become a core design principle, ultimately resulting in crop varieties that embody "cultural critique in that [they are] designed by deconstructing [their] inscribing normativity" (Allhutter, 2011, p. 686)?[23]

Encouragingly, findings by Els Rommes (Rommes et al., 2011; 2014) and others (e.g., Jenkins & Cassell, 2008) suggest that designers and technologists who hold feminist values are more likely to "consciously [choose] to design more gender inclusive or even transgressive products" (Rommes, 2014, p. 52). However, as pointed out by Sørensen (1992), "we cannot assume that values are applied explicitly and rationally as criteria in a well ordered situation of technological choice" (p. 14), even when (feminist) values "make their way into design criteria" (p. 14). For instance, similar to what

[21] During the annual product advancement meeting, the breeding programme assesses its performance, sets goals for the coming year and makes population improvement and development decisions (Excellence in Breeding Platform, 2019).

[22] Roccas et al. (2017) define value as "**abstract, desirable** goals. Their importance is **stable over time and across situations.** Values **vary in their importance**; the more important a value is to a person, the more likely she is to act in ways that promote the attainment of that value (Kluckholm, 1951; Rokeach, 1973; Schwartz, 1992). Values are cognitive representations of basic motivations and **are structured according to their compatibilities and conflicts** (Schwartz, 1992)" (p. 16, bold in original).

[23] It may also be worth drawing inspiration from other critical design perspectives that place race, ableness, sustainability, morality and/or justice at the centre of design (e.g., Costanza-Chock, 2020; Deena & Meredith, 2017; Friedman & Hendry, 2019; Pullin, 2009).

Wendy Faulkner (2000) observed in engineering cultures, breeding teams are likely to experience normative pressures to conform that arise from inside and outside of the breeding organisation – from the sociomaterial system – and which may shape and possibly restrict socially constructive and feminist thinking and design.

Thus, what is also needed are feminist sociomaterial systems. To paraphrase Johnson (2010), while the material features of crop varieties are a necessary condition – indeed, they can facilitate or constrain equitable gender relations, including meaningful choices (Polar et al., 2021) – they are not a sufficient condition for feminist change. "Regardless of the intent," Layne (2010) asserts, "new technologies introduced into unjust social systems are apt to end up reinforcing the status quo" (pp. 21-22). Consequently, we have to pry open the very black box of crop breeding programmes and initiatives and their partnering organisations (including the GBI, which some of the interlocutors argued had become inward-looking) to make visible and interrogate existing structures, norms and power relations that shape the sociomaterial system in which gender-responsive crop breeding operates, as addressed next.

6.2. The sociomaterial system: Towards a feminist crop breeding system

With the second research question, I ask what drives and shapes the co-construction of gender, crops and crop breeding, and with what effects. Together with Ola Westengen, Poul Wisborg and Katharina Glaab, I explore this question in the second article by situating the new tools and practices of gender-responsive crop breeding within the larger market-led turn currently dominating within and beyond the CGIAR. As also observed in the first article, gender-responsive and market-based approaches to crop breeding are becoming increasingly conflated. This is evident in the ways in which the G+ Tools draw on marketing frameworks and concepts, such as the Segmenting-Targeting-Positioning approach (Orr et al., 2018). In turn, principles and tools of gender-responsive crop breeding are themselves being incorporated into market-based approaches, as apparent from the integration of the G+ Tools into the EiB product profile development framework. In analysing this conflated relationship, we develop and use a feminist political agronomy lens which combines perspectives from political agronomy and feminist STS.

Political agronomy and its contested agronomy argument, along with the key concept of knowledge politics, helps foreground the performative role of human actors, institutional settings and broader narratives and discourses. The analysis reveals the ways in which the co-construction of gender, crops

and crop breeding is shaped and driven by the interrelation between the neoliberal project, the participation agenda and what we refer to as the gender agenda. We further demonstrate how the co-production of gender, crops and crop breeding is shaped by organisational and interdisciplinary power dynamics that situate crop breeders and in particular donors in powerful positions relative to gender specialists. Accordingly, these findings expand on observations made in the first article on the relationship between gender specialists, crop breeders and donors. In turn, feminist STS help broaden the analytical frame to materiality and nonhumans, considering the performative role of crops and the G+ Tools and other research and marketing concepts and devices (e.g., the 1000Minds software) in driving and shaping the co-construction of gender, crops and crop breeding.

To further investigate the effects of the factors that drive and shape the co-construction of gender, crops and crop breeding, we set out to unpack the market, demand and gender and their co-production. By conceiving of the market as a relational performance consisting of intra-acting discourses, practices and human and nonhuman actors, we document how the market is constructed and used as a socioeconomic institution for soliciting demand, but also as a normative agenda. Next, I consider some of the gendered implications of the differential meanings of the market and pay particular attention to the agenda-setting and decision-making role of crop breeders and donors. I further consider what these findings may tell us about the sociomaterial system in which gender-responsive crop breeding operates and the challenges and opportunities it holds for developing a feminist sociomaterial system.

When the market is applied as a socioeconomic institution, gender tends to become reduced to a variable used to delineate and describe market or customer segments and demand. As touched upon, this represents a politically strategic way of rendering gender tangible, which can help advance gender objectives in and through crop breeding. However, in being one variable among many according to which markets and demands are defined and targeted, and where crop breeders hold much of decision-making power, gender may risk being swamped by agroecological, agronomic and biophysical factors (e.g., Cobb et al., 2019). This is not meant to imply that crop breeders are not aware of or sympathetic to the needs and preferences of women. As pointed out in the first article, many of the crop breeders interviewed during the research expressed a great deal of concern about gender issues in agriculture, but commonly felt that biophysical, technical, budgetary, regulatory and political constraints – in other words, components of the sociomaterial system – limited the extent to which they could breed for certain traits that tend to be more important to women, such as quality traits which are often controlled by multiple genes and interactions with the environment.

In the second article, we also demonstrate the substantial agenda-setting and decision-making power that private sector donors or philanthrocapitalists hold. For instance, the Gates Foundation commissioned the assessment of CGIAR breeding programmes in 2016, which identified the need for market-informed product profiles premised on the value chain approach (see Chapter 1). Additionally, the Gates Foundation's role in driving the gender agenda is well known and was voiced by most interlocutors (e.g., Farhall & Rickards, 2021; Gates, 2014; Gates, 2019). The Syngenta Foundation, in turn, has been pivotal in the development of market-based approaches to crop breeding (e.g., Persley & Anthony, 2017). These findings indicate that donors such as the Gates Foundation are likely to have a big say in how market segments and demand are defined and targeted, around which product profiles and crop varieties will be designed. Donors may or may not favour market segments that include gender objectives, depending on whether these are perceived to have the highest achievable impact and how impact is measured and valued.

We also show the role that donors play in shaping the normative meaning and use of the market. For instance, the normative meaning of the market taps into the efficiency argument for gender equality (Berik, 2017; Chant & Sweetman, 2012; Roberts & Soederberg, 2012; World Bank, 2012), which is strongly articulated by organisations such as the Gates Foundation (e.g., Bill and Melinda Gates Foundation, 2012; Farhall & Rickards, 2021; Fejerskov, 2017). Notably, what convinced Bill Gates to include gender in the work of the Foundation was casting gender equality as a means of increasing efficiency and impact (Gates, 2019). The efficiency argument portrays women as competitive, entrepreneurial, responsible and efficient (e.g., Lyon et al., 2019; Prügl & Joshi, 2021), but prevented from reaching their full, 'untapped' potential due to gender inequalities in, for instance, access to productive resources and markets (e.g., FAO, 2011; World Bank, 2012). Thus, the efficiency argument holds that reducing gender inequality and investing in women, such as by integrating women more tightly into markets, result in more effective economic performance and improved development outcomes, including gender equality and women's empowerment.

However, the conceptual and empirical basis for women-focused and market-based agricultural development remains relatively poor (Anderson et al., 2021; Doss, 2017; Doss, 2018; Gengenbach et al., 2018; O'Laughlin, 2007). Contrary, several studies have shown that the commercialisation of crops (in particular food and subsistence crops) can enhance men's control over crops and decision-making at the cost of female disenfranchisement and drudgery (Carney & Watts, 1990; Carney & Watts, 1991; Dolan, 2001; Dzanku et al., 2021; Fischer & Qaim, 2012; Njuki et al., 2011; Sørensen, 1996; Tavenner et al., 2019). Moreover, many feminist scholars are critical of the efficiency argument, contending that its individualistic and neoliberal notion of agency offsets feminist goals of structural change and

strengthens rather than challenges patriarchal and capitalist ideologies, interests and values (e.g., Chant & Sweetman, 2012; Cornwall & Rivas, 2015; Esquivel, 2017; Lewis, 2001; Roberts & Soederberg, 2012; Wilson, K., 2015).

Thus, many questions remain about the kinds of beings and ways of being, including the types of feminist political agency, that are allowed to flourish amid increasing forms of neoliberal inclusion. Thus, in the second article, we pick up on a question posed in the first article, where I ask what will happen to people, crops and crop traits that are not considered 'valuable', 'marketable' or 'investable' enough? We find that, across the continuum from socioeconomic institution to normative agenda, the market is pivotal in the creation of an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded value. The analysis reveals how humans and nonhumans that do not readily fall within the confines of such a framework may stand in danger of being excluded; as belonging to a 'deficient' or even 'dead' nonmarket. We further identify what we refer to as 'trait fetishism' (building on Donna Haraway's (1997) concept of 'gene fetishism'), where the trait itself becomes the source of value, with some traits being rendered less visible or invisible altogether. Consequently, markets are boundary and world-making, bringing some human and nonhuman actors into being at the expense of others. Thus, it matters what markets are made.

What becomes apparent, then, is that the sociomaterial system in which gender-responsive crop breeding operates, and the knowledge politics that characterises the system, holds both challenges and opportunities for advancing feminist social relations. However, a limitation of the research was its focus on a select few human and nonhuman actors, thus providing only a limited perspective of the sociomaterial system. Indeed, a more general challenge when dealing with sociotechnical or sociomaterial systems is knowing how to delineate them. As noted by Johnson (2010): "what is inside or what is outside a particular system (…) seems to be entirely a matter of how the researcher or viewer chooses to draw the lines. (…) How a sociotechnical system is delimited may, thus, skew what can be said about its gender relations and whether the system is feminist" (p. 50).

Consequently, future research should turn its analytical gaze to other human and nonhuman actors to get a more complete understanding of the sociomaterial system of gender-responsive crop breeding, including leadership and management of crop breeding organisations, national governments, varietal release committees, industry and commercial partners (e.g., seed companies) (see for instance Tegbaru et al., 2020; Voss et al., 2021), non-governmental organisations and the men and women farmers and other user groups themselves. Important nonhuman actors include policies and regulatory documents, seed supply channels, seed marketing and promotion materials, agricultural technologies,

crop varieties, livestock, poultry and other entities of the agroecological landscape. By using a feminist political agronomy lens, such research can help highlight how gender and ideas about equality and women's empowerment become constructed, performed and negotiated by, and in relations between, such human and nonhuman actors.

However, one thing is identifying the barriers to promoting a feminist sociomaterial system, another is to suggest ways to overcome such barriers. While it is beyond the scope of this thesis to provide a detailed overview of measures meant to help challenge and transform formal and informal gender structures, ideologies, norms and biases as they occur across the entire value chain (including on the farms themselves), I would like to note some measures at engendering agricultural research in and beyond the CGIAR (also see, e.g., Cole et al., 2015; Farnworth et al., 2013; Meinzen-Dick et al., 2010; Njenga et al., 2011; Njuki, 2016).

Spurred by donor requirements (Polar et al., 2022), gender was formally mainstreamed in the CGIAR in 2012, which became reflected in planning, budgeting, staffing, implementation, monitoring, evaluation and accountability mechanisms of the CRPs (CGIAR Consortium Board, 2011). However, results from various independent assessments reveal that such mainstreaming efforts have, in many cases, fallen short of their objectives (CGIAR-IEA, 2017; Karlsson & Russell, 2017; MOPAN, 2020). Despite the potential of supporting feminist goals (Moser & Moser, 2005), gender mainstreaming more broadly has been criticised for bureaucratising gender in such a way that it absolves "organizations from doing anything substantive about gender discrimination that arises out of inequalities in power relations" (Arora-Jonsson & Leder, 2021, p. 15; also see Arora-Jonsson, 2014).

Thus, many questions remain about how best to support structural, institutional, organisational and behavioural changes. However, I would like to draw attention to efforts by the Gender-Responsive Researchers Equipped for Agricultural Transformation (GREAT) project, which is a collaboration between Makerere University in Uganda and Cornell University in the United States (Mangheni et al., 2021; Travis et al., 2021; Tufan et al., 2021). The project has pioneered a training model that rests on four pillars – self-reflection, interdisciplinarity, applied learning and an enabling environment and learning community – and "that seeks to challenge the status quo of crop improvement research, questioning norms and focusing on attitudinal shifts and practice change" (Tufan et al., 2021, p. 1). It enables "social scientists and biophysical scientists (…) to learn through practice while gaining research capacity in gender-responsive agricultural research" (Tufan et al., 2021, p. 1). The GREAT project also shares close ties with the GBI, as described by Polar et al. (2022): "Starting in 2018, GREAT training

involved key individuals from the GBI organizing committees and introduced principles of gender-responsive crop improvement developed by the GBI" (p. 487).

Additionally, African Women in Agricultural Research and Development (AWARD) has played an important role in developing gender research capacity and institutionalising gender-responsive change in agricultural research and development (AWARD, 2021). Notably, several of the participants I interviewed had completed or was in the process of completing GREAT and/or AWARD training. Beyond these practical efforts, however, a feminist metaphysics and a feminist imaginary might also contribute positively to both feminist sociomaterial design and a feminist sociomaterial system, as addressed in the next two sections.

6.3. The metaphysical: Towards a feminist ethico-onto-epistemology

With the third and final research question, I ask how feminist crop breeding can be advanced through conversations between feminist technoscience studies, critical plant studies and molecular breeding. A key argument of this thesis is that, to advance feminist crop breeding, we also need to go beyond the realms of sociomaterial design and the sociomaterial system: if we are to imagine and practice feminist social relations in and through crop breeding, we need new concepts and frameworks that grapple with the very fundamentals of crop breeding, namely its ontology, epistemology and ethics; or, in the words of Karen Barad (2007), its ethico-onto-epistemology. One such radical new conceptualisation is the feminist crop, which I develop and present in the third article based on insights from feminist STS and critical plants studies.[24, 25]

In the article, I argue that gender-responsive and transformative crop breeding implicates transgressing the nature/culture and social/material dualisms, both of which are highly institutionalised in crop breeding. These dualisms collapse in the feminist crop which, building on the concepts of natureculture and sociomateriality, is meant to capture the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. The concept contributes to an ethico-onto-epistemological and methodological investigation of how intersectional gender identities

[24] In hindsight, it may have been more appropriate to call it *a* as opposed to *the* feminist crop, in acknowledging that there is not just one but indeed several types of feminist crops. As noted in the third article, the concept is meant to be adaptable to multiple understanding of feminism and womanism.

[25] In contrast to Gibson and Gagliano's (2017) term 'the feminist plant', which they use to describe the feminist nature of the water lily, the feminist crop is meant to capture the gender relations and feminist politics of plant–people entanglement.

and power relations are embedded not only in human systems, but also in plant–people entanglements, which I demonstrate in the third article using examples from banana, yam and cassava. Notably, the feminist crop asks us to take plantiness, plant agency and planty knowledge seriously, whether in the lab or in the field, which "force[s] us to rethink some of the fundamental tools we use to understand political subjectivity: power, agency, action, the individual, even the time scales of which change can occur" (Rezvani, 2021, p. 15). Moreover, making plant–people entanglements the central analytical focus of both crop breeders and gender specialists helps carve out new ways of thinking of and doing crop breeding in multi, inter and transdisciplinary ways. Ultimately, then, the feminist crop contributes to advancing feminist crop breeding.

Over the next few paragraphs, I would like to expand on some of the epistemological, methodological and ethical discussions that the feminist crop engenders, starting with how we can bring plants and plant–people entanglements into the analytical frame through more-than-human and multispecies ethnography (e.g., Archambault, 2016; Bastian et al., 2017; Kohn, 2013; Nathen, 2018). Indeed, as Laura Foster (2019) notes, we can "develop ways of learning with and from plants as witnesses to human suffering, producers of memory, preservers of flesh, guides for learning, healers of caring, wise knowers, and builders of more than-human worlds" (p. 2).

Natasha Myers (2017) calls for a 'planthropology' that "document[s] the affective ecologies taking shape between plants and people" (p. 300); a call to which Tihana Nathen (2018) responds by developing the methodology of 'herb-I-graphy', which builds on Rastafari cosmologies that "emphasise plants and humans as subjects within and of research" (Nathen, 2018, p. 116). Similar to Nathen (2018), several other scholars advocate the need to engage with plants through plant experts (e.g., Ellis, 2018; Gibson, 2018; Gibson & Ellis, 2018; Hitchings, 2003; Hitchings & Jones, 2004; Pitt, 2015). For instance, Gibson (2018) uses several different methods, including sensorial ones (e.g., smell, taste, texture and colour), to "reflect on (…) and dwell with" (p. 93) plants together with plant practitioners in South Africa (also see Gibson & Ellis, 2018). Gibson (2018) notes: "By showing, watching, strolling among, discussing, doing, picturing and being guided by plants, we can come to appreciate their agency. By engaging in the practices of people who worked with plants, we could gain insight into the multiple 'matterings' that emerged in and through such plant practices" (p. 96).

Gender specialists, then, could explore plant–people entanglements and the understandings of identity, agency, power and (dis)empowerment they provoke by engaging in and with the plant practices and planty knowledge of different intersectional groups of women and men farmers and other user groups, as well that of biophysical researchers. As I argue in the third article, this would also

require asking new types of questions that capture both sides of the co-constructed, naturecultural and sociomaterial equation, such as what plants themselves (not only people) can tell us about, for instance, why and how gender-differentiated trait preferences arise. The information generated from such investigations could, in turn, inform the practices of crop breeders, allowing them a heightened appreciation of how breeding decision-making imply choices about who and what gets entangled, in what ways and with what effects. This could help translate an abstract concept such as the feminist crop into specific design criteria and decisions.

The questions of who and what gets entangled, in what ways and with what effects are fundamentally a question of values, ethics and justice. Having previously addressed values, I here consider how the feminist crop situates ethics and, albeit less explicitly, justice at the heart of crop breeding. More specifically, it promotes a decision-making process guided by an ethics of mattering and an ethics of exclusion, inspired by Karen Barad (2007) and Eva Giraud (2019), respectively. An ethics of mattering asks us to take "responsibility and accountability for the lively relationalities of becoming of which we are a part" (Barad, 2007, p. 393). As summarised by Katherine Hayles (2015): "[f]or Barad, ethics is located in the individual actions of scientists. [They discuss] how ethics basically enters at every step of the way: how experiments are organized, how scientific discourses are constructed, etc. The point [they make] is that content is never separated from the practice of science, and vice versa" (p. 28). In other words, what scientists (myself included) think, say and do matters, literally and figuratively, which has ethical and political implications. The choice of which market or customer segments and crops and crops traits to breed for, for instance, implies a choice of which plant–people entanglements are brought into being. Thus, in developing and using the concept of the feminist crop, different – and I would argue more socially constructive – plant–people entanglements may come to matter.

The question of what comes to matter – which markets, which crops, which traits, which people, whose demand and so forth – is intimately connected with the question of what becomes excluded, which is a theme that runs, more or less explicitly, through all three articles. For instance, exclusions and exclusionary practices are central in the second article which considers markets as boundary and world-making phenomena, which may exclude some beings (human and nonhuman) and ways of being (such as those that do not necessarily abide to neoliberal values and assumptions). While Barad address exclusion in their work, I find it useful to complement Barad with Eva Giraud's (2019) ethics of exclusion. Giraud (2019), who herself draws on Barad, argues that exclusions are "frequently treated as *secondary* to relations. (…) In theoretical work that insists on the relation as the smallest unit of analysis, the ethical emphasis remains on the potential inherent in encounters, relations, and comings-together rather than on the boundary-making practices that instantiate them" (pp. 172-173, italics in

original). Thus, Giraud (2019) argues for an ethics based on exclusion, "which pays attention to the entities, practices, and ways of being that are *foreclosed* when other entangled realities are materialized. (…) Centralizing and politicizing these exclusions (…) [are] vital in carving out space for intervention" (pp. 2-3, italics in original).

Giraud (2019) further notes how every political, epistemological and ethical approach carries its own omissions and exclusions. However, exclusions are not inherently negative and can in fact be productive and creative: "it is sometimes necessary to contest certain relations in order to clear space for alternatives (indeed, this is often central to feminist and antiracist struggle)" (Giraud, 2019, p. 4). Certainly, the feminist crop comes with its own set of omissions, such as the exclusion of crop traits that are harmful to women and discriminatory organisational norms and practices. The use of the concept is likely to enact less beneficial omissions as well, as it may serve to benefit some people in some places at some times at the expense of others. "What is vital", Giraud (2019) notes, "is ensuring that any form of exclusion happens in a way that is responsive and open to contestation" (p. 68).

I further argue that an ethics of mattering and an ethics of exclusion necessitate a research practice that centres on the concept of situated knowledges and that promotes epistemic justice. Visvanathan (2005) developed the concept of epistemic justice to describe the processes through which systems of knowledge that have been overshadowed by scientism and (molecular) colonialism are recovered. Epistemic justice can be of particular importance with respect to molecular breeding, as the more laboratory-oriented and technically advanced, and thus less accessible, knowledge underlying this form of crop breeding may increase the 'distance' between scientists and lay people (or, rather, lay experts) (e.g., Fitting, 2010; Kinchy, 2012).

Epistemic justice can be facilitated through, for instance, transformative learning and participatory action research (e.g., Anderson et al., 2017; Callon et al., 2009; Mezirow & Associates, 2000; Song & Vernooy, 2010; Wakeford & Sanchez, 2018; Weasel, 2011). Mezirow (1997) defines transformative learning as "the process of effecting change in a frame of reference" (p. 5), with the frame of reference referring to habits of mind and point of view. Gender transformative learning has been applied in agricultural research and development (Duveskog et al., 2011; Percy, 2005; Song & Vernooy, 2010), often with the aim of enabling "rural people to analyze and reflect on their livelihoods in a way that could be said to be empowering or transforming" (Percy, 2005, p. 127). However, we can also imagine transformative learning to be reciprocal, meaning that rural people and researchers learn from one another in transformative ways.

Such a collaborative process is key in participatory action research, where rural people and researchers are both active participants in the design of research projects and development interventions (e.g., Song & Vernooy, 2010). Thus, transformative learning and participatory action research can help establish a productive dialogue between crop breeding teams and women and men farmers and other user groups, in which they together learn about women's and men's views and ways of knowing and doing, and together design crop breeding projects. In the third article, I argue that such methodological principles can help institutionalise local and Indigenous knowledges and women as knowing subjects and technological agents in crop breeding, including plant genome editing.

I end this section by pointing out two short-comings and/or paradoxes of this thesis. The first concerns the broader question of justice, given its centrality to gender equality. Beyond a consideration of epistemic justice, I chose to focus on ethics rather than justice. This owes to my research interest in the "rational and methodological application of values or principles for creating rules of conduct and oral courses of action" (Mamo & Fishman, 2013, p. 161) in crop breeding as opposed to the public matter of "common human interests, equitable distribution of social goods, resources, and opportunities, and commitment to fostering empowered political participation" (Mamo & Fishman, 2013, p. 161). In other words, I see ethics as being tied more strongly to the practices of crop breeding. Thus, while justice guides this thesis in the sense that it is a "project appealing to universal principles of fairness and equity" (Mamo & Fishman, 2013, p. 160), I am more interested in how different understandings of ethics might get us there. Future research, however, may want to explore "'justice' as a concept, an object of study, and a goal" (Mamo & Fishman, 2013, p. 160) in crop breeding, which may further add to the 'justice gap' within the wider STS literature (Mamo & Fishman, 2013).

The second short-coming/paradox concerns the ethical project of the thesis compared to that of other more-than-human scholarships. The ethical objective of the latter is commonly to contest human exceptionalism and anthropocentrism in order to forge more responsible and sustainable ways of living together with nonhumans on a shared planet (e.g., Ginn, 2014; Hall, 2011; Haraway, 2016; Hitchings & Jones, 2004; Jones & Cloke, 2002; Krzywoszynska, 2019; Myers, 2017; Tschakert, 2020). In a sense, then, I may be seen as appropriating more-than-human perspectives, including concepts of plant agency, planty knowledge and the plants themselves for the benefit of humans (i.e., to get an improved understanding of gender power relations in agriculture and to advance gender equality and women's

empowerment) and therefore re-centring the human. Indeed, the very concept itself – the feminist crop – may be accused of anthropomorphism (see, e.g., Gibson & Gagliano, 2017).[26]

However, the feminist crop is an acknowledgement of the agential (and even feminist) capacities and selfhood of plants, as recognised in Indigenous cosmologies and knowledge systems for centuries. Furthermore, while I am more concerned about human as opposed to plant rights, the feminist crop is meant to promote the need to bring both neglected humans and plants – neglected plant–people entanglements – into the fold of (feminist) crop breeding. If I were to develop the social and environmental justice aspect of this research, however, I would have taken into account the critiques of rights-based and social justice-based approaches developed by posthuman scholars (e.g., Giraud, 2019; Wolfe, 2009; Zembylas & Bozalek, 2014). Some of these critiques centre on how rights-based approaches entail "a predetermined notion of what convivial relationships between humans and nonhumans might look like" (Giraud, 2019, pp. 72-73).

Still, there are surely those who would argue, and at times rightfully so, that it may not be in the best interest of the plants nor for some groups of women and men in agriculture to become integrated in crop breeding programmes. Indeed, in this thesis, I do not question crop breeding in and of itself. While there is a need to critically examine the practices and organisations of plant breeding, I am of the belief that crop improvement has positively contributed to society and will continue to do so *if* done within a framework characterised by respect for all human and nonhuman life. This means also knowing when crop breeding is *not* the best or most appropriate solution. Indeed, some people may not need or desire improved crop varieties (genetically engineered or otherwise), while other interventions are often more cost-effective, such as improvements in infrastructure (e.g., roads and market access) and seed systems or other technologies such as fertilisers, irrigation, mechanisation and improved agricultural practices. These technologies, as with crop varieties, should be designed and implemented with gender and other intersecting factors in mind.

[26] In a podcast interview, Robin Wall Kimmerer points out how "[s]cientists are very eager to say that we ought not to personify elements in nature for fear of anthropomorphising. And [what] I mean when I am talking of the personhood of all beings, plants included, is not that I am attributing human characteristics to them. Not at all. I am attributing plant characteristics to plants. Just as it would be disrespectful to try and put plants in the same category through the lens of anthropomorphism, I think it is also deeply disrespectful to say that they have no consciousness, no awareness, no beingness at all" (Tippett, 2020).

6.4. The imaginative: Towards feminist CRISPR crops (?)

Imagination represents an important resource for many feminist scholars in inspiring transgressive thinking (e.g., Haraway, 2016; Hobson, 2021; Lewis, 2007; Upton & Joseph, 2021). In this section, I am delving into the imaginative by exploring how plant genome editing grounded in the feminist crop concept could become a tool for feminist politics and transformation in and through crop breeding. While I address more of the technical possibilities that CRISPR has to offer gender-responsive and transformative crop breeding in the third article, in this section I attend more to the ways we may use CRISPR as a feminist thought tool and cultural deconstruction and reconstruction tool. Accordingly, this section poses more questions than answers. The hope is, however, that these questions may spark critical discussions and reflective thinking and research that forward the dialogue between plant genome editing and feminist and womanist perspectives on science, technology, innovation, agriculture, gender, plants and beyond.

The sub-heading above contains a question mark, albeit in parentheses, for two reasons: first, given the speed at which CRISPR is being advanced, feminist CRISPR crops may not, in fact, be a figment of our imagination; the second is meant to question the rather controversial proposition that genetic engineering may in fact be feminist, given its oftentimes capitalist, patriarchal and colonialist situatedness (e.g., Boyd, 2003; Cooper, 2008; Ezezika et al., 2013; Murphy, 2017; Sunder Rajan, 2006). Indeed, will we inevitably be led down the path of scientism and molecular imperialism (e.g., Christophe et al., 2014)? Will the plants themselves, in "interspecies resistance" (Beilin & Suryanarayanan, 2017, p. 210) and "interspecies political alliance" (Rezvani, 2021, p. 15) with humans, resist productivist paradigms reinforced through genetic engineering?

In this section, however, I allow myself to put the polarised debate on genetic engineering aside and revel in a cautious enthusiasm for the opportunities presented by plant genome editing using CRISPR-Cas. Just as Haraway reclaimed and appropriated the masculine and militarist cyborg (Haraway, 1985; Haraway, 1991), so too is there perhaps something particularly alluring and powerful in reclaiming and appropriating CRISPR-Cas – a biotechnological tool developed in the West who many perceive as emblematic of capitalist and colonialist values and interests – as something feminist and emancipatory. Inspired by Deboleena Roy (2018), I am "drawn to thinking more closely about the radical potential of recombinant DNA technologies as tactical tools for feminist scientists" (p. 133) and "how we might think about molecular biology and feminism together, how we may be able to work together to create new lines of flight to think about the world that we inhabit, and how we can produce knowledge about that world" (Roy, 2018, p. 24).

Grounded in the feminist crop concept and developed using participatory action research and transformative learning, I contend that CRISPR can allow us to engage more profoundly with plant–people entanglements in socially constructive ways. CRISPR, with its seemingly 'endless' possibilities, allows us to not only *think* of how things could be otherwise, but to *do* things otherwise; to not only imagine but indeed breed for characteristics and traits that women and men desire, some of which may contribute to overcoming traditional gender roles and expectations and configuring new paths along which women and men, in entanglements with crops, can pursue novel life goals and opportunities.[27] Using CRISPR-Cas, we encounter and form entanglements with plants at an extremely intimate, cellular and genetic level, and there are few places where the constructed boundaries between nature and culture, nature and technology, the social and material, the subject and object and so forth so vividly collapse. In other words, CRISPR does not simply 'cut and paste' DNA: it cuts and pastes plant–people entanglements in ways that allow us to imagine disruptions and reconfiguration of dominant and hegemonic relations in order to advance feminist crop breeding.

Such (re)imaginations and speculations, however, must be done from African vantage points, in all their complexities. What would genome editing look like if it was grounded in, to borrow a phrase from Lizelle Bisschoff's (2020) work on African cyborgs, "African ontologies and cosmologies that do not adhere to the empiricist paradigms of the western Enlightenment" (p. 610), including African feminist and womanist perspectives? How may plant genome editing and the opportunities and challenges it holds, including with respect to gender, be (re)interpreted through African (feminist and womanist) knowledges and narratives of the past, present and future (e.g., Amadiume, 1987; Becker, 2003; Bisschoff, 2020; Gasa, 2006; Korieh, 2010; Lamoureaux & Rottenburg, 2021; Mougoué, 2021; Omelsky, 2012; Omelsky, 2014; Oyěwùmí, 1997; Oyěwùmí, 2002; Talk, 1987; Wane, 2011)? It does not stop at the imaginative, however; it also matters who produces knowledge and where (e.g., Benjamin, 2009; Foster, 2017; Osseo-Asare, 2014; Pollock, 2014; Tilley, 2011). Could African women and men scientists take a leading role in developing CRISPR technology and feminist CRISPR crops and, if so, what may the implications be for belonging and meaning-making, for empowerment and disempowerment, especially in postcolonial settings?

[27] CRISPR is much more technically challenging than what is commonly portrayed in much of the popular science and some of the scientific literature. Indeed, plantiness limits the ease of applicability of CRISPR. For instance, the rigid plant cell wall is a major barrier to the delivery of the CRISPR system to the plant cell (e.g., Demirer et al., 2021). It is important to stress this because, when presented with such a powerful tool as CRISPR-Cas, it is easy to revert back to human exceptionalism, when crop breeding is in fact "anything but formulaic or human-centered" (Mendum, 2009b, p. 327).

7. Conclusion

Crops, seeds and food are an essential part of our social and gender identities, belonging, connectedness, meaning-making and ways of knowing. They can also be a source of worry, frustration, marginalisation, oppression and domination. In other words, crops and gender are closely interrelated. Accordingly, crop breeding represents an important site for feminist social action and change, as it offers possibilities for understanding, negotiating and reworking intersectional gender identities, norms and relations. Thus, in this thesis I asked: How can crops and crop breeding be feminist? I subsequently broke the question down into three research questions which I explored through an ethnographic case study of the G+ Tools for gender-responsive crop breeding. I found that the dynamic and co-constructed relationship between gender, crops and crop breeding yields complex and ambiguous effects that may both constrain and support gender equality and women's empowerment.

In the first article, I demonstrated how gender-responsive crop breeding was practiced and negotiated using the G+ Tools, which centre on the initial stages of the crop breeding process, notably varietal design. In intra-action with the crop breeding teams, the G+ Tools take on several performative roles through which women and men farmers and other user groups and their crops, as well inter and intradisciplinary power relations, become constructed and negotiated. As such, in the article, I provide insights into how gender, crops and crop breeding become co-constructed through the practices and negotiations of gender-responsive crop breeding. Accordingly, the article contributes to feminist STS by expanding its scope to the underexplored topic of development-oriented crop breeding.

In the second article, on the question of what drives and shapes the co-construction of gender, crops and crop breeding, and with what effects, we situated gender-responsive crop breeding in the market-led turn currently dominating within and beyond the CGIAR. We identified both human and nonhuman actors, and material and discursive factors, that drive and shape this mutually shaped relationship: the interrelated neoliberal project, participation agenda and gender agenda; disciplinary and organisational power dynamics that situate crop breeders and in particular donors in powerful positions; and nonhuman actors such as the G+ Tools and the crop plants themselves. In exploring the implications of the conflation of gender-responsive and market-based practices, we developed and used a novel feminist political agronomy lens to unpack the market, demand and gender and their co-construction. Our analysis revealed that, across the continuum from socioeconomic institution to its normative meaning, the market constitutes an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded different value. Humans and

nonhumans that do not readily fall within the confines of such a framework stand in danger of being excluded; as being part of a deficient or even dead nonmarket.

In light of these findings, what conclusions can we draw about the feminist nature and potential of the G+ Tools? In many ways, the G+ Tools attempt to change and use crop breeding to move towards more equitable gender relations, including varieties that benefit or perhaps even favour women. The work of the GBI, including the development and institutionalisation of the G+ Tools, does challenge the knowledge politics of crop breeding and spurs critical reflections about who decides which traits to breed for, why and how, which in turn determine whose knowledges, preferences, needs, desires and demands come to matter and are excluded. The Tools do so by, among others, putting into question taken-for-granted values and traits such as productivity and yield, respectively; by rendering priority-setting, decision-making and trade-offs more transparent; and by attempting to strengthen the voice and influence of (women) gender specialists. Thus, if methodological challenges associated with gender-responsive crop breeding can be overcome, including the lack of representative data, we could consider the G+ Tools to contain elements of a feminist technology.

Still, important questions remain about the type of feminist social relations that the Tools will ultimately contribute to developing, particularly as they become integrated into a sociomaterial system where the knowledge politics is dominated by the views and values of donors and crop breeders, among others. As such, there is a need to interrogate the sociomaterial system of crop breeding to identify and challenge inequitable structures, norms, cultures and behaviours. Feminist political agronomy can be helpful in this respect. Furthermore, the G+ Tools are but one of many conceptual and methodological principles, frameworks, tools and interventions needed to advance feminist social relations and goals, in all their complexities, in and through crop breeding.

In the third and final article, I asked how feminist crop breeding can be advanced through conversations between feminist technoscience studies, critical plant studies and molecular crop breeding. I proposed the concept of the feminist crop, which captures the ways crops are entangled with women's embodied practices, knowledges, capabilities and power. Indeed, to understand gendered power relations in agriculture requires us to observe the deep and complex bonds of plant–people entanglements. Such a radical new concept, which challenges the fundamental groundings of crop breeding by positing a more-than-human, naturecultural and sociomaterial ethico-onto-epistemology, shifts the ways we think about and do crop breeding. This includes a consideration of how plant genome editing – informed by the new imaginaries and ethical commitments that the feminist crop engenders, along with transformative learning and participatory action research that

renders women the co-authors of their own feminist varietal scripts – may be wielded as a feminist tool. Ultimately, then, the feminist crop contributes to advancing feminist crop breeding.

Given the renewed attention to gender equality and women's empowerment in agricultural research and development in recent years, along with the rapidly advancing field of plant genome editing and the institutionalisation of market-based approaches, this represents a particularly opportune and critical time to champion feminist crop breeding and feminist varieties – not least as we face global climate, food and humanitarian crises where gender (in)equality and women's (dis)empowerment are central. A feminist agenda should be an explicit part of the justification for and direction of plant breeding, in which the inequalities and problems defined by feminism are addressed from the outset and throughout the crop breeding process, including during design, testing and dissemination of crop varieties.

By exploring the interrelation between gender, crops and crop breeding through dialogue between feminist technoscience studies, critical plant studies and political agronomy, the thesis contributes empirically and theoretically to each of these fields. Furthermore, I contribute to championing feminist crop breeding by providing an improved understanding of the co-production of gender, crops and crop breeding and by suggesting ways to advance feminist action and politics in crop breeding through the interrelated realms of sociomaterial design, the sociomaterial system, the metaphysical and the imaginary.

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Part II: Full length articles

Tools in the Making: The Co-Construction of Gender, Crops, and Crop Breeding in African Agriculture

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Abstract

Crop breeding for development has a relatively long tradition of including the perspectives of men and women farmers. However, the lack of adoption and development impact of improved crop varieties, particularly in African countries, has led to a growing interest in frameworks and tools for making crop breeding more responsive to the needs, preferences, and demands of both men and women in agriculture. Still, many questions remain about how *gender-responsive* crop breeding should be done in practice, as well as its impact on making crop breeding more efficient and gender equitable. In 2020, the CGIAR Gender and Breeding Initiative (GBI) piloted the Gender+ Tools in several African-based breeding programs, which are meant to inform gender-responsive decision-making in crop breeding. Using perspectives from feminist technoscience studies, I "follow the Tools" to explore their performative roles as they emerge in interaction with the crop breeding teams. I find that the Tools take on several interrelated performative roles through which gender, crops, and crop breeding are co-produced: as a diagnostic and screening tool, as a communication and marketing tool and as a management tool. The paper contributes to feminist technoscience studies by expanding its scope to the underexplored topic of crop breeding for development in Africa.

Keywords: Africa, CGIAR, crop breeding, feminist technoscience studies, gender

Introduction

A now voluminous literature demonstrates the many ways in which "gender matters" in agriculture and, consequently, to crop breeding (e.g., Food and Agriculture Organization of the United Nations, 2011; Quisumbing et al., 2014; Raney et al., 2011). For instance, gender differences in status, rights, and labor may significantly shape the varietal and trait preferences and demands of men and women in food and cropping systems (e.g., Marimo et al., 2020; Weltzien et al., 2019). Crop breeding for development has a relatively long tradition of engaging with both men and women farmers at different points and at various degrees in the breeding process (e.g., Chambers et al., 1989; Farnworth & Jiggins, 2003; Richards, 1985; Scoones & Thompson, 1994). Commonly however, farmers have been invited to evaluate released or soon-to-be-released crop varieties, which limits the extent to which they can express trait preferences beyond those already selected by the crop breeders (also see, e.g., Voss et al., 2021). Furthermore, social scientists, including gender specialists, have historically had little influence and decision-making power during priority-setting and varietal design, as their input has been considered most relevant later in or in the aftermath of the crop breeding process, such as during adoption studies and impact assessments.

However, failing to meaningfully engage with gender is believed to be one explanatory factor for low levels of adoption and development impacts of improved crop varieties, including in African countries (e.g., Acevedo et al., 2020; Fisher & Carr, 2015; Smale et al., 2018; Thiele et al., 2021). Still, many questions remain as to how best to render crop breeding *gender-responsive*, practically and methodologically speaking, as well as about the impact of gender-responsive crop breeding in making crop breeding more efficient and gender equitable. In 2020, the Gender and Breeding Initiative (GBI) of the Consortium of International Agricultural Research Centers (CGIAR) (previously the Consultative Group for International Agricultural Research), the world's largest agricultural research and innovation system, piloted the Gender+ (G+) Tools: a set of gender-responsive crop breeding tools meant to help inform decision-making in crop breeding in ways that take gender systematically into account, including at the very initial stages when priorities are set and crop varieties are designed.

In this paper, I "follow the Tools" through their construction and use by engaging in conversations with those involved in their creation and piloting, as well as with actors from the wider gender and breeding community; close observation made during the piloting project; and interaction with the Tools themselves and other resources produced by the GBI and their partnering organizations. While the G+ Tools are described as a decision-support tool and can, fundamentally, be considered an ideological and political tool working towards social justice, gender equality, women empowerment, and other developmental

outcomes in agriculture, the findings of this paper reveal that the Tools take on several performative roles through which gender, crops, and crop breeding are co-produced.

In better understanding and conceptualizing these processes, I draw on perspectives from feminist technoscience studies, which over the last few decades have demonstrated the centrality of intersectional gender identities and power relations within the dynamic interactions of science, technology, and society (e.g., Cockburn, 1983, 1985; Faulkner, 2001, 2007; Haraway, 1985, 1997; Harding, 1986; Wajcman, 1991). Constructivists within this tradition have theorized the relationship between technoscience and gender as one of mutual shaping, contingency, and malleability (e.g., Berg & Lie, 1995; Cockburn & Ormrod, 1993; Gill & Grint, 1995; Horowitz & Mohun, 1998; Kirkham, 1996; Oudshoorn et al., 2004; Rommes et al., 1999; Wajcman, 2004).

In demonstrating the mutually shaped relationship of gender and technoscience, feminist scholars have among others shown how scientists, technologists, and engineers – often based on their own social identity and embeddedness – may incorporate gender ideologies, values, symbols, and stereotypes into the material and symbolic design of technical artefacts according to *gender scripts* (e.g., Akrich, 1992; Friz & Gehl, 2016; Rommes, 2002; Van Oost, 2003). In turn, such scripts may shape the agency of the users by delegating particular statuses, motives, competencies, skills, roles, and responsibilities. For instance, consider a hypothetical example where a senior male breeder trained in productivist paradigms, in anticipating what farmers want (who for a long time were assumed to be men), selects a genetically encoded agronomic trait that confers higher yield and marketability at the cost of taste, texture, and early maturity. He may further choose to test the experimental variety under favorable conditions which men more so than women farm under (e.g., good soil quality). While rarely the intention of the breeder, once this variety is disseminated, it may come to strengthen men's position in farming and the marketplace, while condemning women to a comparative disadvantage, thus shaping the roles and responsibilities of and relations between men and women, as well as between people and plants.

Just as important, however, has been the emphasis on how different types of users themselves shape and co-design technological trajectories. Here, *interpretative flexibility* and *de-scription* may come into play, which refer to the different ways in which users may interpret, appropriate, modify, transform, or even reject scripts to create new meanings and uses of technology (Akrich, 1992; Pinch & Bijker, 1984). Interpretative flexibility and de-scription may be highly gendered, as gender performances are negotiated with and in relation to technical artifacts, as well as social actors and institutional configurations of power.

One might imagine a scenario where, for example, women farmers use the crop variety described above for other purposes than intended by the crop breeder, such as for livestock feed.

The paper starts with a description of my encounter with the field and the gender and breeding community, which provides insights into the context in which the Tools are embedded, followed by the origin story of the GBI and the G+ Tools, along with an exploration of the materiality of the Tools. Subsequently, I use the concepts of gender scripts, interpretative flexibility, and de-scription to explore how gender, crops, and crop breeding become co-produced as the Tools take on different performative roles in interaction with the crop breeding teams: as a diagnostic and screening tool, a communication and marketing tool, and a management tool. The paper contributes to feminist technoscience studies by expanding its scope to the underexplored topic of crop breeding for development in Africa. Such an analysis is particularly timely given the renewed attention and commitment to gender equality and women's empowerment in agricultural research for development over the last decade, including within crop breeding.

Encountering Gender and Crop Breeding

My entry into Kenya as part of my doctoral fieldwork in the fall of 2019 was no easy undertaking. For several months, I had tried to get access to different crop breeding programs of the CGIAR and their partnering organizations to better understand how these were addressing gender and women's interest and empowerment in their work, only to get rejected. This had left me pondering: Why was it such a challenge for me to get access? While I considered my formal background as a molecular breeder an advantage in convincing the "hard scientists" who are commonly in charge of crop breeding projects to take me onboard, my lack of expertise in gender studies meant that I struggled in truly understanding and explaining the value of my proposed research. Consequently, I hid my uncertainty behind big, bold, and rather abstract (buzz)words – *empowerment*, *gender equality*, *social justice, androcentrism*, *gender mainstreaming*, and *sustainability* – without being able to concretely relate to the meaning of such concepts in specific contexts.

However, I could not help but think that my rejection was also due to some other reasons. Unless they are "forced to" by the donors (a verb that several of the interlocutors would use), it can oftentimes take "hard scientists" and management a lot of convincing to devote adequate time, money, and resources to do gender research. This partly reflects a hierarchy of the sciences, which is furthermore a gendered hierarchy (e.g., Beintema, 2014; Beintema & Di Marcantonio, 2009; Cernea & Kassam, 2006; Independent Evaluation Arrangement of the CGIAR, 2017): CGIAR is a highly technology-focused and biophysical-

oriented organization where the natural sciences and crop breeders, the majority of whom are men, have held particularly high positions. Further down the hierarchy one finds the agricultural economists, most of whom are also men, followed further down still by the gender specialists, who are most commonly women. From both men and women scientists, I would hear stories of sexual and racial harassment, unfavorable working conditions, and side-lining of gender research and researchers, particularly as it related to black women. “It is an extraordinarily patriarchal research system, you know”, as one of my informants bluntly expressed it.

Many of the crop breeders I spoke to were aware of and sympathetic to gender issues in agriculture, but commonly felt that they were constrained by technical and economic requirements (e.g., short-term funding and genetic and technical constraints in breeding for particular traits considered important to women). In contrast, several social scientists argued that crop breeders mostly cared about the number of varieties released, papers published, “mega-environments”, and “big impact traits”. A few even contended that crop breeders lacked a vision and a broader, social perspective. What emerged then, was a natural-social science divide – the lack of a common understanding and language – where people worked in separate silos, even when sharing next-door offices.

As has now become apparent, I did manage to get access to Kenya in the end. Thanks to some key contacts, I made it to Nairobi, the bustling capital of Kenya, which is the home of several CGIAR offices and research stations, and I was soon put in touch with both social and natural scientists working in various crop breeding programs in the CGIAR Consortium.[1] After a while, I started to gain an overview of the gender and breeding research and policy community, only to realize that there was a whole plethora of conceptual and methodological understandings of gender in agricultural research and development: *Gender neutral, gender aware, gender sensitive, gender intentional, gender inclusive, gender mainstreaming, gender functional, gender strategic, gender integration, gender transformative*… Furthermore, it appeared as if every other organization – be it national governments, non-governmental organizations, donor agencies, or research institutes – had its own set of policies and strategies on how to address gender (unless they were *gender blind*, to throw another word into the mix) (e.g., Alliance for a Green Revolution in Africa, n.d.; African Union, 2018; Bill and Melinda Gates Foundation, 2012, 2018; Food and Agriculture Organization of the United Nations, 2020; International Fund for Agricultural Development, 2015; Republic of Kenya, 2019; CGIAR Research Program on Roots, Tubers and Bananas, 2013; US Agency for International Development, 2020). No wonder why some of the informants argued

that there was a lot of confusion regarding what gender actually is and for what purposes the concept is used.

What cropped up (no pun intended) in most of my conversations and readings, however, was *gender-responsiveness* and more specifically *gender-responsive* crop breeding. Most of the people I talked to seemed to share a more or less common understanding of what gender-responsive crop breeding entailed in principle: the development of plant varieties that respond to the knowledges, challenges, needs, interests, and preferences of women and men in agriculture, which builds on an understanding of why they express such needs and preferences. The "why" may reflect intersectional gender norms and divisions of status, rights and labor (e.g., Marimo et al., 2020; Weltzien et al., 2019; Polar et al., 2021). Furthermore, gender-responsive crop breeding requires an understanding of how crop varieties may interact with gender dimensions once they are disseminated so that potentially harmful and beneficial effects can be avoided and targeted, respectively. Ultimately, gender-responsive crop breeding is meant to ensure equality of choice in and outcomes of crop breeding for both men and women (Polar et al., 2021), and is further framed as a way to increase adoption rates and development impacts of improved crop varieties, such as poverty alleviation, food and nutrition security, and gender equality (e.g., Ashby et al., 2018; Holmes, 2018; Orr et al., 2018; Tufan et al., 2018).

The Origin Story of the GBI and G+ Tools

However, when I asked the interviewees what gender-responsive crop breeding entailed in practice, methodologically speaking, many would go a bit quiet or chuckle and say something along the lines of, "that's what no one really knows". As luck would have it, an opportunity arose during my fieldwork that would allow me to delve deeper into this question. I was able to join a project co-organized by the CGIAR Gender and Breeding Initiative (GBI) and the CGIAR Excellence in Breeding Platform (EiB), with the aim of piloting a set of gender-responsive crop breeding tools, the Gender+ (G+) Tools.

In the period between 2013 and 2015, Jacqueline Ashby – then the senior advisor for gender research and coordinator of the Gender and Agriculture Research Network at the CGIAR System Management Office – observed that progress in the integration of gender into annual workplans of plant breeding research was proving exceptionally slow in comparison to other research areas. Her discussions with gender researchers concluded that poor integration of gender research into breeding, a pivotal and strategic domain of CGIAR research, would be a serious handicap to the overall credibility and efficacy of gender research in the CGIAR. As a result, the Gender and Agriculture Research Network prioritized gender and breeding as a cross-system initiative. In 2015, the Network began organizing a dialogue between breeders

and gender researchers and established a cross-program Coordinating Committee to plan two international workshops on Gender, Genomics and Breeding to be hosted in 2016 and 2017.

The first workshop identified that a critical stage in which gender dimensions could be integrated was when crop breeders were setting objectives, prioritizing traits, and selecting parental lines (Ashby et al., 2018; Ashby & Polar, 2019).[2] Breeders often develop crop varieties based on an *ideotype,* which describes the ideal plant variety and its traits (Donald, 1968). Additionally, with *index selection* currently being the most efficient way of simultaneously improving several quantitative traits, breeders often use what is known as the *breeder's index.* The breeder's index usually consists of a table that lists, weighs, and ranks all the traits of interest based on a set of selection criteria (e.g., the level of genetic advancement over time and economic weight). Yield, in its various forms, is typically the highest-ranking trait.

Most I spoke to argued or agreed that (senior) breeders have most of the decision-making power in developing the ideotypes and in determining which traits make it onto the breeder's index and their comparative ranking, and that most do so in an informal manner. Comparably less attention have been devoted to how the design of the ideotype and trait prioritization involves a choice about who to prioritize – producers or processors, marketers or consumers, men or women, young or old, widows or married couples, able-bodied or disabled, landowners or tenants, rural or urban, poor or middle-income.

Consequently, if the priority-setting and decision-making process became more responsive to user needs and demands, and one could find ways of systematically incorporating social and gender targeting even at the very earliest stages of variety design, this could help move gender beyond just being an add-on considered during late-stage variety evaluation, adoption studies, or impact assessments. This thinking aligns with a relatively recent trend in public crop breeding, namely *demand-led* or *market-led* plant breeding, where market intelligence informs the priority-setting and decision-making of variety design (e.g., Persley & Anthony, 2017). The approach originates in the private sector and entails a formalized breeding process that consists of several stage-gates. This framework provided a background against which the GBI would come to conceptualize the possible entry points for social sciences and gender research in crop breeding.

In the CGIAR, market-led crop breeding is spearheaded by Module 1 of the Excellence in Breeding Platform (EiB); a platform established in 2017 that is meant to help streamline and "modernize" breeding in the CGIAR and beyond. The central concept of their approach is the *product profile* (Mashonganyika, 2018), which can be considered a more elaborate and market-informed version of the ideotype. Thus, the EiB

became a relevant partnering organization to the GBI considering its role as the coordinating platform for innovation in breeding, particularly in fostering the use of tools for market-led crop breeding across the CGIAR.

While Ashby pinpointed the need for and marshalled resources to support proactive dialogue among breeders and gender researchers, it was the sustained commitment of a larger ensemble of people, post-docs, organizations, funding, conceptual understandings, and crops that enabled the GBI to gather momentum. In 2017, the initiative was formally handed over to the Research Program on Roots, Tubers and Bananas (RTB) and the International Potato Center (CIP), whose leadership was critical given RTB-CIP's own investment in and experience with gender-responsive breeding.

A question remained, however: we now know when and where in the breeding cycle social considerations, including gender, can usefully be integrated, but how? This gave rise to a discussion on the need for a set of tools that could help inform decision-making in crop breeding. Over the course of a few years, this culminated in the creation of the Gender+ (G+) Toolbox (see below), which is meant to inform decision-making in breeding in ways that systematically take gender and other social differences into account. With funding and support from the EiB, a project was organized where prototypes of the Tools would be piloted in several African-based breeding programs and be adapted to fit the EiB product profile development framework.

The G+ Toolbox

The G+ Toolbox is a digital toolbox (PDF format) that consists of the G+ Customer Profile Tool, the G+ Product Profile Query Tool, the Standard Operating Procedure (SOP), and the G+ Report (Fig. 1). A social scientist with gender training is meant to take a leading role in applying the Tools, albeit in a co-managed relationship with a breeder, whereas major product advancement decisions are to be made in the larger crop breeding team. The G+ Customer Profile Tool provides breeding teams with an improved understanding of who they are breeding for and why, taking gender into account (Orr et al., 2021). The Tool consists of three main stages: segmenting, targeting, and profiling. Segmenting involves the creation of a product map with a gender dimension, a customer map with a gender dimension, an evidence table, and a decision matrix. The questionnaires for the product map and customer map ask the breeding team to provide a range of sex-disaggregated geographical and socioeconomic data on each breeding product in the value chain and for each potential customer segment the breeding program may address. For the customer map, the breeding team also needs to make a narrative summary of four gender gap questions related to (i) use of unpaid farm labor, (ii) on-farm or off-farm employment or other forms of income

generation, (iii) input use, and (iv) control over produce, by-products, sales, income, or other direct benefits from the crop variety in question. All the information is collated and summarized in the evidence table, together with information about the expected development impact of the products and segments.

Using a scale from 1 to 3 (where 1 = low and 3 = high), the decision matrix allows the breeding team to score each customer segment according to several development impacts. Ultimately, a final score is provided which can be compared with the scores of the other potential customer segments. Subsequently, a voting form lets the broader breeding team rank the customer segments in order of importance, as determined by the objectives and priorities of the breeding program. Next, the product preferences and opinions of men and women in the targeted customer segment(s) are identified and, ultimately, a G+ Customer Profile is generated which provides a comprehensive, gendered description of each target customer segment.

The G+ Product Profile Query Tool, in turn, allows the breeding team to inspect all the crop traits in the product profile for their potential gender effects (positive, negative, or neutral), as well as potentially identifying other traits that are important from a gender perspective (Ashby & Polar, 2021a). The Tool consists of three main stages: information, analysis, and scoring. During the information stage, the product profile proposal is identified and information about gender gaps and sex-disaggregated trait preferences for the target segment is obtained (by using the G+ Customer Profile Tool).

The second stage of analysis consists of the "Do No Harm" and "Positive Benefits" analyses. During the "Do No Harm" analysis, each trait is scored against the four gender gap questions (see above). For each of these, the trait can be scored 0 (neutral), -1 (avoid or amend), or -2 (reject).[3] Additionally, the trait is scored according to whether women perceive it negatively or whether there is a conflict of opinion between men and women. During the scoring stage, a scoring guide helps the breeding team weigh the different scores relative to one another to provide a final score that can inform the product profile proposal. The process is the same for the "Positive Benefits" analysis, but the questions asked and the scores are somewhat different. Here, the trait can be scored either 0 (neutral), +1 (nice to have), +2 (important), or +3 (required).

The "Do No Harm" and "Positive Benefits" scores need to be evaluated relative to each other to understand any potential trade-offs. If a trait scores 0 on both the "Do No Harm" and the "Positive Benefits", it is considered gender neutral. If there is insufficient data available to generate a score, a warning signal is used. Breeding teams are then advised to proceed product advancement with caution.

At the very least, the breeding program should avoid potentially harmful traits (i.e., a score of 0 on the "Do No Harm"). The decision to proactively target one or more traits that may benefit men and women will be a program management decision. By doing so, the GBI argues that crop breeding could potentially become gender transformative.

The SOP explains in a stepwise manner how to use the G+ Tools and identifies key questions, topics for discussion, and decisions points, along with suggestions for gender analysis and other action points (Ashby & Polar, 2021b). Using the SOP yields a G+ Report that reports on the outcomes of using the G+ Tools, including a record of key decisions informed by gender analysis, which can be used when communicating the results (Polar & Ashby, 2021).

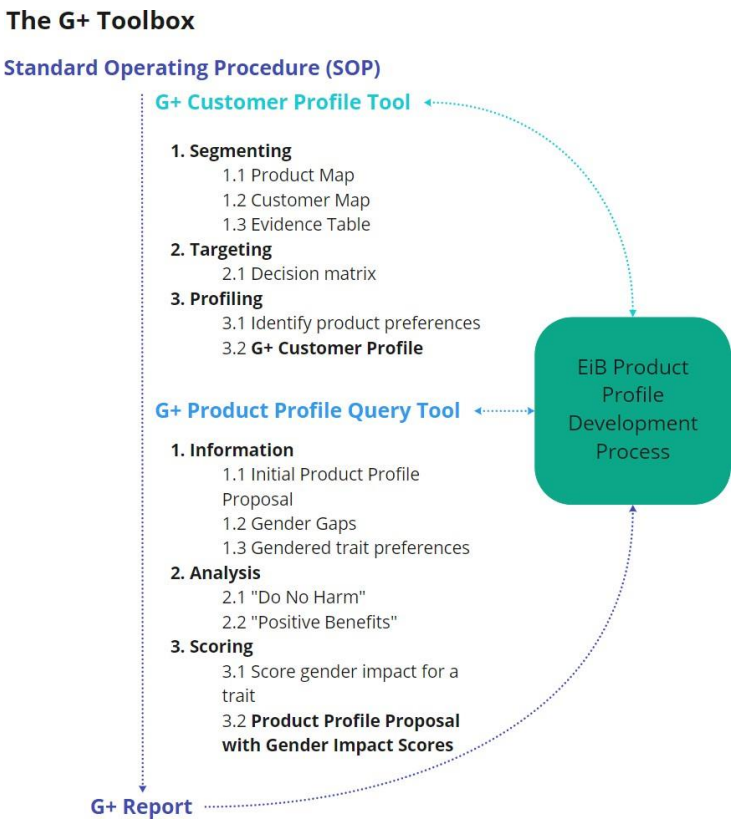

Figure 1. The G+ Toolbox. The arrows are double headed to indicate that the Tools are themselves shaped by the EiB Product Profile Development Process. Figure produced by author.

Pilots and Pandemics

Two CGIAR breeding programs were selected and financially supported by the EiB to participate in the piloting project: beans in Zimbabwe and cassava in Nigeria. Additionally, two CGIAR breeding programs joined on their own initiative: the sweetpotato program in Uganda joined at beginning of the piloting, while the cereals and lentils program in the Central and West Asia and North Africa region joined a few months into the project. The piloting was meant to last from March until October of 2020, starting with the "Knowledge-Sharing and Planning Workshop" and rounding off with the "Evaluation and Learning Workshop", both to be arranged in Nairobi. In between workshops, each team would pilot the Toolbox at their respective research organization.

Just as the world started to realize the severity of what would become a global pandemic, the GBI and the EiB managed to organize the "Knowledge-Sharing and Planning Workshop". The workshop brought together just under 20 social and natural scientists from across the African continent and beyond, most of whom represented the beans, cassava, and sweetpotato piloting teams. The four intense days of workshopping consisted of a mixture of presentations given by the GBI, the EiB, and the participants, along with some initial attempts at applying the Toolbox. Additionally, an icebreaker activity had the participants pick their favorite crop varieties and explain why their mum would love it, to which most of the responses reflected women's role in household food and nutrition security and food preparation. While this exercise highlighted the importance of quality traits for the acceptance and adoption of crop varieties (e.g., texture, color, taste, aroma, and cooking properties), which have historically been overlooked in much of crop breeding, it also reproduced the traditional image and narrative of women as "mothers" and "food-makers" and further envisioned "her" interests, knowledges, and competencies as associated with such roles and responsibilities.

Following the workshop, the cassava, beans, and sweetpotato teams returned to their respective breeding organizations to pilot the G+ Toolbox and to make recommendations for ways to revise and improve the Tools, as well as make suggestions for adjustments to the EiB templates. Having to adapt the Tools to the EiB framework did, however, leave some of the piloting participants feeling that they were having to retrofit the Tools in a way where gender became, as before, an add-on. Others said that the piloting became more about adjusting the EiB framework than refining the actual G+ Tools, but this was nevertheless considered an important outcome of the piloting project.

As the Tools were largely dependent on existing data, their use was relatively unaffected by the COVID-19 pandemic. However, as working conditions changed for all participants, the piloting project

experienced delays. As a result, the piloting project got an extension until the end of the year and the "Evaluation and Learning Workshop" was turned into a series of online meetings, workshops, and other types of digital interactions expanding over several months (from September to December 2020).

Discussion

Next, using the concept of gender scripts, I identify several interrelated performative roles through which the G+ Tools in their interaction with the breeding team come to co-produce gender, crops, and crop breeding: as a diagnostic and screening tool, a communication and marketing tool, and as a management tool. Indeed, while most of the piloting participants used the Tools more or less according to the SOP, many interpreted, appropriated, and expressed their own set of ideas of what the Tools actually are, what they do, and what aspects were most useful about them. In other words, they exercised interpretative flexibility and de-scription. What also surfaces through this analysis, however, are instances where potential users of the Tools may come to reject the G+ Tools.

Diagnostic and screening tool

In rendering crop breeding gender-responsive, there is a need to "diagnose" and make visible the diverse knowledges, skills, desires, needs, and preferences of various groups of men and women in relation to their crops, and to screen crop traits according to their differential impacts on women and men. One of the most important outcomes of using the Tools was highlighting the pivotal roles that women play along the entire agricultural value chain, not only as producers and consumers, but as processors, traders, and marketers. In other words, women – in all their complexity – are essential "customers" of crop breeding programs and, consequently, their knowledges, demands, and preferences are central to crop breeding and varietal design.

However, a major obstacle faced by the piloting teams in correctly diagnosing the needs and preferences of men and women and in screening the gender impacts of traits, was the lack of up-to-date, good quality, and representative data, which reflects broader methodological challenges of gender-responsive crop breeding (e.g., Ashby & Polar, 2019; Polar et al., 2021; Voss et al., 2021; Weltzien et al., 2019). In commenting on some of the questionnaires of the G+ Tools, a crop breeder noted:

> How in the world are we supposed to answer these questions? A lot of the public sector breeding programs for these food security crops do not know the answer to these questions. Especially with [this] customer profiling tool. You know, "what % of the market is occupying this". That information is unknown. Period.

Thus, while both the beans and cassava programs had been chosen based on, among others, their availability of relevant data, even these struggled at times in completing the information requested in the templates of the Tools. In some cases, the piloting teams would, admittedly so, compensate by making inferences and educated guesses from studies conducted elsewhere and elsetime. As a result, there often appeared to be some level of ambiguity, uncertainty, and at times contestation when describing and targeting customer segments and screening crop traits. For instance, one discussion centered on whether vine yield should be avoided, as it could increase drudgery for women, or targeted as vine yield could be important in providing women with a source of animal feed (silage) and represent a potential future business opportunity.

However, the Tools stress the importance of making decisions based on sound evidence that is representative of the customer segment. Still, there is a danger that, in relying on existing information, crop breeding teams may resort to outdated and unrepresentative data, which can have the unintended effect of scripting men and women users, including their relationships with crops, according to binary and heteronormative gender stereotypes. This is at odds with an understanding of gender, including the relationship between gender and crops, as contingent, dynamic, and constantly negotiated. For instance, echoing the "why my mum would love it" exercise, women may become scripted as marginalized, mostly concerned with household child and nutrition security, and as preferring traits associated with, for instance, cooking. Men, in turn, may become scripted as user groups who are mostly motivated by commercial and economic interests, with their trait preferences reflecting such interests (e.g., traits related to increased marketability). Compared to men then, women's practical needs may become more commonly addressed as opposed to their strategic needs, the latter of which could possibly better help challenge existing gender roles and relations.

While such gendered representations may in many instances hold "true", unless based on sound empirical evidence and holistic methodological research approaches, they may also stand in danger of reproducing snapshot-nature understandings and biases, stylized "facts" about men and women in agriculture, and gender stereotypes and myth (e.g., Almekinders et al., 2019; Doss et al., 2018; Goebel, 2003; Leach, 2007). Further down the line, once a variety has been developed with input from the G+ Tools, such socially constructed users and gender stereotypes may become materialized in the crop itself, which in turn may shape the agency, behavior, and relations of men and women in agriculture, as per the concept of gender scripts.

Communication and marketing tool

The Tools were also considered a communication device, as their output supported gender specialists in presenting gender data and input in ways that were tangible to largely quantitative researchers. Through standardization and the use of ordinal values, as well marketing concepts, the Tools translate complex gender issues and dimensions in ways that adhere to the practices, language, and values of crop breeders, as well to private sector donors. Indeed, of conceived importance was also the role that the Tools and their output played in building and making investment cases to attract funding from donors. Both market-led approaches and gender equality are being highly promoted by several bilateral and multilateral funding agencies as a way to increase the efficiency and effectiveness of crop breeding for development. Thus, some of the interviewees considered gender more as a "selling point" for the larger project of social inclusion in crop breeding, where other intersecting social identities and dimensions were often considered just as, if not more, important than gender (e.g., age, ethnicity, regionality, poverty level, and educational level). As expressed by a social scientist:

> I think our entry point is gender because... Everybody has to do it, right? So, if we made it the Social Inclusion Product Profile Query Tool, maybe that wouldn't get the same buy-in or same level of interest from the donors than the gender one.

In their turn to standardization and market logics, however, the Tools can be seen as producing values that are part of the larger, neoliberal valuation machinery and mode of governing in agricultural research for development (e.g., Fuglie, 2016; Kilby, 2021; Moran, 2014; Moseley et al., 2015; Sumberg & Thompson, 2012). Indeed, in drawing on approaches from consumer marketing (Orr et al., 2018), using concepts such as "customer profiles" and "product profile", and in their reference to men and women in agriculture as "customers", the Tools appear to have a servicing role to markets. Thus, while not referred to as such by the piloting participants, some might question whether the G+ Tools are, in fact, a marketing tool in that they allow further micro-segmentation and the identification of underserved market segments, and thus the creation of crop varieties more highly tailored to different gendered "customers".

Consequently, the Tools may themselves come to perform markets (Callon et al., 2007), and script men and in particular women in agriculture as "untapped markets" and "valuable investments" (also see, e.g., Berik, 2017; Chant & Sweetman, 2012; Lyon et al., 2019). What happens, then, to people, crops, and crop traits that are not considered "valuable", "marketable", or "investable" enough? Additionally, could the conflation of gender and markets have the effect of depoliticizing gender at the expense of its social justice thinking and feminist edge, as suggested by feminist scholars in their criticism of the relationship between

gender equality, feminism, and neoliberal-capitalism (e.g., Boyd, 2016; Cornwall, 2018; Cornwall et al., 2008; Cornwall & Rivas, 2015; Esquivel, 2017; Lyon et al., 2019; Prügl, 2015; Wilson, 2011, 2013)?

Management tool

Finally, the Toolbox attempts to manage institutional and interdisciplinary (gendered) power relations and negotiations. As mentioned, a social scientist with gender training is meant to take a leading role in applying the Tools. Implicitly, there is move towards strengthening the voice of (women) gender specialists; the need of which was vocalized several times by the interlocutors, including several of the piloting participants. Encouragingly, one of the participants noted how this was the first time since she started her position as a gender specialist that the breeders had engaged in conversations about gender and crop traits. Another one of the gender specialists found that the Tools had reinforced her ability to influence people to move in a particular direction without having to directly tell them to do so. Additionally, an earlier contributor to the development of the Tools told a story of where they had used aspects of the G+ Product Profile Query Tool together with breeders to critically scrutinize a series of traits, upon which even yield was questioned as the Tool helped highlight how enhanced yield may increase drudgery for women (e.g., due to increased harvesting requirements). This was considered ground-breaking due to the almost unquestionable status of yield.

We thus see how the G+ Tools may be appropriated and used differently and for different purposes by its users, subject to interpretative flexibility and de-scription. However, the G+ Toolbox is itself scripted in ways that shape the agency, behaviors, and relations of the users of the Tools, perhaps even in gendered ways. For instance, the SOP suggests when and what questions to ask and topics to discuss and by and with whom. The script also assumes a certain type of user: most piloting participants commented that the Tools were “heavy”, complex, and time and labor-intensive. Implicitly then, the user of the Tools was presumed to be someone with significant gender expertise, a high work capacity, and with the systematic and analytical skills required to identify, investigate, and organize appropriate data; along with the interpersonal skills needed to engage in interdisciplinary discussions and communication.

Still, several spoke of difficulties in getting the attention and sustaining the involvement of crop breeders, and at times also agricultural economists, in using the Toolbox. Tellingly, few crop breeders and biophysical researchers were present during the digital meetings despite being invited, including some of those who had been present during the initial “Knowledge-Sharing and Planning Workshop” (crop breeders may, however, be prevented from attending meetings due to conflicting responsibilities in the field or in the laboratory). As such, the digital meetings were dominated by social scientists and one of

the participants noted in a later interview how, during the piloting, they were often "singing to the choir". This echoed a worry expressed by another participant that, for system-wide behavioral and cultural change to be achieved, "we can't have individual gender experts having individual conversations". Consequently, despite the recognition by the project organizers and participants of the need to ensure that crop breeders felt ownership in developing and using the Tools, the Toolbox was predominantly piloted by social scientists. The lack of input from and engagement by biophysical researchers may have the unintended effect of making the Tools less intelligible for use in cooperation with plant breeders, which may challenge the extent to which the Toolbox will effectively be able inform priority-setting and decision-making in crop breeding.

Furthermore, through conversations with people from the wider gender and breeding community, it became clear that some gender researchers had reservations toward the Tools. Among others, the G+ Tools can be seen as performing an integrative or accommodating approach to gender research, where gender is included as a variable or a component to be integrated into biophysical research and innovation, which contrasts to a gender strategic or systemic approach (van der Burg, 2019). Indeed, some argued that the tools stood in danger of operationalizing gender issues too much. As one researcher commented: "It toolizes it [gender]". Others feared that the Tools would promote a "culture of box-ticking" where, without ever having to leave the office, breeding teams using the Tools could get a "gender approval" stamp. By not being "out there", interacting with "people in the ground", the Tools could come to passivate women and men in agriculture and further increase the "distance" between scientists and "lay people".

Others argued that the complexity, contingency, and highly qualitative nature of social and gender dimensions does not allow for standardization and ordinal valuation. As one informant put it: "it is not just a yes/no answer and, you know, that nice decision tree", which starkly contrasts to a statement by a social scientist who participated in the piloting project:

> Looking at the process whereby breeders do trait prioritization; these are numbers, right? (...) You have to be willing to sort of come down to a single yes/no. And the social scientists [have] chronic difficulties with that because everything is contextual, everything is contingent, you know.

Additionally, although the Tools are meant to be adaptable enough to accommodate a wide range of crops and breeding contexts, there were those who considered the Tools as having largely been designed for perishable roots and tuber crops. In other words, the Tools produces not only gender but also particular

kinds of crops. As such, a social scientist proclaimed: “That is why I, politely enough, refuse to be a part of that family. Because it doesn’t work for everybody. Don’t force me to use it the way it is”. This echoed a broader reservation whereby some felt that the GBI, since having become hosted and coordinated by RTB-CIP, had become inward-looking. As one social scientist expressed it: “in the institutional life of the initiative, things have changed in a way that (...) not all crops and all people have been involved in the same way”. A crop breeder further argued:

> That’s why I felt [the piloting] is a little premature because we haven’t had enough reflections on these tools. They have been very top-down, very like.. Here it is. Here is how we are going to apply it. (...) It is the usual; not co-creating something, and that is a community that is pretty closed and.. I felt like that was another sentiment of, like, inclusiveness. There weren’t enough people in the room that should have been in the room.

To address this inclusion/exclusion issue, the organizers of the piloting project had extended invitations to participate in the piloting widely in their networks. This was also the reason why Nairobi was selected to host the piloting workshops, as it is a hub for CGIAR offices and research stations in Africa. At the “Knowledge-Sharing and Planning Workshop”, representatives from several breeding programs were present (see note 1), but some of these did not follow the piloting process further. This could reflect the lack of time and resources to do so, as the piloting could only financially support the beans and cassava teams, and/or aforementioned reservations towards the Tools. Indeed, what surfaces through this analysis is how the gender research community itself has different schools of thought, which in some cases may result in de-scription and rejection of the G+ Tools.

Conclusions

Using the concept of gender scripts, interpretative flexibility, and de-scription, the paper demonstrated how the G+ Tools co-produce gender, crops, and crop breeding through several interrelated performative roles. As a diagnostic and screening tool, the G+ Tools diagnose what is or needs to be known about men and women farmers and other user groups, including their gendered status, rights and roles, and screen crop traits according to their social impact. Importantly, the Tools help highlight the significance of women as essential “customers” of crop breeding programs and thus the importance of taking into consideration their knowledges, demands, and preferences. However, in relying on existing data, which are sometimes outdated and unrepresentative, the Tools may stand in danger of scripting, reproducing, and materializing stereotypical notions of men and women and their relationships with crops, and further passivate men and women in African agriculture. This is at odds with an understanding of gender as contingent, dynamic,

and constantly negotiated in relation to both human and nonhuman actors (including plants), and of women and men as active participants and co-producers of knowledge and innovation.

The Tools also perform the role as a communication device by translating complex gender dimensions in ways that adhere to the language, practices, and values of crop breeders and funding partners. While this can be a strategically important way of making gender relevant in a highly biophysical and donor-driven organization such as the CGIAR, the turn to a market logic may result in the perception that the G+ Tools are, in fact, a type of marketing tool, which in turn may script men and in particular women as "untapped markets" and "valuable investments". This raises important questions about who and what will be considered "valuable", "marketable", and "investable" enough within such a framework, as well as the ways in which gender equality and feminist goals may become depoliticized as gender and market-led approaches become increasingly conflated.

Finally, the Tools attempt to manage institutional and interdisciplinary power relations and negotiations by strengthening the position and voice of gender specialists (many of whom are women) relative to crop breeders (many of whom are men). However, while the need to include crop breeders as well as agricultural economists in developing and using the Tools was thoroughly recognized, albeit not always achieved, what the Tools may fail to manage are intradisciplinary negotiations and resistance within the gender research community itself.

The paper expands the scope of feminist technoscience studies to the underexplored area of crop breeding for development in Africa, demonstrating how a co-constructive understanding can provide insights into how gender, crops, and crop breeding are co-produced through novel practices and tools of gender-responsive crop breeding. Such insights are particularly timely given the given the renewed attention and commitment to gender equality and women's empowerment in agricultural research for development over the last decade, including within crop breeding.

Notes

1. Nairobi hosts, among others, the International Livestock Research Institute (ILRI), the International Institute of Tropical Agriculture (IITA), the International Potato Center (CIP), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the international Rice Research Institute (IRRI), the International Center for Tropical Agriculture (CIAT), World Agroforestry (ICRAF), and the International Maize and Wheat Improvement Center (CIMMYT).

2. Generally, we can think of a breeding program as consisting of five main stages: (i) setting goals and priorities; (ii) creating or identifying variability for relevant traits; (iii) selecting experimental varieties; (iv) testing and evaluating experimental varieties; (v) variety release, seed production, and distribution.
3. Amend means that, although a trait is considered to have a negative gender impact, the crop variety in question can be accompanied by other innovations or measures that can help counteract the negative impact (e.g., if the trait increases threshing for women and thus their time- and labor-burden, it could be introduced together with small-scale threshers).

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“Whose Demand?”: The Co-Construction of Markets, Demand and Gender in Development-Oriented Crop Breeding

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Abstract

Advancing women’s empowerment and gender equality in agriculture is a recognised development goal, also within crop breeding. Increasingly, breeding teams are expected to use ‘market-based’ approaches to design more ‘demand-led’ and ‘gender-responsive’ crop varieties. Based on an institutional ethnography that includes high-profile development-oriented breeding initiatives, we unpack these terms using perspectives from political agronomy and feminist science and technology studies. By conceptualising the market as an ongoing, relational performance made up of discourses, practices and human and nonhuman actors, we trace how the market is understood as an effective socioeconomic institution for soliciting demand, but also becomes a normative agenda. Construed as a demand variable, the relational and structural dimensions of gender are rendered less visible, which might strengthen rather than transform power relations’ status quo. On the other hand, a feminist science and technology perspective broadens the field of vision not only to the gendered dimensions of crop breeding, but also to the nonhuman actors, such as the crops and traits falling outside the market sphere of interest. By putting political agronomy and feminist science and technology studies into conversation, the article contributes to the development of a feminist political agronomy.

Keywords: Africa, CGIAR, crop breeding, gender, markets, demand, co-construction, feminist political agronomy

Introduction

Advancing women's empowerment and gender equality in agriculture is a recognised development goal, also within development-oriented crop breeding. At the same time, market-based approaches, founded on techniques and methods adapted from commercial crop breeding, have become highly advocated in crop breeding for development, especially in African countries, and strongly supported by private sector donors and political commitments and policies at the regional level (e.g. CGIAR System Council 2018; 2018; NEPAD 2016; Persley and Anthony 2017). By "putting clients, market requirements and value chain needs at the centre of the design and development process for new varieties" (Kimani 2017, p. 21), market-based approaches promise to increase varietal adoption rates and enhance development impacts by making crop breeding more demand-led (Persley and Anthony 2017). By further including social variables such as gender to better understand and meet the demands of the 'client', market-based approaches are also being framed as a way to render crop breeding more gender-responsive, meaning that "the perceptions, interests, needs and priorities of women and men (which differ because of their different roles and responsibilities in farming) will be considered in planning and decision-making" (Ashby and Polar 2021a, p. 2).[1] This is evident from initiatives and high-level institutional commitments in the CGIAR Consortium of International Agricultural Research Centers (hereafter the CGIAR), including the Excellence in Breeding Platform (EiB) and the Gender and Breeding Initiative (GBI) and the conceptual and methodological frameworks and tools they have developed (Ashby and Polar 2021a, b; Orr et al. 2018, 2021; Ragot et al. 2018).

The differences and links between 'market-based', 'demand-led' and 'gender-responsive' crop breeding tend to blur and require investigation. The former two are often used interchangeably by interlocutors and in the literature. For analytical clarity, however, we conceive of market-based approaches as a way to contribute to demand-led and gender-responsive crop breeding. While the latter two have become increasingly interrelated (see e.g. Polar et al. 2022), we consider them to be conceptually and methodologically distinct. For instance, demand-led breeding is not gender-responsive if gender is not taken into account (although one may question whether this is, then, truly demand-led). Furthermore, demand-led and gender-responsive breeding may or may not rely on market-based approaches and could instead be supported by, for instance, more traditional participatory approaches to plant breeding (e.g. Ceccarelli and Grando 2007; De Haan et al. 2019; Joshi et al. 2007; Sperling et al. 2001). While the adaptation of private sector and market-based approaches

[1] The 'client' is defined as "a customer, buyer, purchaser or receiver of a new crop variety, its crop produce or processed material from a seller, vendor or supplier in the value chain for a monetary or other consideration" (Tongoona et al. 2017, p. 65).

to crop breeding for development is not novel (e.g. Sumberg and Reece 2004; Sumberg et al. 2013a), the extent to which and the ways in which these approaches are now being institutionalised is unprecedented and thus warrant critical attention.

The conflation of gender and market-based approaches in agricultural research and development is far from new and has been subject to criticism by feminist scholars in the broader development literature (e.g. Collins 2016, 2018; Cornwall et al. 2008; Esquivel 2017; Gengenbach et al. 2018; Lyon et al. 2019; Prügl et al. 2021; Roberts and Soederberg 2012). However, few studies have examined the actors, discourses, practices and tools of the new market-based approaches to demand-led and gender-responsive crop breeding. Furthermore, despite the now frequent use of the term 'market' in crop breeding discourse, little critical attention has been paid to its meaning and how it is co-constructed with 'demand' and 'gender', particularly in relation to societal development objectives, including gender equality and women's empowerment.

Based on an institutional ethnography of high-profile development-oriented breeding initiatives, we unpack these terms and their co-construction, with the aim of contributing to the understanding of how gender-responsive demand is constructed in development-oriented crop breeding. In the analysis, we use perspectives from political agronomy to foreground the performative role of human actors, institutional settings and broader narratives and discourses, while insights from feminist science and technology studies (STS) further draw materiality and nonhuman actors into the analytical frame. We contend that, by putting these two scholarly streams into conversation, we gain a richer empirical and theoretical understanding of the mutual shaping of markets, demand and gender.

We find that the market is understood as an effective socioeconomic institution for soliciting demand, but also becomes a normative agenda. Across the continuum from socioeconomic institution to its normative meaning, the market is pivotal in the creation of an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded value. We identify a form of 'gene fetishism' (Haraway 1997), or what we refer to as 'trait fetishism', whereby the crop trait itself becomes the source of value, with some traits rendered less visible. Thus, it matters which markets are made, by whom and how, which in turn shape whose demand comes to matter. Indeed, markets are boundary-making and world-making (Barad 2007; Haraway 2016).

The article contributes to political agronomy and feminist STS by empirically investigating the co-construction of markets, demand and gender in crop breeding for development, which remains an underexplored topic in both fields. Additionally, we expand on the 'contested agronomy argument' of political agronomy, arguing that the 'gender agenda' must be recognised alongside other agendas that have shaped development-oriented agronomy over the last decades (Sumberg et al. 2012). By further

putting political agronomy and feminist STS into conversation, the article is novel in its contribution to advancing a feminist political agronomy.

In the following sections, we start by presenting the analytical framework and the methods and materials upon which the article is based. Subsequently, we outline the rise of market-based approaches to demand-led and gender-responsive crop breeding, drawing particular attention to the work of, and partnership between, the EiB and GBI. Subsequently, we unpack and discuss the market and its mutually shaped relationship with demand and gender from the perspective of political agronomy and feminist STS, before concluding.

Towards a Feminist and More-than-Human Political Agronomy

Political agronomy foregrounds the knowledge politics (i.e. the normative assumptions, political-institutional agendas and epistemological and technological logics) through which agricultural knowledge and technological innovations become constructed, shaped and contested. Scholars in political agronomy put forth the contested agronomy argument (Sumberg et al. 2012), which holds that the neoliberal project and the environmental and the participation agendas have "undermined the long-standing unity of purpose between government policy and agronomic objectives which dominated the politics of agricultural science for much of the last century" (Sumberg et al. 2013b). The neoliberal project refers to the growing role that the commercial sector plays as a driving force for agrarian change (e.g. Akram-Lodhi 2013; Friedmann and McMichael 1989; Friedmann 1993; Kherallah et al. 2002; Moseley et al. 2015), while the environmental agenda has drawn attention to the health and environmental impacts of (industrial) agriculture (e.g. Carson 1962; Loevinsohn 1987; Newell and Taylor 2018; Pimentel and Pimentel 1990; Pingali and Rosengrant 1994). Finally, the participation agenda, in attending to the rights and emancipation of farmers as a goal in and of itself, as well as a way to achieve more efficient development management (Sumberg et al., 2012), has called for de-centralised, participatory and bottom-up approaches to agricultural research and development (e.g. Chambers et al. 1989; Richards 1985; Scoones and Thompson 1994, 2009).

Thus, political agronomy helps attend to the human actors, institutional settings and broader narratives and discourses involved in the contestations over the place of the market, demand and gender in crop breeding. However, to gain a fuller understanding of this dynamic relationship, we argue in favour of adding a fourth element to the contested agronomy argument: the gender agenda. Indeed, the topic and dimensions of gender have challenged and to some extent shaped agricultural research and development since at least the 1970s (e.g. Farhall and Rickards 2021; Prügl and Joshi 2021; Pyburn and Eerdewijk 2021; Sachs 2019; Sachs et al. 2021; van der Burg 2019). This includes the numerous ways in which gender has shown to be integral to the neoliberal project and the

environmental and participation agendas (e.g. Ampaire et al. 2020; Collins 2018; Farnworth and Jiggins 2003; Galié 2013; Johnson et al. 2004; Jost et al. 2016; Nelson et al. 2002; Prügl et al. 2012; Razavi 2002).

Still, political agronomy has yet to significantly engage with gender studies and feminist theories. In the edited volume by Sumberg et al. (2012) that helped define the field of political agronomy, Sumberg et al. (2012) note how the participation agenda has highlighted women's role in agriculture and the need to empower women farmers, but the authors did not identify a separate gender agenda. When gender is mentioned elsewhere in the book, it is most commonly in passing (e.g. Erenstein 2012, p. 58; Ramisch 2012, p. 152; Sumberg et al. 2012, p. 188; Woodhouse 2012, p. 110). In a more recent contribution to political agronomy, Westengen et al. (2018) identify both the climate smart agenda and the gender agenda as "strategic framings in response to international policy trends" in the context of conservation agriculture in Zambia (also see Whitfield 2016), but do not draw on feminist scholarship or develop a broader argument on gender. Taylor et al. (2021), in turn, argue that divisions of class, ethnicity and gender are often "silenced in agronomic research", but do not extend the gender analysis further in their exploration of the knowledge politics of hybrid NERICA rice in India and Uganda, despite recognising that NERICA is also being promoted as a means to increase gender equality even if women are among the groups likely to experience increased drudgery related to NERICA.

Among the most thorough accounts of gender in the political agronomy literature, a book chapter by Rao and Huggins (2017) addresses gender and women's empowerment in the context of biofortified orange-fleshed sweet potato in Tanzania. The authors argue that the assumption that "women who adopt [orange-fleshed sweet potato] will feed it to their children (and eat it themselves), resulting in nutritional benefits (…) seldom plays out so neatly" (p. 107). Rather, Rao and Huggins (2017) demonstrate how the commercialisation of orange-fleshed sweet potatoes, which is traditionally considered a 'women's crop', is likely to negatively impact women, while favouring men in terms of income generation. Rao and Huggins (2017) assert that "[p]rojects rarely address the underlying gender relations and inequalities (including labour, time and resource allocation) that prevent both men and women from benefiting from these kinds of externally supported initiatives for farmers" (p. 107).

Thus, while gender, if at all addressed, in most cases appears to be lurking in the background of analysis, the literature demonstrates that gender does matter to political agronomy. Indeed, we argue that intersectional gender norms, roles and relations constitute critical components in our understanding of agricultural knowledge production and technological innovation and adoption. Thus, political agronomy has much to gain from engaging with gender studies and feminist scholarships in

similar ways to that which has been achieved in feminist political ecology and feminist political economy (e.g. Harcourt and Nelson 2015; Mollett and Faria 2013; Mutari 2001; Rai and Waylen 2014; Rocheleau and Nirmal 2015). We explore how feminist streams within STS and related fields can help broadening out the perspective on development-oriented crop breeding.

As Susan Leigh Star (1990, p. 43) and Donna Haraway (1997, p. 113) ask: *Cui bono?* Similarly, we may ask: whom do market-based approaches to demand-led and gender-responsive crop breeding serve? Or, said differently, whose demand comes to matter? Both Star and Haraway, along with other feminist scholars writing under such umbrellas as STS, posthumanism and new materialism, further argue that answering such questions require us to attend to both human and nonhuman actors and their relations (e.g. Barad 2003, 2007; Braidotti 2021; Frost 2011; Haraway 2008). In her agential realist framework, Karen Barad coined 'intra-action' (in contrast to interaction) to capture how the ability to act and materialise emerges from within, and not outside of, relationships among things (Barad 2007, 2012). Thus, agential realism extends agency beyond the 'autonomous', 'intentionally driven' and 'solid' human being to an understanding of agency as enacted through intra-action among and between human and nonhuman entities.

Thus, we can conceive of the market as an ongoing, relational performance consisting of intra-acting discourses, practices and human and nonhuman actors (also see Callon et al. 2002, 2007; Doganova and Eyquem-Renault 2009; Doganova and Muniesa 2015; Doganova and Karnøe, 2015; Kjellberg and Helgesson 2007; MacKenzie et al. 2007). This enables an understanding of how the market, demand and gender are given different shapes, meanings and outcomes in co-constructed ways. We can further conceptualise research and market discourses, practices, concepts and tools as Baradian 'apparatuses' that intra-act with other human and nonhuman actors (such as scientists and crops) to produce the matter and meaning of markets, demand and gender. Accordingly, apparatuses enact exclusionary boundaries (Barad 2003).

The question of who and what is rendered visible and invisible when markets become constructed is particularly critical considering that concepts and frameworks that simplify market processes and make them mentally tractable are essential to how markets function (MacKenzie 2009). Furthermore, as noted by Timothy Mitchell (2007): "[m]arkets would not work if people were not allowed to exclude things, to leave certain costs or claims out of the calculation, and to deny responsibility for certain consequences. (…) From this perspective, economics should be analyzed not in terms of the reality it represents (or fails to represent), but in terms of the arrangements and exclusions it helps to produce" (p. 244). In other words, market design and construction are ultimately about the politics of inclusion and exclusion.

Methods and Materials

Methodologically, we use institutional ethnography to study the discourses, practices, tools and lived experiences and tensions of scientists and other experts involved in formulating and implementing market-based approaches to demand-led and gender-responsive breeding programmes. The article draws on qualitative data collected mainly during field research in Kenya and Tanzania in 2019–2020. A total of 48 semi-structured and open-ended interviews were conducted either physically or virtually with crop breeders, agricultural economists and gender specialists (several of which are or were involved in the EiB and the GBI), along with national research institutes, donor representatives, governmental and non-governmental organisations and other academics and consultants. Additionally, observations were carried out during a workshop on trait prioritisation and evaluation in rice organised by the International Rice Research Institute, the Tanzanian Agricultural Research Institute and the private company AbacusBio; the EiB Virtual Meeting of 2020 and 2021; and a project co-organised by the GBI and the EIB, in which two gender-responsive breeding tools building on market-based approaches were piloted in several African-based breeding programmes of the CGIAR. Finally, document analysis of resources produced by the relevant actors was carried out, which included high-level organisational documents of the CGIAR, policies and frameworks of donor agencies and other development organisations, annual reports and other digital resources produced by the EiB, as well as workshop reports, working papers, briefs and additional resources produced by the GBI.

The Rise of Market-Based Approaches to Demand-Led and Gender-Responsive Crop Breeding

In 1986, when Janice Jiggins carried out the first assessment of gender-related impacts of the CGIAR, finding that crop breeding programmes largely failed to include the needs, preferences and selection criteria of women, she further argued that research programming should shift "the balance of decision-making to the collaborative model of commercial and industrial technology development, in which consumers and producers as well as the academic community, agricultural scientists, and the food industry have a determining voice" (Jiggins 1986, p. 85). Jiggins distinguished between agricultural research and technology development, contending that "[t]he latter has no function outside a definable market or market potential and the process of meeting the needs of that market cannot be effective and profitable without the involvement of members of that market in the determination of research criteria, design, testing and evaluation, or without early consideration of promotion, sales and servicing" (Jiggins 1986, p. 21).

The report by Janice Jiggins would contribute to the establishment of the CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation in 1997, which was meant to help develop "methodologies and organizational innovations for gender-sensitive participatory research" in plant breeding and natural resource management (CGIAR Science Council 2007, p. 1; also see Farnworth and Jiggins 2003). Testament of the interrelations between the participation and gender agendas, the project helped strengthen the need to engage both men and women farmers in participatory approaches to plant breeding, which has commonly involved evaluation of soon-to-be-released varieties either on-farm or on-station (i.e. participatory varietal selection). However, questions have been raised about the extent to which participatory approaches adequately reflect the wider conditions under which different social groups perform agricultural labour, their preferences beyond the (often production-related) traits already selected by the breeders, and their real-life decision-making and adoption behaviours, as well as the extent to which social and gender researchers are able to influence varietal design (e.g. Almekinders et al. 2019; Ashby et al. 2013; Cairns et al. 2021; Cernea and Kassam 2005; Voss et al. 2021; Weltzien et al. 2019).

However, the link that Jiggins made between gender, technology (varietal) development and definable markets, and the more collaborative model of decision-making, would not be tested in practice until almost four decades later. Dissatisfied with the low levels of adoption and development impacts of improved crop varieties (and thus low returns on investments), especially in African countries (e.g. Acevedo et al. 2020; Fisher and Carr 2015; Thiele et al. 2021), the Bill and Melinda Gates Foundation (hereafter the Gates Foundation) commissioned in 2016 an assessment of several CGIAR breeding programmes. The assessment would be carried out using the Breeding Program Assessment Tool (CGIAR System Management Office 2018), which employs criteria used to evaluate the effectiveness and efficiency of commercial crop breeding programmes. The development and use of the tool were led by the University of Queensland, Australia, which is a key partner of the Demand-Led Breeding (DLB) group.

Established in 2014, the DLB consists of a partnership between several African academic and research organisations (some of which are also part of the CGIAR), supported by the Alliance for Food Security in Africa, which comprises of the Australian Centre for International Agricultural Research, the Crawford Fund and the Syngenta Foundation for Sustainable Agriculture (hereafter the Syngenta Foundation) (Persley and Anthony 2017)**.** In 2017, the group published the handbook "The business of plant breeding: Market-based approaches to plant variety design in Africa" which described demand-led breeding as combining "the best practices in market-based new variety design with innovative plant breeding methods and integrates both of these with the best practices in business as

a new way of approaching the business of plant breeding to deliver benefits" (Persley and Anthony 2017, p. xi). Closely associated with both the neoliberal project and participation agenda, market-based approaches are said to go beyond the limited geographical and user scope of participatory approaches to plant breeding, with proposed benefits including "higher adoption rates, the tapping of larger markets and hence the use of economies of scale. It can lead to better returns to investment and is potentially attractive to private investment" (Kimani 2017, p. 21).[2]

The assessment of CGIAR breeding programmes using the Breeding Program Assessment Tool identified a key missing component to be the "systematic use of product profiles, based on continually updated market intelligence and stakeholder consultations, to ensure that new varieties are designed to meet the requirements and preferences of women and men farmers, consumers, traders, processors and others along the value chain" (CGIAR System Council 2018, p. 7). Product profiles, which are standard in most commercial crop breeding programmes, can be defined as "the full set of targeted attributes, or the ideotype, that a new plant variety or animal breed is expected to meet to successfully be released onto a market segment" (Ashby and Polar 2021a, p. 2).[3] The market segment constitutes a "geographic area or a group of people having a relatively homogeneous demand for a commodity" (Ragot et al. 2018).[4] The assessment of CGIAR breeding programmes would further come to inform the establishment of the Funder-led Crops to End Hunger initiative which is meant to help facilitate "a comprehensive modernization agenda for crop breeding in the CGIAR", which includes the institutionalisation of market-informed product profiles (CGIAR System Council 2018, p. 1).

Established in 2017, the CGIAR Excellence in Breeding Platform (EiB) – which has drawn on the work of the DLB, as evidenced during an interview with a representative from the EiB, who had the DLB handbook on display in their office – was tasked with coordinating and overseeing the Crops to End Hunger initiative (EiB n.d.). Module 1 of the EiB on product design and management is responsible for institutionalising the market-based product profile development framework, which in practice entails assisting CGIAR breeding teams and national partners in segmenting the market in which the breeding programme operates and thereafter aligning breeding pipelines and designing product profiles (also

[2] While the environmental agenda is less evident in the context of the new market-based approaches to demand-led and gender-responsive crop breeding, it is present in arguments that crop varieties developed using such principles can help increase adoption rates of climate resilient varieties.

[3] The plant ideotype was first defined by Donald (1968, p. 389) as, in the broadest sense, "a biological model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, a crop ideotype is a plant model which is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar".

[4] The concept of market or customer segments is similar to what was known in the 1970s and 1980s as "recommendation domains", defined as "[a] group of roughly homogeneous farmers with similar circumstances for whom we can make more or less the same recommendation" (Byerlee et al. 1988 [1980], p. 71).

see Mashonganyika 2018). Thus far, in close cooperation with breeding programmes, the EiB has identified 320 market segments across 26 crops, boasting that these reflect "a unique combination of grower and consumer needs and all are gender-inclusive" (EiB 2021, p. 3). Indeed, since 2017, the EiB had engaged in conversations with the CGIAR Gender and Breeding Initiative (GBI) to explore the possibility of incorporating their gender-responsive breeding tools into the EiB's product profile development framework (EiB 2018, 2019).

In 2016, a group of crop breeders, geneticists, economists and gender specialists from and beyond the CGIAR met in Nairobi, Kenya, to discuss how to "help catalyze a deliberate shift towards gender-responsive breeding in the CGIAR" (CGIAR Gender and Breeding Initiative 2017, p. 1). The group convened the following year, this time officially known as the GBI, hosted and coordinated by the CGIAR Research Program on Roots, Tubers and Bananas and the International Potato Center. During its foundational workshops, the GBI also invited a private sector company and engaged a consultant with expertise in commercial breeding to inspire new ways and frames of thinking on how to systematically bring gender into the crop breeding process, including at the very initial stages when priorities are set and varieties are designed. We thus see instances of the conflation of the neoliberal project and gender agenda. Together with the consultant, the GBI developed a working paper titled "From market demand to breeding decisions: A framework", which presented a framework based on market segmentation and product profiles meant to help capture and respond to gendered needs and market demands through breeding (Ragot et al. 2018). Notably, the consultant also boasts the Syngenta Foundation among its clients which, as mentioned, is one of the key partners of the DLB (Nouvelle France Genetic n.d.), thus indicating cross-cutting relations and knowledge sharing.

In a companion paper, Orr et al. (2018) further argued that gender and social targeting for resource-poor stakeholders requires a marketing approach. The paper advocates the use of an adapted version of the consumer marketing approach Segmenting-Targeting-Positioning, around which the GBI would come to design a set of gender-responsive crop breeding tools known as the Gender+ (G+) Tools (Ashby and Polar 2021a, b; Orr et al. 2021; also see Forsythe et al. 2021). The G+ Tools consist of the G+ Customer Profile Tool and the G+ Product Profile Query Tool, both of which are to be used by a social scientist with gender expertise together with a breeder familiar with market-based breeding approaches.[5] By collating geographical, gender and other social variables, the G+ Customer Profile

[5] The GBI uses the concept 'customer segments', which expands somewhat on the definition of a market segment: "[a] group of users who have both a common set of constraints and a common, unique and relatively homogenous need (demand) for a breeding program product" (Orr et al. 2021, p. 19). Similar to the definition of the 'client', the 'customer' is defined as "the growers who use the breeding product (crop varieties or animal

Tool helps segment, target and profile the customers of a breeding programme (Ashby and Polar 2021a). The G+ Product Profile Query Tool "conducts an analysis of gender gaps in agriculture to help a breeding program detect whether a given trait has implications for gender equity in farming and in the rest of a commodity's value chain" (Ashby and Polar 2021b, p. 2), and generates "positive and negative ordinal values for a gender impact score to help breeders score and rank the traits to prioritize" (Ashby and Polar 2021b, p. 2). In 2020, the G+ Tools were piloted in several African-based breeding programmes of the CGIAR, including cassava, sweet potato and bean breeding programmes, in a project co-managed and co-sponsored by the GBI and EiB (also see Polar et al. 2022). Besides refining and adjusting the tools, the project was also meant to explore ways of adapting the tools to the EiB product profile development framework.

Unpacking the Market and its Co-Construction with Demand and Gender

Next, we consider how the discourses, practices and human and nonhuman actors involved in the new market-based approaches to demand-led and gender-responsive crop breeding come to mutually shape the matter and meanings of the market, demand and gender. We find that the market is understood as an effective socioeconomic institution for soliciting demand, but also becomes a normative agenda.

The gendered and more-than-human marketplace

In the DLB handbook, the market is defined very concretely as "a forum that allows buyers and sellers of a specific good or service to interact in order to facilitate an exchange" (Tongoona et al. 2017, p. 77). In other words, the market is understood in the more conventional sense of a socioeconomic institution – in this case a marketplace – for exchanging goods. Consistent with Moseley's (2021) argument that the market has become equated to the value chain in development literature, the market in market-based approaches is further defined according to the agricultural value chain, which describes "a set of value-adding activities performed by all actors from production through to the consumption of a specified product. (…) Value chain analysis helps in understanding the buying and selling decisions of each stakeholder in the supply chain from farmer (or producer) to consumer" (Kimani 2017, p. 17). Demand, then, can be understood as the "needs and/or preferences expressed by different value chain actors" (Ragot et al. 2018, p. 9).

The piloting of the G+ Tools revealed the character of this value chain understanding of markets and demand, and further demonstrated how gender enters the equation. Using the G+ Customer Profile

breeds), and the other value chain actors, like traders, processors, or consumers who use one or more of the end-products" (Orr et al. 2021, p. 5).

Tool, the piloting teams mapped different crop products and sex-disaggregated actors along the respective value chain. Combined with an understanding of gender differences in rights, roles and status, demand (i.e. preferences and needs) was seen as reflecting the unique responsibilities and labour of men and women along the value chain, which further differed according to whether they were involved in formal or informal markets or urban or rural markets. In several cases, the available data revealed that men more so than women were engaged in large-scale marketing and transportation, which was translated into men expressing higher demands for agronomic traits for income generation (e.g. various forms of yield), among others. In turn, women's demands were often seen as reflecting their roles in labour-intensive production and post-harvest activities, such as weeding, harvesting, processing and cooking, as well as in food security. In some cases, the role of industry in shaping demand was also highlighted, leading to a differentiation between the food market and the industrial market.

Additionally, using the G+ Customer Profile Tool, the customer segments were described according to such factors as the size of the market, market value, average selling price, predicted growth (visioning and foresight are key in market-based approaches) and expected development impacts (e.g. poverty alleviation, food security, malnutrition, gender equality and climate mitigation). Together with output generated using the G+ Product Profile Query Tool, the G+ Tools thus provided information that could be utilised for segmenting and targeting market or customer segments, upon which product profiles could be designed, taking gender into account. For instance, for cassava in Nigeria, the piloting team selected a segment consisting of small and medium-scale farmers and processors (many of whom are women) that produce fermented cassava products (e.g. *gari* and *fufu*) both for home consumption and for marketing in rural and urban areas. Similarly, for sweet potato in Uganda, the piloting team targeted a segment consisting of men and women smallholder farmers producing orange-fleshed and white-fleshed sweet potato either food use (boiled or as flour) or for processing (also see Polar et al. 2022). Thus, demand also reflected the end use of the product and its processing.

Consequently, the construction of markets and gender appears mutually reinforcing: the market provides an analytical lens through which to delineate gendered customers and demand. In turn, including gender as a variable allows further micro-segmentation of the market and the potential identification of underserved market segments, thus providing an improved understanding of who the clients are and their demands. As a gender specialist put it:

> *Especially in Africa, women are big decision-makers on what is planted, what is eaten, what is utilised at the household. (…) So that places women at a very special place [in] unlocking this whole demand.*

According to literature on the shaping of markets (e.g. Callon et al. 2007; Doganova 2020; Doganova and Eyquem-Renault 2009; Doganova and Karnøe, 2015; Kjellberg and Helgesson 2007; MacKenzie et al. 2007), devices such as the G+ Tools do not only describe but indeed construct the market. Thus, through intra-action between the piloting teams and the G+ Tools (i.e. Baradian apparatuses), differential markets are brought into being, consisting of different arrangements of intra-acting and gendered value chain actors, crops, crop traits and products, geographical areas and other variables, which in turn co-produce demand and gender. This is a power-driven and political act, as it implicates moving humans and nonhumans from outside to inside the market. That which falls outside the market thus becomes "constituted in terms of its relation to the market – that is, in terms of its deficiencies, as the nonmarket, as something defective or dead" (Mitchell 2007, p. 248). What happens, then, to those human and nonhuman beings and ways of being that are part of the nonmarket or whose demand is not considered homogeneous enough to be considered demand in the first place? Or does the inclusion of gender as a variable in market segmentation and targeting result in the construction of fairer and more just markets and demands?

As expressed by several interlocutors, to include gender as a variable or component represents a powerful rhetorical resource and politically strategic way of rendering gender tangible in a more technical and biophysical way, which in turn can help support gender objectives in and through crop breeding. Indeed, as noted by Polar et al. (2022), "[u]sing the G+ tools stimulated (…) a demand for deeper gender analysis" (p. 504). In a sense then, similar to that observed by Comaroff and Comaroff (2009) on ethnicity, gender is "rendered negotiable by means of the abstract instruments of the market" (p. 24). However, when demand and gender are reduced to a variable or component, notably sex-disaggregated trait and varietal preferences, there is a danger of masking the relational, structural, institutional and normative dimensions of demand and gender, as addressed further below. Moreover, trait and varietal preferences may not fully predict adoption and buying behaviour (e.g. Cairns et al. 2021) nor do they necessarily represent meaningful choices and may in several cases reflect "a self-subordinating adaptation to a restricted choice, to accommodate (…) inferior access to labor, capital, farm equipment, seed, fertilizers, pest control products and market access" (Polar et al. 2021).

Furthermore, research methods for eliciting demand are themselves performative and (re)produce only certain aspects of demand (e.g. Almekinders et al. 2019; Law 2009; Law and Ruppert 2013). For instance, Almekinders et al. (2019) note how "willingness-to-pay studies enable farmers to display the behaviour of a market actor that takes rational decisions. (…) They may, for example, not consider farmers' behaviour as employers of landless labourers, as parents wanting to teach their children, or as good community members that feel the obligation to share with and/or use seeds". Many of the

behaviours that Almekinders et al. (2019) describe are likely shaped by gender norms and relations. Thus, when defined according to expressed preferences and needs generated using methods that provide only partial perspectives, we gain only a limited understanding of what constitutes demand, including its gendered nature. Consequently, this may render other needs less visible, including the need for relational, structural and collective change.

Additionally, gender is just one of many factors used to define the market and demand. Our own and others' observations indicate that the definition of market segments in the CGIAR have thus far been biased towards agroecological zones and agronomic factors. For instance, Cobb et al. (2019) note how "social science teams at institutions such as CGIAR centers have developed protocols for assigning relative values to traits in interactions with particular subsets of farmers, but this has rarely carried through to the design of formal product profiles". These findings indicate that, despite multidisciplinary breeding teams being a key principle in market-based approaches, much of the decision-making power remains in the hands of the crop breeders, which in turn render the work of gender specialists, and the gender specialists themselves, less visible. A participant at the EiB Virtual Meeting in 2020 observed a discussion taking place in the digital chat, which told of the EiB's lack of engagement with social scientists:

> *I think the point has come up in the chat a couple of times regarding the role of social scientists [and] getting help from social science teams in both characterising market segment and designing product profiles, and we know that EiB has [inaudible] no capacity in that area.*

However, due to the increasing role they play in international development, donors are likely to have a greater impact on the choice of market segments and product profile design than crop breeders (e.g. Haydon et al. 2021; Richey and Ponte 2014; Pingali et al. 2012, 2016). As a crop breeder put it: "behind the scenes, everything is driven by the donors. So, they tell you: 'we have money to do drought'. You cannot tell them: 'no, no, no, we cannot do drought because nutrition is the biggest problem'. They won't listen to you. You lose the money". Indeed, almost every respondent we talked to argued or agreed that private sector donors, notably the Gates Foundation, were the major drivers of both the gender agenda and market-based turn in the CGIAR. In other words, through the lens of knowledge politics, we see how institutional and disciplinary power dynamics situate some groups of human actors, many of whom have diverging interests and values, differently in the broader system of crop breeding organisations. This renders such actors, notably crop breeders and donors, more 'powerful' and strategically positioned in market design and construction. Thus, the question of *whose* demand is intimately connected to the question of *who* demands.

Donors may or may not favour market segments that include defined gender objectives, depending on whether these are perceived to have the highest achievable impact and how impact is measured and valued. Other factors such as the level of poverty, the size of the market, the market value, the number of farmers and predicted growth may come to outweigh gender objectives (although these are not mutually exclusive). Notably, a gender specialist shared a story of when she had been told by a donor representative that what was most critical was the market and the economics at play, and that "we can get it without gender, but with gender it sounds nice". This may suggest that gender commitments are, at times, mostly tokenistic and an act of lip service. As an interlocutor observed: "[T]he Gates programme officers that I know, mostly haven't taken gender very seriously".

These comments raise important questions about what will, in fact, be considered 'valuable' within a market-based framework to crop breeding. As argued by Doganova (2020), the broader question of "what is the value of (…)?" is "increasingly addressed in the language of quantification and economic calculation" (p. 256). Tellingly, there are increasing efforts in the CGIAR to generate market intelligence that allows economic values to be assigned to different crop traits. Among others, several CGIAR breeding programmes, some with financial support from the EiB, have carried out projects in cooperation with the private company AbacusBio (e.g. Balogun et al. 2022; Ibabao 2019; Teeken et al. 2021). AbacusBio uses a software called 1000Minds, which is based on conjoint analysis that 'forces' surveyed value chain actors to make trait-by-trait trade-offs, where each trait has a quantitative value (Balogun et al. 2022). The output of the survey "provides insights into segmentation of the population (…) [and] also informs derivation of economic values that can be employed by breeders in making selection decisions" (Balogun et al. 2022). Thus, 1000Minds represent another type of boundary-making and world-making Baradian apparatus.

However, attaching monetary values to the social functions of crops has proven difficult, as expressed by a crop breeder:

> *We hear this in cassava for example, "in-ground storability", how long something can stay in the ground after it has matured. You can't put a dollar value on that because the reason for that is its flexibility and harvest. It is a food security function. (…) So, try to define a market around that or put a value on that... I mean, good luck! I don't even know how you can. So, we are struggling with that a little bit and re-defining what a market means is. (...) Because otherwise we are not going to get out of that same rut of yield. Because yield means more profit, right, you can't argue with that. There is a dollar value very heavily attached to that.*

Thus, some interlocutors expressed concerns about what would happen to crops and crop characteristics, trait and products considered unproductive or less economically valuable. As a gender

specialist expressed it: “My worry though is, like, the big funders of breeding research are very, very interested in the market-based breeding. And so, over time, you’ll find that the breeding for these nonmarket-oriented varieties become a bit of a challenge”. They further pointed out that many women small-holders are customarily in charge of nonmarket-oriented varieties, which often constitute subsistence or food security crops. In contrast, crops such as maize were described by an agricultural economist as “one of the business-wise most interesting crops. It’s bulky, it is cultivated everywhere and they can buy it every year [because it is a hybrid]. So, seed companies have a real interest in growing maize. Unlike if you grow sorghum; as a company, that is not really a money-maker”. What is articulated here is a recognition of the fundamentally important role that the crops and their characteristics play in shaping agricultural development.

The ways in which the traits of for example cassava and maize have primed for very different agricultural, and therefore societal, trajectories have long been recognised by agrarian scholars and environmental historians (e.g. McCann 2007; Scott 2009, 2017). Contemporary studies of the same crops have shown that also today their characteristics may both promote or inhibit enrolment in market relations (e.g. Fischer 2022; Roman and Westengen 2022). Fischer (2022) uses the concept of intra-action to describe how the properties of maize intra-act “with local ecologies and farm practices as well as with markets and policies”. Moreover, crops are also implicated in the performance of gender (e.g. Fritz 1999; Howard 2003; Padmanabhan 2007; Tapia and De la Torre 1998). For instance, Amadiume (1987) and Korieh (2007, 2010) show how yams and cassava have been a defining feature of male and female identity in Nigeria, respectively. Thus, we have to, as Catriona Sandilands argues when discussing the feminist vegetal turn, “look at the specific, material ways in which particular people have relations with particular plants in particular moments, both as these relations may serve the interests of heteropatriarchal capitalism and as they might offer sites of resistance” (Cielemęcka and Szczygielska 2019).

However, upon questioning, a crop breeder from the DLB was quick to argue that market-based approaches would leave no trait behind:

> *Almost any trait has economic value. If somebody values it, that is a market. [...] If somebody likes it, that is a market. Everything has a market! What may differ is the size of that market. What you may say is that there are niche markets and there are bigger markets. There are winning traits and must-have traits. [...] So this is why I find it completely encompassing.*

This is reminiscence of Donna Haraway’s ‘gene fetishism’ (building on Marx’s ‘commodity fetishism’), where genes themselves are seen as the source of value (Haraway 1997). “This kind of gene fetishism”, Haraway (1997) argues, “rests on the denial and disavowal of all the natural-social articulations and

agentic relationships among researchers, farmers, factory workers, patients, policy-makers, molecules, model organisms, machines, forests, seeds, financial instruments, computers, and much else that bring 'genes' into material-semiotic being" (p. 143). Similarly, the kind of 'trait fetishism' (which is fundamentally a type of gene fetishism) we have observed in market-based approaches to demand-led and gender-responsive crop breeding may have the effect of concealing the human-nonhuman intra-actions and the knowledge politics involved in bringing the trait into being or indeed render some traits (and their underlying relational arrangements and politics) less visible, notably those considered less economically valuable or for which it is challenging to determine a monetary value.

Gender and the market as a normative agenda

Ideologically, the market was seen by proponents of market-based approaches as a way to transform 'traditional', subsistence-based livelihoods of resource-poor, small-scale farmers. Firmly situated within the neoliberal project, a crop breeder involved in the DLB expressed: "we want to transform farmers livelihood mainly with income generation"; while another argued that "you don't have to grow something because you eat it. No, it is because it has a market. Once you have the money, you can decide what to eat". Moreover, the market and market-based approaches were portrayed as equitable, fair and self-sustaining, as exemplified by a statement by a crop breeder of the DLB:

> *The more you do business-oriented breeding, the more it helps everybody. (…) It does not disadvantage any group. (…) It doesn't matter whether you are a man or woman. Anybody can do business.*

Indicative of the conflated relationship between the neoliberal project and the gender agenda, this and similar statements further echoed a perception of women as entrepreneurial, business savvy and "pretty competitive. (…) just go downtown [to the marketplace] and you'll see", as one interlocutor said. Such a perception also aligns with a normative perspective where individuals are expected "to take care of themselves and operate successfully under competition" (Altan-Olcay 2015; also see Rankin 2010). Highlighting such characteristics are seen as moving beyond (albeit not fully replacing) traditional and more degrading conceptions of 'third world women' as "helpless beggars" (Bajde 2013) and "suffering victims" (Valencia-Fourcans and Hawkins 2016) who lack agency and become passive recipients of development (e.g. Mohanty 1984; Peterson 2010; Spivak 1988; Wilson 2011). As a gender specialist expressed when talking about African women agri-business owners:

> *[Let's] not paint a black tone picture [of] a woman with a [hand] hoe, you know, struggling there with a torn kitenge (…) Look, they are providing employment! Look, they have overcome so many barriers for them to be where they are!*

Constructing women in this way shares strong parallels also to neoliberal and normative arguments for efficiency. As touched upon, market-based approaches more broadly are framed as a way to increase the efficiency and effectiveness of crop breeding in terms of, most notably, higher varietal adoption and turnover rates and, as a result, enhanced development impacts and (nonmonetary) returns on donor investments. More specifically, market-based approaches also tap into the "efficiency argument for gender equality", which is strongly related to the "business case for gender equality" and "gender as smart economics" (e.g. Berik 2017; Chant and Sweetman 2012; Roberts and Soederberg 2012; World Bank 2006, 2012), thus further demonstrating the conflation of the neoliberal project and the gender agenda.

With a legacy dating back to the Women and Development paradigm of the 1970s (Chant and Sweetman 2012), the efficiency argument holds that reducing gender inequality and investing in women results in more effective corporate performance, higher economic growth and improved development outcomes. Women are often portrayed as being more efficient and responsible than their male counterparts (e.g. for child health, nutrition and education) (e.g. Lyon et al. 2019; Prügl and Joshi 2021), but prevented from reaching their full, 'untapped potential' due to gender inequalities in, for instance, access to productive resources and markets (e.g. FAO 2011). Thus, by integrating women more tightly into the market, market-based approaches are also framed as a way to contribute to gender equality and women's empowerment.

Doss (2017, 2018), however, draws attention to how the conceptual thinking and empirical basis for women-focused agricultural development have yet to be well developed (also see e.g. Anderson et al. 2020; O'Laughlin 2007). Gengenbach et al. (2018) further note how the assumption that "simply incorporating women farmers into agricultural value chains will boost rural incomes and food security" is problematic as it tends to ignore "varied axes of differentiation among rural women" (Gengenbach et al. 2018). Among others, access to well-functioning markets, market information and bargaining power during market exchanges can be highly structured according to intersectional gender norms and relations (World Bank et al. 2009). Thus, while place and time-specific nuances exist (e.g. Crossland et al. 2021; Forsythe et al. 2015, 2016; Orr et al. 2016; Quisumbing et al. 2015; Rousseau et al. 2019), several studies have shown that the introduction of new crop varieties and shifts in markets and on-farm practices can enhance men's control over crops and decision-making at the cost of female disenfranchisement, particularly when food and subsistence crops become commercialised, while women continue to supply the agricultural labour (e.g. Carney and Watts 1990, 1991; Dolan 2001; Dzanku et al. 2021; Fischer and Qaim 2012; Kent 2018; Njuki et al. 2011; Sorensen 1996; Tavenner et al. 2019). Thus, a gender specialist expressed her concern about the attention afforded to commercialisation in the CGIAR:

> *[A] lot of the work that we do is about commercialisation. And I find that quite problematic for two reasons: because commercialisation I think is very gendered, and two, because I don't think necessarily everybody wants to go for commercialisation. (…) I think when you go into commercialisation then (…) suddenly you change the division of labour and the benefits. And then there is probably the question also for those who are interested in commercialisation [but] can't actually get there.*

In other words, the evidence base supporting market-based approaches to gender equality and women's empowerment remains poor (Gengenbach et al. 2018). Furthermore, the efficiency argument for gender equality has been strongly criticised by feminist scholars for defining agency and empowerment as an exercise of individual choice and preferences and in terms of efficiency, productivity, market participation and acquisition of assets. They argue that such a narrow definition may undermine relational, structural and collective dimensions of agency and gender and strengthen rather than challenge patriarchal and capitalist institutions of power (e.g. Chant and Sweetman 2012; Collins 2016; Cornwall and Rivas 2015; Esquivel 2017; Haydon et al. 2021; Lewis 2001; Roberts and Soederberg 2012; Wilson 2011, 2015).

However, as noted by Ferguson (2015), there is currently little funding outside of the "business case for gender equality" framework, which means that gender experts often "end up speaking in this language and preparing reports, speeches and presentations that reinforce the embedding of a narrow and problematic vision of gender equality". Indeed, the efficiency argument has become highly advocated by private sector donors, including the Gates Foundation (e.g. Gates Foundation 2008, 2012, n.d.; Farhall and Rickards 2021; Fejerskov 2017, 2018; Gates 2014, 2019; Haydon et al. 2021). For instance, in their orientation document on "Creating gender-responsive agricultural development programs", women are considered instrumental to the success of the foundation, including for the adoption of agricultural technologies (e.g. crop varieties) and for increasing agricultural production (Gates Foundation 2012). Furthermore, published in 2018, the first Foundation-wide gender strategy focuses on women's economic empowerment (Gates Foundation n.d).

Thus, when the market is promoted as a normative agenda entailing a set of neoliberal values, such as individualism, effectiveness and competition, according to which demand, gender equality and empowerment become defined, it may contribute to changing the "perceptions of individual worth or value, away from an inherent humanness or collection of basic rights, and towards consideration of what they [women] can contribute economically" (Haydon et al. 2021). Thus, while the market as a normative agenda may bring the individualised demand of the 'entrepreneurial woman' to the fore, many questions remain about the potential of market-based approaches to bring about socially just

change at the collective, normative and structural level. Furthermore, what may the implications be when gender equality and women's empowerment come to hinge on the uncertainty of the market and the commercial success of crop commodities and produce?

Conclusion

Market-based approaches have become a prominent mean to contribute to more demand-led and gender-responsive crop breeding. This is evident from initiatives and high-level organisational commitments in the CGIAR, including the conceptual and methodological frameworks and tools developed by the Excellence in Breeding (EiB) Platform and the Gender and Breeding Initiative (GBI). However, despite the now frequent use of the term market in crop breeding discourses, little critical attention has been paid to the meaning of this concept and its co-construction with demand and gender, including in relation to societal development objectives. Using a combination of perspectives from political agronomy and feminist STS, we sought to unpack these concepts and their mutual shaping, with the aim of contributing to the understanding of how gender-responsive demand is constructed in development-oriented crop breeding. We argue that, by putting these two scholarly streams into conversation, we gain a richer empirical and theoretical understanding of the co-construction of markets, demand and gender.

Conceiving of the market as an ongoing, relational performance consisting of intra-acting discourses, practices and human and nonhuman actors enables an understanding of how the market, demand and gender are given different shapes, meanings and outcomes in co-constructed ways, including in ways where the market discourse often comes to dominate. Political agronomy helps foreground the human actors, institutional settings and broader narratives and discourses. In particular, through the lens of knowledge politics, we saw how disciplinary and institutional power dynamics situate crop breeders and donors in especially powerful and strategic positions in market design and construction. Additionally, the contested agronomy argument helped situate and contextualise market-based approaches, especially as they relate to the neoliberal project and the participation and gender agendas. Feminist STS, in turn, in this case using a Baradian framework, allowed us to expand the analytical lens to include materiality and nonhuman actors, including the performative role of the G+ Tools, the 1000Minds software, research methods and crops in the co-construction of markets, demand and gender. Accordingly, feminist STS can complement the cultural and discursive analysis of political agronomy, taking gender into account beyond a mere nod to its importance. Furthermore, feminist perspectives draw into sharp relief the question of who becomes included and excluded as markets become constructed, determining whose demand comes to matter.

We found that the market in one sense simply means utilising the socioeconomic institution, the marketplace, as the solicitor of demand. In the marketplace, gender tends to be reduced to a variable used to constitute market segments. Including gender as a variable or component represents a politically strategic way of rendering gender tangible in a more technical, biophysical and integrative sense, which in turn can help support gender objectives in and through crop breeding. However, such an integrative component approach may mask the complexity, relationality and institutional and structural dimensions of gender and thus limit our understanding of what constitutes demand. Furthermore, in being one variable among many according to which markets and demands are defined and targeted, and where crop breeders and donors hold much of decision-making power relative to gender specialists, gender appears to take a backseat.

The market-based understanding of gender thus becomes political. As a normative agenda, the market represents a way to transform 'traditional', subsistence-based livelihoods of resource-poor, small-scale farmers in ways that are fair, equitable and sustainable. Gender and demand are framed in neoliberal agential terms, with women constructed as competitive, business savvy, entrepreneurial, responsible and efficient, which in many ways casts women and their agency in more empowering ways. However, there is currently little evidence supporting market-based approaches to gender equality and women's empowerment in agriculture. Indeed, such claims remain problematic as intersectional gender norms and power relations often shape access to markets and information, as well as bargaining and buying power. Furthermore, defining agency and empowerment in terms of individualism, efficiency and market access may undermine, as above, the relational, structural and collective aspects of agency and gender and strengthen rather than challenge patriarchal and capitalist institutions of power.

Across the continuum from socioeconomic institution to normative agenda, the market is pivotal in the creation of an economic and ideological framework through which people, crops and crop products, traits and characteristics are afforded value. This further gives rise to a form of trait fetishism that may come to conceal the human and nonhuman intra-actions and the knowledge politics that bring traits into being, while rendering some traits less visible. Indeed, the analysis revealed how humans and nonhumans that do not readily fall within the narrow confines of such a framework may stand in danger of being excluded; as being part of a 'deficient', 'defective' or even 'dead' nonmarket. In other words, the market creates insiders and outsider, inclusions and exclusions. Thus, it matters which markets are made, by whom and how, which in turn shape whose demand comes to matter. These are considerations that should be at the forefront as market-based approaches to crop breeding

for development are being developed and promoted, including in relation to gender and other social development objectives.

The article contributes to political agronomy and feminist STS by empirically investigating the co-construction of markets, demand and gender in crop breeding for development, which remains an underexplored topic in both fields. Additionally, we argue that gender needs to be added as a fourth agenda to the contested agronomy argument, and that doing so allows us to better contextualise and evaluate new market-based approaches. We further assert that political agronomy can benefit from taking feminist STS analysis of materiality and nonhumans seriously, among others because they are sites of human and material resistance to ideologically driven constructions of markets, demand and gender. Given the centrality of gender in farming systems and agricultural knowledge production and technological innovation, the gender agenda and feminist analysis have the potential for broader applications in political agronomy. As such, this article contributes towards advancing a feminist political agronomy.

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Feminist Crops: A More-Than-Human Concept for Advancing Feminist Crop Breeding for Development

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Abstract

Gender matters in agriculture and crop breeding teams are increasingly being asked to develop plant varieties that respond to the needs and preferences of both men and women. Achieving gender-responsive crop breeding requires communication and cooperation across disciplines, not least between crop breeders and gender specialists. The coming together of plant sciences and gender studies necessitates novel ideas, concepts, and approaches that unite nature with culture and the material with the social. However, the development of such approaches is still in its infancy. Empirically grounded in experiences in and observations of social and natural scientists working at the intersection of gender and crop breeding in an African context, this article contributes to filling this gap by proposing the concept of the "feminist crop". The feminist crop captures the entanglement of crops with women's embodied practices, knowledges, capabilities, and power, and contributes to an ethico-onto-epistemological and methodological investigation of how intersectional gender identities and relations are embedded in plant–people entanglements. Using examples from banana, yam, and cassava, I explore how the feminist crop can expand the boundaries of how we think about agency, power, and empowerment in agriculture, as well as how plant genome editing grounded in the feminist crop concept may be used as a feminist tool to entangle plants and people in more socially just ways. Ultimately then, the feminist crop contributes to advancing feminist crop breeding.

Keywords: Africa, crop breeding, gender, genome editing, plant agency

Introduction

Gender matters in agriculture: gender norms and relations shape how, under what conditions, and to what ends different groups of men and women produce, process, consume, store, trade, and market seeds, crops, and crop products (e.g., FAO 2011; Kerr 2017; Quisumbing et al. 2014; Raney et al. 2011). This, in turn, may manifest itself in the form of different knowledges of and preferences for crop species and traits (e.g., Weltzien et al. 2019; Marimo et al. 2020). For instance, women farmers in West Africa have been found to prefer sorghum varieties that can withstand low soil fertility as they experience less reliable access to fertile land, manure, and fertilizers (Leiser et al. 2018). Public crop breeding has a relatively long tradition of including the perspectives of men and women farmers, commonly during evaluation of released or soon-to-be released crop varieties (e.g., Ashby and Sperling 1995; Chambers, Pacey, and Thrupp 1989; Sperling, Loevinsohn, and Ntabomvura 1993), while input from social scientists has been considered most relevant later in or in the aftermath of the crop breeding process, such as during adoption studies and impact assessments. More recently, in a bid to increase adoption and development impacts of improved crop varieties, more systematic approaches for incorporating gender and social sciences perspectives earlier in the crop breeding process are being developed (e.g., Ashby and Polar 2019; Forsythe et al. 2021). Such initiatives and projects are making important conceptual and methodological strides toward gender-responsive and transformative crop breeding.

However, interdisciplinary application of natural and social sciences is hampered by the different onto-epistemological groundings on which the disciplines are based. Of most concern for the present article is the nature/culture and material/social dualisms which crop breeders and gender specialists largely operate on either side of, respectively. Thus, in moving towards feminist practices and outcomes of crop breeding, there is also a need for novel ethico-onto-epistemological (Barad 2007) ideas, concepts, and approaches.

Inspired by feminist technoscience studies, critical plant studies, and related scholarships, this article explores what may be gained from applying a naturecultural and sociomaterial ontology and more-than-human and distributive notion of agency in the context of crop breeding for development by introducing the concept of the "feminist crop". The largely theoretical exploration is empirically grounded in personal experiences in trying to combine a background in molecular crop breeding with gender and feminist studies, as well as through interactions with natural and social scientists working at this intersection. As part of my doctoral fieldwork, I interviewed crop breeders and gender specialists working in or together with the Consultative Group for International Agricultural Research (CGIAR) Consortium in Africa about

the ways in which they incorporate gender and women's interests, needs, and empowerment in their work. I also observed first-hand the struggles and successes in working across disciplines through participation at workshops and conferences that dealt with gender-responsiveness and transformation in crop breeding and seed systems in Africa.

I start by illustrating the close entanglements that exist between people and plants, and the ways such entanglements may be gendered. Subsequently, I introduce the feminist crop, before exploring the onto-epistemological and methodological implications of this concept for crop breeders and gender specialists, using banana, yam, and cassava as examples. This will include an investigation of how plant genome editing may be wielded as a tool for feminist intervention and politics in and through crop breeding. Through this exploration we arrive at the ethical groundings of the feminist crop, which asks us to take responsibility what comes to matter and what becomes excluded in plant–people entanglements.

The article contributes to both the field of crop breeding and gender studies—not least in being among the first to address the intersection of feminism and plant genome editing, thus adding to a growing literature on the societal implications and democratization of the technology (e.g., Jasanoff, Hurlbut, and Saha 2015, 2019; Montenegro de Wit 2020; Shaw 2020; see also Bryant and Pini 2006 and Ezezika et al. 2013)—as well as to feminist technoscience studies by expanding its scope to the relatively unexplored area of crop breeding for development in an African context. African (feminist) science and technology studies is a growing, albeit comparably small, field of study (WiSER, n.d.; but do see e.g., Augusto 2007; Bauchspies 2009; Borenstein 2021; Foster 2017; Henry, Oliver, and Winters 2019; Lamoureaux and Rottenburg 2021; Mavhunga 2017; Okune 2020; Paxling 2019a, b; Pollock 2014; Rottenburg 2009). Engaging with both African feminist and womanist scholars, local and Indigenous knowledges in Africa, and African women's and men's unique experiences with material culture and technology can contribute novel ways of understanding innovation, subjectivity, agency, power, philosophy, ontology, epistemology, and ethics, all of which are at the heart of feminist technoscience studies. Agricultural knowledge and (bio)technological innovation represents an important vantage point from which to study such and related aspects, given the centrality of agriculture in the lives of many African women and men, as well as the situatedness of plant breeding at multiple intersections of interest, including North-South, local-global, coloniality-indigeneity, nature-culture, material-social, plant-people, and masculinity-femininity. There is furthermore a need to treat the African continent not simply as a place from which data can be extracted and to which Western-derived concepts can readily be applied, but a place of theory-building and concept-

formation (Mavhunga 2017). This article attempts to do just that, all the while recognizing my own position and privileges as a white scholar from the North.

Plant–People Entanglements and the Construction of Gender

Historically, plants, seeds, and food are thought to have been particularly important in the construction and reproduction of the "female self", including in African countries, as women have been, and in many communities continue to be, the primary experimenters, collectors, exchangers, carers, domesticators, and processors of plants (e.g., Amadiume 1987; Avakian 1997; Avakian and Haber 2005; Carney 2001; Hastorf 1998; Fritz 1999; Howard 2003; Inness 2001; Jaffe and Kaler 2016; Shirungu and Cheikhyoussef 2018; Steenkamp 2003; Tapia and De la Torre 1998; Tyler and Fraser 2016; Williams-Forson 2006, 2010). In these roles, women may find a source of security, skills, knowledge-making, joy, pride, privilege, and self-esteem, as well as drudgery, frustration, concern, and worry. Undoubtedly, crops and food also play an important role in the construction of male identity and masculinity (e.g., Greenebaum and Dexter 2018; Korieh 2007, 2010; Saugeres 2002; Sumpter 2015). For instance, in Northern Ghana, cultivation of millet, including the delicate practice of weeding, is at the heart of men's identity (Padmanabhan 2007).

In turn, humans help make plants who and what they are: through "formal" and "informal" crop breeding, we literally help determine what the plants look like, can do, and what they experience. As human behaviors and social systems, including the structures and practices of crop breeding, are often strongly delineated along lines of gendered power relations, the biological-material properties and capacities of plants—their "plantiness", defined by Head, Atchison, and Gates (2012, 27) as "an assemblage of the shared differences of plants from other beings"—may come to invite or inhibit the doing of particular gender performances and relations. Head, Atchison, and Gates (2012, 27) further note how "[t]he specifics of plantiness help us to consider the specifics of plant agency – how it comes out of certain material capacities – and how that prefigures relations with people".

We thus see how plants and people are not separate, bounded entities but rather emerge through and in naturecultural and sociomaterial relations with each other: they are plant–people entanglements (van der Veen 2014); a concept used by Hodder (2011) to describes the various ways and forms in which humans and things get caught up with and depend on each other (see Barton and Denham 2018 for a beautiful visual illustration of plant–people entanglements). Such an ontological understanding has

epistemological, methodological, and ethical implications, which will be explored following the introduction of the feminist crop concept.

The Feminist Crop Concept and the Advancement of Feminist Crop Breeding

The concept of the feminist crop captures the entanglement of crops with women's embodied practices, knowledges, capabilities, and power. It delineates a co-constituted nature of humans and plants that is at the same time ubiquitous, grounded, and gendered. The concept contributes to an ethico-onto-epistemological and methodological investigation of how intersectional gender identities and relations are embedded not only in human systems, but in plants and more specifically plant–people entanglements, which shifts the thinking and practices of both biophysical researcher and social scientists. By bringing together the natural and the material on the one hand, and the social and cultural on the other, the feminist crop further provides a common ground on which the two disciplines can engage. Another key feature of the feminist crop is that it situates ethics and justice at the heart of crop breeding. More specifically, the feminist crop advances a decision-making process guided more explicitly by an ethics of mattering and exclusion, which asks scientists and their institutions to promote epistemic justice and take responsibility for what comes to matter and what becomes excluded in plant–people entanglements**.** Ultimately then, the feminist crop contributes to advancing feminist crop breeding.

The feminist crop should not be mistaken for promoting a feminine science (Harding 1991) or breeding for 'women's traits' or 'women's crops'. Such language may reinforce heteronormative and essentializing assumptions that can have real sociomaterial implications, for instance by restricting access to and control over more lucrative income-generating opportunities by women (e.g., Polar et al. 2021). Additionally, calling crops feminist may be accused of anthropomorphism (Gibson and Gagliano 2017), which may seem paradoxical given that a more-than-human ontology is meant to challenge human exceptionalism and subvert the tendency of perceiving nonhumans from an anthropocentric perspective. Furthermore, given the plurality of feminisms, it may appear contradictory to talk of a feminist crop in the singular. However, the feminist crop is meant to be adaptable to multiple ways of understanding feminism or African womanism, as well as being an acknowledgement of the agential (feminist) capacities and selfhood of plants, as recognized in Indigenous cosmologies and knowledge systems for centuries (e.g., Kimmerer 2013; Kohn 2013; Miller 2019; Nathen 2018).

Next, I explore some possible implications of the feminist crop to the thinking and doing of crop breeders and gender specialists.

Breeding Plant–People Entanglements

The main concern of crop breeders is how the genetics of the crop plant interact with the environment to give the plant its phenotype. Comparably less attention has been paid to how the choices crop breeders make in the field or in the lab implicitly involves a decision about who and what gets entangled and disentangled and in what ways. Applying the feminist crop concept infers not only an appreciation of the constitutive role that nonhumans play in the making of plant breeding knowledge but also acknowledging that, once disseminated, crop plants have agency in shaping human identities, roles, and relations.

To illustrate this, I draw on my past experiences working as a biotechnologist on genetically modified bananas (*Musa* spp.) in a plant sciences laboratory in Nairobi, Kenya. Through the incorporation of two genes from sweet pepper (i.e., *Hrap* and *PflpI*), these bananas were modified to become resistant against the plant disease Banana Xanthomonas Wilt (BXW). My daily laboratory life consisted of a whole mishmash of "actants" (see, e.g., Latour 1996 for a definition): bacteria, genes, embryonic banana cells, antibiotics, nutrients, enzymes, petri dishes, pipettes, PCR machines, and computer software. I felt disappointed, frustrated, and sad when the bacteria did not behave as I wanted them to or the banana plants died, even after long hours of tending to. I felt confident, excited, and joyful when green, fluorescent light was emitted from the banana cells, literally signalling to me that they had successfully been genetically transformed. The power of hindsight ultimately led me to understand that every one of these actants played a meaningful role in the making of this knowledge, which in turn produced the very actants themselves, myself included. In what ways, then, did the choices made in the lab, which were structured by this array of actants and their relations, imply a choice about who or what would become entangled and disentangled and in what ways?

Bananas are of cultural and ritual importance in several African countries, as well as a pivotal source of income and food high in starch and some essential vitamins and minerals (Karamura et al. 1999; Mbabazi et al. 2020). In choosing bananas as the crop of choice and BXW as the problem to be addressed, the around 100 million people who depend on the cultivation of bananas, most of whom are small-scale farmers residing in East and Central Africa (Karamura, Karamura, and Tinzaara 2012; Tripathi et al. 2009, 2013), initially became entangled. This, in turn, partly disentangled those whose more pressing concerns include low soil fertility, drought, socio-economic factors such as lack of markets and roads, and other pests and diseases (e.g., Panama disease, sigatoka, weevils, and nematodes) (e.g., Wairegi et al. 2010). Furthermore, the choice of the cultivars 'Sukali Ndiizi' and 'Cavendish Williams' narrowed the plant–people entanglement to those who cultivate small dessert bananas and larger commercial bananas,

respectively. Additionally, those apprehensive about or unable to adopt (for instance due to lack of money and other productive resources) improved crop varieties and, more specifically, genetically engineered crops became further disentangled.

Moreover, prioritizing agronomic traits implicitly meant prioritizing those socioeconomic and sociocultural groups whose main interests relate to production and marketing and less so with processing and consumption (e.g., good taste and aroma, soft texture, and yellow color). Due to gender norms and roles in banana farming and value chains, women have been found to be more concerned with cooking quality (and thus cooking bananas), such as heat retaining ability, and men with beer quality (and thus beer bananas) and cultivars with big bunches and extended shelf life (e.g., Marimo et al. 2020; Rietveld and Farnworth 2018; Sanya et al. 2018). Furthermore, in East Africa, men are commonly the ones controlling the banana plantations although women contribute much of the labor, such as during weeding and management of disease (Rietveld and Farnworth 2018). Consequently, breeding for increased productivity (through disease resistance) may disentangle women whose preferences and needs are not met or entangle women in ways that increase their drudgery (e.g., Addison and Schnurr 2016). In other words, becoming entangled is not intrinsically positive. Thus, it is not enough to merely ask who and what gets entangled and disentangled, but also in what ways and to what outcomes.

Then again, breeding for BWX resistance may entangle in beneficial ways those men and most notably women who spend time and drudgery having to manage the disease, and who may lose income and other opportunities because of the disease. It may also help re-entangle women who have adopted other crops (e.g., maize) in favor of bananas due to the high disease pressure caused by BXW. Ultimately however, as bananas often represent a cash crop, men are traditionally responsible for harvesting and controlling the income from sales (Rietveld and Farnworth 2018). In some cases, women feel like they have no choice but to sell bananas without their husbands' permission, which may result in domestic violence (Rietveld and Farnworth 2018). Again, we see how women and men become differentially entangled.

What may technical advances within molecular crop breeding hold for feminist crops and feminist crop breeding? Could molecular breeding tools expand our possibilities of engaging with plantiness and plant agency in ways that allow for more socially just entanglements to be made? Following Roy (2018), I will argue for a reframing of "how we might think about molecular biology and feminism together, how we may be able to work together to create new lines of flight to think about the world that we inhabit, and how we can produce knowledge about that world" (Roy 2018, 24). I draw attention to genome editing

and more specifically the clustered regularly interspaced short palindromic repeats (CRISPR) and CRISPR-associated protein (Cas) system. CRISPR-Cas takes advantage of an adaptive immune system in bacteria and archaea to control the introduction of targeted, sequence-specific variation (Jinek et al. 2012). While there is still a long way to go before CRISPR editing of plants become economically and technically feasible (e.g., Massel et al. 2020), as well as politically, regulatory, socioculturally, and ethically acceptable in certain parts of the world (e.g., Bartkowski et al. 2018; Rock and Schurman 2020), new opportunities for feminist crop breeding may unfold as CRISPR-Cas becomes increasingly advanced and versatile.

For instance, improved opportunities for conducting functional assessments of gene functions and regulatory elements can enhance our understanding of the molecular and physiological basis of preferred plant characteristics that have yet to be translated into "breed-able" traits (e.g., 'good aroma' and 'ease of threshing'). Genome editing can also help conserve genetic variation and desirable qualities of landraces and local varieties that are often highly appreciated for their culinary and cultural value or introduce genetic variability in cases where the gene pool does not contain genetic variability for traits important for certain end-uses and end-users. Additionally, genome editing can prove helpful in breeding for polygenic traits (i.e., controlled by multiple genes), such as in the case of many quality traits that traditionally are considered more important to women (e.g., Marimo et al. 2020; Teeken et al. 2018; Weltzien et al. 2019). Furthermore, the ability to now add both qualitative and quantitative traits to elite varieties in a single generation without the effect of linkage drag (i.e., where undesirable genomic segments are linked to the gene of interest) enables breeding teams to respond more swiftly to new understandings of the gendered nature of plant–human entanglements and to shifting user preferences (e.g., Scheben and Edwards 2018).

Finally, the development of "lab-free" genome editing protocols, where genome editing is performed directly in glasshouses and growth rooms (e.g., Massel et al. 2020), could help meet some of the critique that the more laboratory-oriented and technically advanced, and thus less accessible, knowledge underlying this form of crop breeding may increase the "distance" between scientists and lay people (or, rather, lay experts) (e.g., Bonneuil, Foyer, and Wynne 2014; Montenegro de Wit 2020; Wynne 2001). Still, emphasis should be placed on developing a democratic and inclusive innovation process, particularly in light of findings suggesting limited integration of user and gender perspectives in banana research and technology development (e.g., Kawarazuka et al. 2020; Sanya et al. 2017), which has contributed to low levels of varietal adoption in some cases (e.g., Akankwasa et al. 2013; Marimo et al. 2020; Thiele et al.

2021). This is sobering considering the experiential and tacit knowledge and expertise that both men and women hold as a result of their central roles in banana food and cropping systems and value chains (e.g., Ajambo et al. 2018; Bechoff et al. 2020; Karamura et al. 2004; Kawarazuka et al. 2020), which is (or should be) central to the breeding process.

A democratic and inclusive research and innovation process would require opening up spaces for meaningful participation and decision-making and institutionalizing local and Indigenous knowledges and women as intellectual and technological agents through creative, collaborative, and participatory action research and transformative learning (e.g., Baker 2012; Callon, Lascoumes, and Barthe 2009; Mezirow and Associates 2000; Montenegro de Wit 2020; Shaw 2020; Song and Vernooy 2010; Wakeford and Sanchez 2018; Weasel 2011). Developed in such a way, and grounded in the concept of the feminist crop, CRISPR-Cas can come to play important roles in advancing gender-responsive and transformative crop breeding.

Tracing (Dis)Empowerment Pathways along Plant–People Entanglements

Many social scientists are concerned with the closely interlinked concepts of agency and power in understanding social structures, behaviors, and relations, including pathways of empowerment and disempowerment (e.g., Cornwall 2016; Galiè and Farnworth 2019; Gammage, Kabeer, and Rodgers 2016; Kabeer 1999; Pansardi 2012; Rowland 1997). Most commonly, nonhumans are treated simply as resources and assets that affect, among others, a person's ability to bargain and make decisions. However, by conceiving of human agency and action as mediated not only through social relations but through and (re)configured by plantiness and plant agency, we can come to understand the construction and reproduction of intersectional gender identities and relations and (dis)empowerment in agriculture in novel ways.

An illustrative example includes that of yam and cassava in Nigeria. Until more recent times, the starchy yam (*Dioscorea spp.*) played an important political, economic, sociocultural, and ritual role in Nigeria and in particular among the Igbo people, as evident in the Eating of New Yam Festival (*ikpo ji*) and the celebration of the yam spirit (*Ahiajoku*) (Amadiume 1987; Korieh 2010). Known as the "king of crops" (Achebe 1959, 33-34; Korieh 2007, 2010), yam was considered a men's crop and a defining feature of male identity, prestige, and authority (Amadiume 1987; Korieh 2010). The cultivation of yam further helped shape production relations, trade, land use and tenure systems, and marriage and social alliances (Korieh 2010), often in favor of men who came to control the most important factors of production, including women and children who often provided much of the labor in producing and processing yams (Korieh 2010).

However, as land became degraded and labor scare during times of hardship and war, starting with the 1918 influenza pandemic and World War I, the hardy, woody root crop cassava (*Manihot esculenta*) fared better than yam (Korieh 2010). Up until then, partly due to its toxic and bitter compounds, cassava was considered a "poor man's crop" mostly used for animal feed (Korieh 2007). Reinforced by the food crisis of World War II, the demand for cassava further increased and its production became rather lucrative (Korieh 2010). Thus, by the 1970s and onwards, the Igbo went from a "yam people at heart" to a "cassava people at heart" (note, however, that yam remains an important crop in many parts of Nigeria, see e.g., Obidiegwu and Akpabio 2017) (Korieh 2007).

Most noteworthy to our story, however, is that, while men also participated in cassava production, it was Nigerian and Igbo women, at times with contribution from their children, who dominated production, processing, and marketing (and, in several parts of the country, continue to dominate) (e.g., Apata 2019; Taiwo and Fasoyiro 2015; Wossen et al. 2017). Korieh (2007, 299) notes how "many women were eager to admit that their role in household subsistence had increased significantly in recent times. This transformation in some cases brought out negative responses from the men who now see themselves as welding less authority in their households". In other words, cassava helped strengthen the economic position of women and thus shaped the social and economic relations between women and men, and with it came a fracturing of the male-yam identity (Korieh 2010). Moreover, women and women's groups started to build new knowledges, skills, practices, and cultures associated with cassava, which in turn enhanced their sense of self-esteem, independence, and confidence (e.g., Korieh 2007, 2010; Ottenberg 1956). The strengthening of women's (economic) position can further be seen in relation to historical gender ideologies, including the "ideology of female industriousness, economic self-help, and self-sufficiency" (Amadiume 1987, 40).

We thus see how agency and various forms of power became mediated through women–cassava entanglements, which helped configure empowerment pathways along which women could define and pursue novel life choices and goals. Furthermore, it was not only women who benefited from these women–cassava entanglements: as the once-neglected "poor man's crop", which was mostly considered appropriate for animal feed, became a national symbol, cassava was itself empowered; it dethroned yam, the "king of crops", and became the "mother of all crops" (Korieh 2007).

The empowerment mediated through women–cassava entanglements can only be understood in the context of the larger ensemble in which plant–people entanglements are embedded, which in this case included such things as the H1N1 virus, soil quality, warfare, gender ideology, capitalist agriculture,

colonial rule, food scarcity, and urbanization. For the purpose of this article however, I draw attention to how the plantiness of cassava "affords" (Nally and Kearns 2020) particular possibilities and actions that may benefit (some) women.

The ability of cassava to grow in relatively marginal soils with little input even during dry spells may benefit women who have less reliable access to fertile land and other productive resources (e.g., Ferraro et al. 2016; Korieh 2010). Furthermore, cassava allows for more flexible time management and provides a source of food when no other fresh food is available as it can be left in the ground for over two years while still retaining most of its nutritional value (Korieh 2010; Uchechukwu-Agua, Caleb, and Opara 2015). Like potatoes then, cassava exhibits a "survival ecology" affordance (Nally and Kearns 2020) that helps support household food security, which traditionally is the responsibility of women. This contrasts to yams, which are seasonal, challenging to store, and require more labor (e.g., Ferraro et al. 2016; Korieh 2010). Additionally, cassava can be processed and consumed in multiple ways that often reflect regionality and ethnicity (Etejere and Bhat 1985). Today, fermented cassava products such as *fufu, lafun,* and *garri* make up a key component and source of carbohydrates in the diets of many Nigerians, while the more highly nutritious leaves are used in preparing leaf sauce and for animal feed (Achidi et al. 2005; Ferraro et al. 2016).

However, one should avoid painting an overly romanticized picture of the relations between women, and people and small-scale farmers more generally, and plants. Importantly, there is a need to integrate an intersectional lens in the study of plant–people entanglements. Indeed, plant–people entanglements are contingent, flexible, and dynamic: not all women (and men) become entangled with cassava in the same ways (and some become disentangled all together) and there are limits to the extent to which the plantiness of cassava can be empowering. For instance, the toxic properties of cassava, along with low levels of lipids, minerals, vitamins, and protein, mean that it interacts with the human body in ways that may put people (e.g., pregnant women) and children at risk of zinc, iron, and vitamin A deficiency and neuropathy (Gegios et al. 2010; Osuntokun 1980). Additionally, in-ground storage means that women are often victims of theft. Albeit a study from Malawi, Chiwona-Karltun et al. (1998) found that poor women in particular, who due to their lower social status are more vulnerable to theft, plant bitter cassava to deter thieves (also see Forsythe, Posthummus, and Martin 2016), even though this comes at greater need for processing and thus labor to render the roots edible. In other words, bitter taste and toxicity could represent a strategy of "interrupting power" (Foster 2019), as Laura Foster (2017, 2019) observed for

Hoodia plants in South Africa, only here bitterness offers a way for poor women in their entanglements with cassava to act against thieves.

Additionally, once harvested, cassava rapidly deteriorates (although, once processed, the cassava products can be stored for up to six months) (Zainuddin et al. 2018), which can be a problem for women who lack of access to post-harvesting facilitates and markets. Moreover, while its cultivation may require less labor than certain other crops, the processing of the root can be laborious, time-consuming, and harmful (e.g., Okareh, Ogunfayo, and Atulomah 2015). Finally, Forsythe et al. (2015, 2015) demonstrated how the extent to which women can benefit from commercialization of cassava depends on such factors as resource endowment, decision-making power, regionality, ethnicity, migratory status, and life-stage.

What then, are some of the implications of the feminist crop concept for social scientists working within crop breeding for development? Most notably, analytical frameworks for investigating agency and power in agriculture, as well as tracing and supporting pathways and interventions through which women's empowerment and social change can be achieved, need to take plantiness, plant agency, and "planty knowledge" (Pitt 2017) into consideration. In the first instance, this could entail empirical investigations of how different intersectional groups of men and women involved in food and cropping systems conceptualize and experience (dis)empowerment in relation to plants. Furthermore, social scientists may need to ask new types of questions that capture both sides of the co-constructive, naturecultural, and sociomaterial equation, such as not only how social identities, relations and structures shape different preferences for crop plants and traits, but how the plants themselves may shape such preferences. Methodological inspiration can be drawn from, among others, more-than-human and multispecies ethnography (e.g., Gibson, 2018; Kohn 2013; Myers 2017; Nathen 2018; Pitt 2015, 2017). As Gibson (2018) notes: "By showing, watching, strolling among, discussing, doing, picturing and being guided by plants, we can come to appreciate their agency. By engaging in the practices of people who worked with plants, we could gain insight into the multiple 'matterings' that emerged in and through such plant practices".

An Ethically Grounded Feminist Crop

The discussion on who or what gets entangled is fundamentally a discussion about ethics and justice. In particular, the feminist crop advances a decision-making process guided more explicitly by an "ethics of mattering" (Barad 2007) and an "ethics of exclusion" (Giraud 2019). An ethics of mattering and exclusion ask us to take responsibility for which plant–people entanglements come to matter, figuratively and literally, through our thinking and doing as natural and social scientists, while stressing the need to make evident and politicize who and what acts; who and what impacts decisions; who and what is responsible;

and who and what becomes entangled and disentangled and in what ways. Whose values, knowledges, worldviews, interests, meaning systems, and lives come to matter and are excluded?[1] How can we bring excluded humans and nonhumans into the crop breeding process? To design for and from the margins of entanglements?

Tending to such an ethics implies tending to the socially situated nature of technoscience (Haraway 1988). In other words, an ethics of mattering and exclusion is an ethics that is reflexive and contextually accountable on both the individual and institutional level: it includes a recognition of how our positionality and social embodiment and embeddedness, including inherent biases and deep-seated norms and values, shape our thinking and doing as scientists; and the need to situate actants, biological and technical events, and the micro-practices and micropolitics of scientific institutions in the broader context of dominant structures and practices of knowledge production (Roy 2018).

Indeed, studies have demonstrated the ways in which agrarian development, plant sciences, and plants themselves have shaped and been shaped by, among others, state formation, capitalism, colonialism, racial politics, and patriarchy (e.g., Brockway 1979; Carney 2001; Cullather 2010; Eddens 2019; Hobhouse 2005 [1985]; Ives 2017; McCann 2007; Mintz 1985; Osseo-Asare 2014; Ross 2014; Schiebinger 2004). This has often come at the expense of local and Indigenous men and in particular women, whose relationships with crops, seeds, and food, and the knowledges, skills, and expertise that arise from these relationships, often fail to be meaningfully acknowledged and integrated in agricultural technoscience (e.g., Allen and Sachs 2007; Alston 2000; Kitetu 2008; Resurrección and Elmhirst 2020; Stads and Beintema 2017; Twagira 2014; Twyman, Muriel, and García 2015), also as it relates to agricultural biotechnology (e.g., Bonneuil, Foyer, and Wynne 2014; Ezezika et al. 2013; Fitting 2010; Montenegro de Wit, 2020). To this day, plant breeding remains highly implicated in North-South relations, where actors such as private sector donors and international development agencies headquartered in the Global North have much of the definitional, agenda-setting, and decision-making power.

Accordingly, far from being objective and neutral, the practices of plant breeding, including priority-setting and varietal design, are highly political, power laden, and value driven. In other words, the feminist crop has to challenge and take root in a larger entanglement characterized by uneven and intersectional power-knowledge hierarchies that tend to favor some values, knowledges, knowing subjects, and plant–people entanglements over others. Thus, the feminist crop also promotes a breeding practice that advances epistemic justice: a process through which knowledge systems that have been overshadowed by scientism and epistemic and molecular imperialism are recovered (Visvanathan 2005).

Concluding Remarks

In the context of agriculture, to understand gendered power relations requires us to observe the deep and complex bonds of plant–people entanglements. I have proposed the concept of the feminist crop to capture the entanglement of crops with women's embodied practices, knowledges, capabilities, and power, and to contribute to an ethico-onto-epistemological and methodological investigation of how intersectional gender identities and relations are embedded in plant–people entanglements. I have further demonstrated how research into African food and cropping systems and plant breeding can help expand the boundaries of how we think about agency, power, and empowerment, and shed light on how plant–people entanglements come, or *can* come, to matter in different ways to different people.

Both natural and social scientists can benefit from thinking in terms of plant–people entanglements: crop breeders ought not to consider plants and their interactions with the environment (the "natural" and "material") in isolation, just as much as gender researchers and social scientists ought not to consider humans (the "social" and "cultural") in isolation. Indeed, crop breeding is a deeply sociomaterial and naturecultural practice that is as much about nature, climate, (epi)genetics, and plant physiology as it is about people, belonging, culture, discourses, value systems, and meaning-making.

What becomes evident, then, is the intimate connections, mutual intelligibility, and complementarity between the thinking and doing of crop breeders and gender specialists: both address plant–people entanglements. Assuming an ethically embedded knowledge practice–which promotes epistemic justice and asks us to take responsibility for what comes to matter and what becomes excluded–each discipline may contribute unique perspectives, knowledges, and skills on how to entangle plants and people in more socially just and constructive ways. Moreover, plant genome editing grounded in the feminist crop concept, along with participatory action research and transformative learning, may represent one way of engaging more profoundly with "plantiness" and plant agency to advance feminist crop breeding.

Notes

[1] Exclusions are not inherently negative and can be productive and creative (Giraud 2019). Productive exclusions in this context could be, for instance, omitting crop traits that are harmful to women and discriminatory institutional norms, practices, and relations.

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Appendices

Appendix 1. List of information in the G+ Customer Profile Tool

	Key questions	Evidence		Sources of information
The product	What is the new breeding product?			
	What product is it replacing?			
	Why is the new product superior?			
	Where is it needed? (AEZ)			
The customer	Socio-economic descriptors of resource-poor users			
	Who will grow this new product? What proportion of the growers are men and women?			
	Expected average yield per hectare *Does average yield usually differ among men and women growers? What is the average yield gap?*			
	Expected volume of production per household			
	Expected income from sales per household?			
Customer preferences	What are main agronomic constraints on production of this new product?	Women	Men	
	Soil fertility			
	Pests and diseases			
	What traits do customers prefer?	Women	Men	
	1st			
	2nd			
	3rd			
	4th			
	What are the reasons for preferring these traits?	Women	Men	
	1st			
	2nd			
	3rd			
	4th			
Gender impacts	What are the gender roles currently associated with this product?	Women	Men	
	Production			
	Processing			
	Marketing			
	What are the gender differences in benefits currently associated with this product?			
	From domestic consumption			
	From processing			
	From marketing			
	Will this new product change women's gender roles and if so, how?			
	Production			
	Processing			
	Marketing			

Source: Orr et al. (2021). Used with permission from Vivian Polar.

Note: The figure shows the template for filling out information needed to create the G+ Customer Profile. The template lists several key questions categorised according to different thematic groups. Most of the requested information has been generated in previous steps of the G+ Customer Profile Tool, including the first step of product mapping (where the spectrum and relative size of different end users and end uses of the product are mapped) and the second step of customer mapping (where the potential customer segments are identified, and it is determined whether these should be defined in terms of gender differences).

Appendix 2. The scoring matrix of the G+ Product Profile Query Tool

USE THE G+PRODUCT QUERY TOOL QUESTIONNAIRE TO FILL IN THIS SCORING MATRIX SHEET FOR ONE TRAIT

TEMPLATE #4: G+ PRODUCT PROFILE SCORING MATRIX SHEET FOR ONE TRAIT "DO NO HARM"						
1. PRODUCT NAME:						
2. Customer segment for this product:						
3.Social category						
4.Trait name:						
5.Evidence sources:						
6.Final gender impact score for "do no harm"						
"Do no harm" questions		Fill in CODE from Questionnaire			Lacks information	Evidence citations and commentary
No.	**Part 1**: "Gender Gap"	-2	-1	0	!!!	Notes on scoring and/or information needed
1	Increases drudgery?					
2	Displaces women's activities?					
3	Depends on input with unequal access?					
4	Decreases control of benefits					
No.	**Part 2**: Trait preferences	Yes: majority	Blank	No	!!!	Commentary
5	Do women in the target customer segment value the trait **negatively**?					
6	Do men in the target customer segment value the trait **positively** (opinion conflicts with that of women)?					

TEMPLATE#4: G+ PRODUCT PROFILE SCORING MATRIX SHEET FOR ONE TRAIT POSITIVE BENEFITS						
1.PRODUCT NAME:						
2.Customer segment for this product:						
3.Social category						
4.Trait name:						
5.Evidence sources:						
6.Final gender impact score for Positive Benefit						
"Do no harm question"		Fill in CODE from Questionnaire			Lacks information	Evidence citations and commentary
No.	**Part 3:**	+2	+1	0	!!!	Notes on scoring and/or information needed
7	Reduces drudgery?					
8	More employment for own income generation					
9	Better control by women of products or by-products?					
No.	**Part 4:** Positive Trait preferences	Yes: majority	Blank	No	!!!	Commentary
10	Do women in the target customer segment value the trait **positively**?					
11	Do most men in the target customer segment value the trait **positively** (agreement with women)?					
12	Do most women in the target customer segment rank this trait more highly than men?					

Source: From Ashby and Polar (2021a). Used with permission from the authors.

Note: The G+ Product Profile Query Tool scores each trait listed on the product profile using the "do no harm" and "positive benefits" scoring matrices.

Appendix 3. Invitation letter, Kenyatta University, Kenya

KENYATTA UNIVERSITY

DEPARTMENT OF BIOCHEMISTRY, MICROBIOLOGY AND BIOTECHNOLOGY

P O Box 43844-00100
GPO Nairobi, Kenya
runo.steve@ku.ac.ke
smruno@gmail.com
CELL: +254 727 346 496

11-Aug-19

RE: INVITATION LETTER FOR MS IDA ARFF TARJEM

Kenyatta University promotes exchange programmes among students, Scholars and Researchers as a means to fostering collaborative and multi-disciplinary research. As such, the Department of Biochemistry, Microbiology and Biotechnology is glad to host you, and provide necessary support to undertake your PhD research project entitled: **Advancing Feminist Sociotechnical Analysis of Technological Innovations in Agriculture: The Case of Genetically Modified and Edited Maize for Africa** between 19th August 2019 and 15th December 2020.

During your stay at Kenyatta University, Dr. Richard O. Oduor will supervise your research activities while your accommodation has been organized at the Kenyatta University Conference Center (KUCC) located within the campus.

Your visit not only enhance research but also strengthens collaboration between Kenyatta University and Norwegian University of Life Sciences.

Dr Steven Runo
Chairman, Department of Biochemistry, Microbiology and Biotechnology

Appendix 4. Affiliate letter, Kenyatta University, Nairobi, Kenya

KENYATTA UNIVERSITY
OFFICE OF DEPUTY VICE-CHANCELLOR, RESEARCH, INNOVATION AND OUTREACH

Ref: KU/DVCR/AFF/VOL. 1/52

Ms. Ida Tarjem
Faculty of Landscape and Society,
Norwegian University of Life Sciences
Oslo
NORWAY

P. O. Box 43844-00100
Nairobi, Kenya
Tel: 020-8710901/19 Ext. 3026
Email: dvc-rio@ku.ac.ke

10th February, 2020

Dear Ms. Tarjem,

RE: REQUEST FOR AFFILIATION TO KENYATTA UNIVERSITY

This is to inform you that your application for affiliation to Kenyatta University dated 7th February, 2020 for the purpose of undertaking research on the topic "*Advancing Feminist Sociotechnical Analysis of Agricultural Innovation: The Case of Gender Responsive Crop Breeding for Africa*" has been considered and approved by the Vice-Chancellor. It is noted that your affiliation period is January - December, 2020 and you wish to be affiliated to the Department of Biochemistry, Microbiology and Biotechnology.

With this approval, you are requested to proceed to pay affiliation fee and complete the process of requesting for a research permit from the National Commission for Science, Technology and Innovation (NACOSTI).

We look forward to interacting with you during the period of your affiliation. Please contact my office on to enable us arrange for your KU identity card.

Yours Sincerely,

Prof. Frederick Q. Gravenir
Deputy Vice-Chancellor
Research, Innovation and Outreach

cc: Vice-Chancellor
Dean, School of Pure and Applied Sciences
Chairman, Department of Biochemistry, Microbiology and Biotechnology

Appendix 5. Research license, National Commission for Science, Technology & Innovation of the Republic of Kenya

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **383499**

Date of Issue: **24/October/2019**

RESEARCH LICENSE

This is to Certify that Miss.. Ida Tarjem of Norwegian University of Life Sciences, has been licensed to conduct research in Nairobi on the topic: Advancing Feminist Sociotechnical Analysis of Technological Innovation in Agriculture: The Case of Genetically Engineered Crops for Africa for the period ending : 24/October/2020.

License No: **NACOSTI/P/19/1256**

383499

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
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7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

Appendix 6. List of interviews

No.	Date	Position	Organisation
1	10/09/2019 23/10/2019 27/02/2020	Gender specialist	ILRI
2	23/09/2019	Gender specialist	CIAT
3	26/09/2019	Policy and decisionmaker	NRF
4	01/10/2019 05/11/2019	Socioeconomist	CIMMYT
5	03/10/2019	Crop breeder	JKUAT
6	20/01/2019	Policy and decisionmaker	NBA
7	21/10/2019 10/02/2020	Gender specialist	ICRISAT
8	29/20/2019	Crop breeder	KALRO
9	30/10/2019	Socioeconomist	CIMMYT
10	30/10/2019	Crop breeder	CIMMYT
11	07/11/2019	Crop breeder	UoN
12	08/11/2019 20/02/2020	Gender specialist	IRRI
13	07/11/2019	Policy and decisionmaker	NACOSTI
14	20/11/2019	Crop breeder	IRRI
15	03/12/2019	Gender specialist	CIMMYT
16	12/02/2020	Crop breeder	BecA
17	13/02/2020	Crop breeder	CIMMYT
18	25/02/2020	Crop breeder	CIMMYT
19	25/02/2020	Socioeconomist	CIMMYT

20	13/022020	NGO	AGRA
21	27/02/2020	NGO	AWARD
22	02/03/2020	Crop breeder	CIMMYT
23	06/03/2020	Crop breeder	ICRISAT
24	11/03/2020 30/03/2020	Crop breeder	CGIAR partner
25	12/03/2020	Crop breeder	CIAT
26	16/03/2020	Donor	IDRC
27	17/03/2020	NGO	SSG
28	23/03/2020	NGO	AGRA
29	25/03/2020	Crop breeder	CIMMYT
30	25/03/2020	NGO	AGRA
31	23/03/2020	Crop breeder	CIMMYT
32	01/04/2020	Policy and decisionmaker	KILIMO
33	14/10/2020	Plant physiologist	CIMMYT
34	06/01/2021	Gender specialist	CIP
35	13/01/2021	Gender specialist	IITA
36	14/01/2021	Socioeconomist	CIP
37	18/01/2021	Gender specialist	IITA
38	20/01/2021	Gender specialist	CGIAR partner
39	21/01/2021	Donor	BMGF
40	29/01/2021	Socioeconomist	CIP
41	02/02/2021	Donor	BMGF
42	04/02/2021	Gender specialist	CIP

Appendix 7. Project approval by the Norwegian Centre for Research Data

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD's assessment

Project title

Advancing Feminist Sociotechnical Analysis of Technological Innovation in Agriculture: The Case of Genetically Modified and Edited Maize for Africa

Reference number

422305

Registered

29.06.2019 av Ida Arff Tarjem - ida.arff.tarjem@nmbu.no

Data controller (institution responsible for the project)

Norges miljø- og biovitenskapelige universitet / Fakultet for landskap og samfunn / Institutt for internasjonale miljø- og utviklingsstudier

Project leader (academic employee/supervisor or PhD candidate)

Ida Arff Tarjem, ida.arff.tarjem@nmbu.no, tlf: 95804384

Type of project

Research Project

Project period

19.08.2019 - 01.09.2021

Status

01.08.2019 - Assessed

Assessment (2)

01.08.2019 - Assessed

Our assessment is that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 17.07.2019, as well as in correspondence with NSD. Everything is in place for the processing to begin.

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify NSD. This is done by updating the Notification Form. On our website we explain which changes must be notified. Wait until you receive an answer from us before you carry out the changes.

TYPE OF DATA AND DURATION
The project will be processing special categories of personal data about political opinions, and general

categories of personal data, until 01.09.2021. Anonymized data will be archived for one year at NSD for verification purposes.

LEGAL BASIS
The project will gain consent from data subjects to process their personal data. We find that consent will meet the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed and unambiguous statement or action, which will be documented and can be withdrawn.

The legal basis for processing special categories of personal data is therefore explicit consent given by the data subject, cf. the General Data Protection Regulation art. 6.1 a), cf. art. 9.2 a), cf. the Personal Data Act § 10, cf. § 9 (2).

PRINCIPLES RELATING TO PROCESSING PERSONAL DATA
NSD finds that the planned processing of personal data will be in accordance with the principles under the General Data Protection Regulation regarding:

- lawfulness, fairness and transparency (art. 5.1 a), in that data subjects will receive sufficient information about the processing and will give their consent
- purpose limitation (art. 5.1 b), in that personal data will be collected for specified, explicit and legitimate purposes, and will not be processed for new, incompatible purposes
- data minimisation (art. 5.1 c), in that only personal data which are adequate, relevant and necessary for the purpose of the project will be processed
- storage limitation (art. 5.1 e), in that personal data will not be stored for longer than is necessary to fulfil the project's purpose

THE RIGHTS OF DATA SUBJECTS
Data subjects will have the following rights in this project: transparency (art. 12), information (art. 13), access (art. 15), rectification (art. 16), erasure (art. 17), restriction of processing (art. 18), notification (art. 19), data portability (art. 20). These rights apply so long as the data subject can be identified in the collected data.

NSD finds that the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13.

We remind you that if a data subject contacts you about their rights, the data controller has a duty to reply within a month.

FOLLOW YOUR INSTITUTION'S GUIDELINES
NSD presupposes that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

To ensure that these requirements are met you must follow your institution's internal guidelines and/or consult with your institution (i.e. the institution responsible for the project).

FOLLOW-UP OF THE PROJECT
NSD will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!

Contact person at NSD: Jørgen Wincentsen
Data Protection Services for Research: +47 55 58 21 17 (press 1)

17.07.2019 - Assessed

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den 17.07.2019 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde:
https://nsd.no/personvernombud/meld_prosjekt/meld_endringer.html
Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle særlige kategorier av personopplysninger om politisk oppfatning og alminnelige kategorier av personopplysninger frem til 01.09.2021. Anonymiserte data skal deretter arkiveres i opp til ett år hos NSD for verifisering.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og art. 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 6 nr. 1 a), jf. art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og eventuelt rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Jørgen Wincentsen
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

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